NAVASOTA RIVER WATERSHED, TEXAS

LETTER

FROM

THE SECRETARY OF THE ARMY

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY, DATED MAY 29, 1968, SUBMITTING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, ON A REVIEW OF THE REPORTS ON NAVASOTA RIVER WATERSHED, TEXAS, REQUESTED BY A RESOLUTION OF THE COMMITTEE ON PUBLIC WORKS, HOUSE OF REPRESENTATIVES, ADOPTED JULY 1, 1958

JULY 1, 1968.—Referred to the Committee on Public Works and ordered to be printed with illustrations

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1968

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LETTER OF TRANSMITTAL

DEPARTMENT OF THE ARMY
WASHINGTON, D.C. 20310

June 24, 1968

Honorable John W. McCormack
Speaker of the House of Representatives
Washington, D. C. 20515

Dear Mr. Speaker:

I am transmitting herewith a favorable report dated 29 May 1968, from the Chief of Engineers, Department of the Army, together with accompanying papers and illustrations, on a review of the reports on Navasota River Watershed, Texas, requested by a resolution of the Committee on Public Works, House of Representatives, adopted 1 July 1958.

The views of the Governor of Texas, the Departments of the Interior, Agriculture and Commerce, and the Federal Power Commission are set forth in the inclosed communications, together with the replies of the Chief of Engineers to the Governor of Texas and the Secretary of the Interior.

The Bureau of the Budget notes that the Chief of Engineers recommends immediate authorization of Millican and Navasota No. 2 Reservoirs with the latter not required until about the year 2010. While the Bureau has no objection to early authorization in the case of the Navasota No. 2 project it recommends that a restudy be completed and approved by the President prior to construction of the project. The complete views of the Bureau of the Budget are attached.

I concur in the views of the Bureau of the Budget. I recommend that legislation authorizing improvements in the Navasota River Watershed include the following provision:

> "Provided, That construction of the Navasota No. 2 reservoir shall not be initiated until the President has approved a report prepared by the Secretary of the Army reexamining the basis on which the project was formulated."

Subject to consideration of its views, the Bureau of the Budget advises there would be no objection to the submission of the proposed report to the Congress. No commitment, however, can be made at this time as to when any estimate of appropriation would be submitted for construction of the project, if authorized by the Congress, since this would be governed by the President's budgetary objectives as determined by the then prevailing fiscal situation.

Sincerely yours,

Stanley R. Resor

1 Incl
Report

STANLEY R. RESOR
Secretary of the Army

COMMENTS OF THE BUREAU OF THE BUDGET

EXECUTIVE OFFICE OF THE PRESIDENT
BUREAU OF THE BUDGET
WASHINGTON, D.C. 20503

June 21, 1968

Honorable Stanley R. Resor
Secretary of the Army
Washington, D. C. 20310

Dear Mr. Secretary:

Mr. Robert E. Jordan's letter of June 5, 1968, submitted the favorable report of the Chief of Engineers on the Navasota River Watershed, Texas, requested by a resolution of the Committee on Public Works, House of Representatives, adopted July 1, 1958.

In its letter of August 29, 1966, the Department of the Interior recommended that additional measures, including acquisition and development of land, be authorized for mitigating wildlife losses that would result from the construction of the proposed Millican reservoir. Pursuant to this recommendation, the Corps of Engineers conducted additional mitigation studies and found that the State of Texas would support acquisition of additional lands for wildlife mitigation only on a willing seller basis. Since this land acquisition policy is impracticable for mitigating project-induced damages, the Department of the Interior has withdrawn its earlier recommendation.

We believe that these adverse conditions on wildlife should be reflected in the economic evaluation of the project. However, if there is a change in the State's present position on land acquisition and additional mitigation measures are approved after authorization of this project, we recommend that the costs for such facilities be included in the total cost of the project and appropriately allocated to the various project purposes.

We note that the Chief of Engineers recommends immediate authorization of both proposed reservoirs, Millican and Navasota No. 2, although the latter is not required until about the year 2010. Generally, the Corps of Engineers policy has been to recommend authorization of only those projects required to be started in the next 15 to 20 years to meet the needs of a region. Since the proposed project has been formulated on the basis of stage development, including reallocation of total storage between the two reservoirs, we have no objection to early authorization in the case of the Navasota No. 2 project. Since there may be changes in the economy, technology, or project purposes during the next 50 years, we recommend that a restudy be completed and approved by the President prior to construction of the project.

Should the Congress decide that authorization of the Navasota No. 2 reservoir is desirable at this time, there would be no objection to the enactment of the legislation provided that it is amended to include the following provision:

> "Provided, That construction of the Navasota No. 2 reservoir shall not be initiated until the President has approved a report prepared by the Secretary of the Army reexamining the basis on which the project was formulated."

Subject to your consideration of the above comments, I am authorized by the Director of the Bureau of the Budget to advise you that there would be no objection to the submission of the proposed report to the Congress. No commitment, however, can be made at this time as to when any estimate of appropriation would be submitted for construction of the project, if authorized by the Congress, since this would be governed by the President's budgetary objectives as determined by the then prevailing fiscal situation.

Sincerely yours,

Carl H. Schwartz, Jr.
Director, Natural Resources
Programs Division

COMMENTS OF THE GOVERNOR OF TEXAS

JOHN CONNALLY
GOVERNOR OF TEXAS

January 25, 1967

Lieutenant General William F. Cassidy
Chief of Engineers
Department of the Army
Office of the Chief of Engineers
Washington, D. C. 20315

Dear General Cassidy:

In reply to your letter of June 3, 1966, I have had a study made of the proposed report of the Chief of Engineers on the Navasota River Watershed, Texas. Our study shows the project to be feasible and we commend it to the Board of Engineers for Rivers and Harbors with the hope that it may be funded by Congress at an early date.

In studying the project the Texas Parks and Wildlife Department notes that there will be a considerable loss of wildlife habitat and a corresponding loss of hunting opportunity resulting from the construction of this reservoir. Colonel Edmund H. Lang's letter of March 8, 1966, indicated that the recommended plan results in the least amount of hunting loss. I trust that careful attention will be given to this aspect of the project in order that there may be as little loss as possible of this prime game habitat.

Finally we would like to request again that development of the reservoir recreation plans be fully coordinated with the Parks and Wildlife Department.

With highest regards,

Sincerely,

John Connally

John Connally

LETTER TO THE GOVERNOR OF TEXAS

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20315

IN REPLY REFER TO
ENGCW-PD

17 February 1967

Honorable John Connally
Governor of Texas
Austin, Texas

Dear Governor Connally:

This is in reply to your recent letter commenting upon the proposed report of the Chief of Engineers on the Navasota River Watershed, Texas.

You called attention to the possible loss of wildlife habitat and a corresponding loss of hunting opportunity resulting from the proposed reservoir construction. The problem of wildlife losses can be treated in the advanced planning stage, if the project is authorized. You may be assured of our willingness to proceed in cooperation with the Texas Parks and Wildlife Department in formulating and determining the feasibility of plans for the mitigation of wildlife losses and in the development of reservoir recreation plans.

Your comments, together with a copy of this reply, will accompany the report of the Chief of Engineers when it is sent to Congress.

Sincerely yours,

F. J. Clarke

F. J. CLARKE
Major General, USA
Acting Chief of Engineers

COMMENTS OF THE DEPARTMENT OF THE INTERIOR

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

August 29, 1966

Dear General Cassidy:

This is in reply to your letter of June 3, 1966 requesting our comments on reports on Navasota River Watershed, Texas.

Construction of the proposed reservoirs would not adversely affect any existing or proposed projects of the Bureau of Reclamation.

Releases on the Navasota River are not expected to improve the low mineral water quality already present in the Lower Brazos River and the Federal Water Pollution Control Administration has therefore not recommended that storage for water quality control purposes be included in either reservoir.

The Fish and Wildlife Service advises that your recommended plan for the Navasota River Watershed, Texas, does not adequately provide for the mitigation of wildlife losses.

Significant wildlife losses would result from construction and operation of the two reservoirs. Revised analysis indicates that about 100,000 acres of prime quality habitat on an additional 60,000 acres would be reduced. Approximately 27,500 man-days of big-game hunting and 60,800 man-days of upland-game hunting would be lost by project developments.

It is not reasonable to assume these losses could adequately be mitigated by mathematically reducing the fishing benefits by an amount estimated as the value of the losses as was done by the District Engineer. The project should be responsible for the replacement of that habitat base and associated lost hunting opportunity. The wildlife loss could be mitigated by the acquisition of land suitable for management and the development of that land so as to provide the amount of lost hunting opportunity.

The Service notes that the District Engineer has independently evaluated benefits for fishing and hunting and did not accept the evaluations of the Bureau of Sport Fisheries and Wildlife. The explicit intent of the Congress in amending the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. et seq.) in 1958 was to have the Bureau serve as the consulting agency on fish and wildlife matters concerning Federal water resource development. The use of fish and wildlife evaluations in lieu of those prepared by the Bureau evades the spirit and intent of this Act.

It is recommended that your report be modified to recognize the wildlife losses which would result from the proposed project modification and that provisions be included in the project plans to mitigate these losses. Mitigation measures considered should include the acquisition and development of additional land for wildlife purposes.

The Bureau of Outdoor Recreation advises that the initial version of the Texas statewide comprehensive outdoor recreation plan analyzes demand, supply, and needs for recreation resources primarily over the period 1965 to 1970. Both the Millican and Navasota No. 2 project segments would become operational after 1970. The Bureau notes, however, that the Governor of the State of Texas has indicated in writing the intention of the State of Texas to participate in the development of the recreation and fish and wildlife facilities at the Millican project in accordance with the Federal Water Project Recreation Act (79 Stat. 213). The Bureau believes, therefore, that the recreation development of the Millican segment would be consistent with the objectives of the State outdoor recreation plan.

The Bureau advises further that a firm determination of the extent to which the proposed Navasota No. 2 recreation development would be consistent with the State plan cannot be made at this time in view of the distant completion date scheduled for this project segment (2010). However, the Bureau believes that this project segment would prove to be a desirable recreation facility. Trends of increasing income, mobility, and available leisure time all point toward rapidly expanding recreation needs in the future. The Bureau is confident that the proposed recreation development could be scheduled and coordinated with future versions of the State's recreation plans and programs. Also, during the preconstruction planning, such development could be scaled economically to meet anticipated future recreation needs consistent with the State's outdoor recreation plan in effect at that time.

Archeological and historical values may be present in the project area. Prior to construction, the National Park Service should be advised so that arrangements can be made for archeological and historical surveys and salvage.

The opportunity of presenting our recommendations is appreciated.

Sincerely yours,

Robert W. Nelson

Deputy Assistant Secretary of the Interior

Lt. General William F. Cassidy
Chief of Engineers
Department of the Army
Washington, D. C. 20315

LETTER TO THE SECRETARY OF THE INTERIOR

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20315

IN REPLY REFER TO
ENGCW-PD

23 September 1966

The Honorable Stewart L. Udall

The Secretary of the Interior

Dear Mr. Secretary:

This is in reply to the recent letter from the Department of the Interior furnishing comments on my proposed report on Navasota River Watershed, Texas.

A recommendation is made that the Navasota River report be modified to recognize the wildlife losses which would result from the proposed construction and operation of the Millican and Navasota No. 2 Reservoirs on the Navasota River and that provisions be included in the project plans to mitigate these losses. The letter indicates that mitigation measures considered should include the acquisition and development of additional land for wildlife purposes.

As you know, the original report of the Regional Office of the Bureau of Sport Fisheries and Wildlife as contained in our Navasota report indicates that losses of 15,500 man-days for big-game hunting and 10,600 man-days for upland-game hunting would be lost due to the proposed project developments on the Navasota River. In our report these losses were recognized. As indicated in the Department's letter, a revised analysis indicates that approximately 27,500 man-days of big-game hunting and 60,800 man-days of upland-game hunting would be lost by the proposed Navasota River developments. I understand that the Texas Parks and Wildlife Department has requested that lands be purchased at project cost as a partial mitigation measure of losses of wildlife habitat and hunting. Such lands under development and operation by the Texas Parks and Wildlife Department for public hunting and wildlife-oriented recreation use would provide an estimated 13,600 man-days of big-game hunting, 12,800 man-days of upland-game hunting, and 20,000 man-days of wildlife-oriented recreation.

The additional time needed for review of the supplemental report prepared by the Regional Office of the Bureau of Sport Fisheries and Wildlife and for studying and analyzing the problem of additional lands for mitigation purposes above the amount currently required for the recommended reservoir projects would result in a delay in submittal of the basic recommended reservoir plan to the United States Congress. However, the acquisition of additional lands for wildlife mitigation purposes under a plan which can be fully justified will require specific Congressional authorization. I believe that the problem of wildlife losses and need of additional lands for mitigation purposes can be treated in a separate report, similar to the report submitted to Congress on John Day Lock and Dam, Columbia River, Washington and Oregon, published as Senate Document No. 28, 89th Congress, 1st Session, under the provisions of the Fish and Wildlife Coordination Act of 1958. You may be assured of our willingness to proceed in cooperation with the Bureau of Sport Fisheries and Wildlife and the State of Texas in formulating and determining the feasibility of plans for wildlife mitigation.

In view of the comment that archeological and historical values may be present in the project area, the National Park Service will be contacted during preconstruction studies in regard to the need for surveys and salvage operations.

The comments of the Department of the Interior, together with this reply, will accompany my report when it is transmitted to Congress.

Sincerely yours,

William F. Cassidy

WILLIAM F. CASSIDY
Lieutenant General, USA
Chief of Engineers

96-129 O-68-2

LETTER TO THE SECRETARY OF THE INTERIOR

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20315

29 April 1968

IN REPLY REFER TO
ENGCW-PD

The Honorable Stewart L. Udall
The Secretary of the Interior
Washington, D. C. 20240

Dear Mr. Secretary:

My proposed report on the Navasota River Watershed, Texas, was referred for comment by letter dated 1 June 1966. I have given further consideration to the matter of mitigating wildlife losses discussed in the Department's letter dated 29 August 1966, subsequent to my letter dated 23 September 1966.

The reporting officers have coordinated further with the Regional Director, Bureau of Sport Fisheries and Wildlife and the Texas Parks and Wildlife Department to reach an understanding as a basis for proceeding with the Navasota River report. Contacts with the State Parks and Wildlife Department disclosed that the State will support acquisition of additional lands for wildlife mitigation only on a willing seller basis. We do not believe this is a practicable or feasible method to accomplish the objective of mitigating project induced damages. Because of the State's position on land acquisition, the Regional Director, Bureau of Sport Fisheries and Wildlife has withdrawn the supplemental report recommending that additional land should be acquired for partial mitigation of wildlife losses caused by the project. Without State support and specific recommendations from the Bureau of Sport Fisheries and Wildlife, we are unable to recommend acquisition of additional lands to mitigate possible wildlife losses.

Also, the reporting officers reconciled the differences between the sport fishing and wildlife hunting benefits as initially determined in our report and as estimated by the Bureau of Sport Fisheries and Wildlife. The area of major difference between estimates was contained in the category of fishing. Our estimates were based upon attendance records and use activities at existing Corps projects in the region without regard for any degree of dedication to particular activities. All who engage in fishing in some manner automatically were classified as fishermen and thus a large group of casual or incidental-type fishermen were included with the hard-core type in estimating fisherman days and the benefits resulting from this activity in our report. The reporting officers agreed this difference could be resolved by classifying casual fishing as general recreation rather than fish and wildlife recreation. Utilization of this realignment of recreation and fish and wildlife activities, as well as adjustments in unit values of the activities, provides a new breakdown of project benefits between the two purposes. The general recreation benefits are now estimated to be $3,744,000, including casual fishing, and the fish and wildlife recreation benefits are now $249,000. The net average annual recreation and fish and wildlife benefits, after recognizing the fish and wildlife losses ($126,000) expected to result from project construction, is $3,867,000. However, the use of these benefits does not significantly affect project evaluation.

For your information, I am inclosing a copy of my report modified to recognize the additional coordination with the Bureau of Sport Fisheries and Wildlife. I would appreciate any comments thereon within thirty days.

Sincerely yours,

WILLIAM F. CASSIDY
Lieutenant General, USA
Chief of Engineers

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COMMENTS OF THE DEPARTMENT OF THE INTERIOR

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

May 22, 1968

Dear General Cassidy:

This is in reply to your letter of April 29, 1968, requesting our comments on your revised report on Navasota River Watershed, Texas.

As stated in your proposed report the Bureau of Sport Fisheries and Wildlife has withdrawn its initial recommendation that additional lands be acquired to mitigate wildlife losses.

Thank you for the opportunity of reviewing your report.

Sincerely yours,

Robert W. Nelson

Deputy Assistant Secretary of the Interior

Lt. General William F. Cassidy
Chief of Engineers
Department of the Army
Washington, D. C. 20315

COMMENTS OF THE DEPARTMENT OF AGRICULTURE

DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C. 20250

20 July 1966

Honorable Stanley R. Resor
Secretary of the Army

Dear Mr. Secretary:

This is in reply to the Chief of Engineers' letter of June 3, 1966, transmitting for our information and comment his proposed report on the Navasota River Watershed, Texas.

The report recommends authorization of two dams to be constructed on the Navasota River, one to be completed by 1975 and the other to be completed at about the year 2010, as the need for water supply develops. The chief purpose of Millican Dam, the first to be completed, is to relieve flood damage in the flood plain of the Brazos River, of which the Navasota is a tributary. The Millican Dam is to supersede an already authorized plan for a smaller dam and reservoir at approximately the same site on the Navasota River.

Total installation cost of Millican Dam would be $58,620,000, and average annual costs, including operation and maintenance costs, are $2,404,500. The Federal Government's share of the installation cost would be $36,874,500.

Average annual benefits are estimated at $6,648,400, of which $3,111,500 would be flood control benefits, $1,320,000 water supply benefits, and $2,216,900 recreation and fish and wildlife enhancement. Although it is stated that the largest proportion of flood control benefits will be of an agricultural nature, the extent of the agricultural flood benefits is not reported. The benefit-cost ratio is calculated to be 2.8 to 1.0.

Total installation cost of the second dam, to be built in the next century, is estimated to be $61,087,000. Average annual costs, including operation and maintenance costs, are estimated to be $2,484,200. Average annual benefits are expected to be $3,648,000, of which $156,700 would be flood control benefits, $1,908,400 water supply benefits, and $1,582,900 recreation and fish and wildlife enhancement. The benefit-cost ratio is calculated to be 1.5 to 1.0.

The proposed plan would inundate or remove from production approximately 50,000 acres of privately owned timber. Reduction in frequency of flooding also will result in accelerated clearing of bottomlands. The report does not indicate that timber values lost as a result of the project have been recognized, nor does it discuss the salvage of timber as a result of clearing operations.

It is recommended that provisions be made to salvage all merchantable timber that will be cleared as a result of the project and that timber clearing operations within areas above conservation-pool elevations be held to a minimum compatible with necessary construction and reservoir operation purposes.

No watershed projects of this Department have been approved for construction on upstream areas above the proposed reservoirs. It is expected that land treatment and structural works of improvement which may be installed on upstream watersheds indicated to be feasible for project development, and discussed on page 34 and elsewhere in this report, will be comprehensive and complementary to the proposed project.

Construction of the project would have no adverse effect upon the water and related land resource projects or programs of this Department.

We appreciate the opportunity to review the report.

Sincerely yours,

John A. Baker

JOHN A. BAKER
Assistant Secretary

COMMENTS OF THE DEPARTMENT OF COMMERCE

THE UNDER SECRETARY OF COMMERCE
FOR TRANSPORTATION
WASHINGTON, D.C. 20230

September 13, 1966

Lieut. General William F. Cassidy, USA
Chief of Engineers
Department of the Army
Washington, D.C. 20315

Dear General Cassidy:

You invited this Department's comments on your proposed report and accompanying reports concerning the Navasota River Watershed, Texas, with special emphasis on flood control and water supply in the Navasota River Watershed, as well as throughout the lower Brazos River basin. You recommended that, in lieu of the authorized Ferguson Reservoir project, a comprehensive plan of stage development, consisting of Millican Reservoir as the initial unit and Navasota Number Two Reservoir as the future unit, and appurtenant channel improvements and/or flood easements for flood release purposes, be authorized. The total first cost of this proposed stage development of the water resources of the basin for flood control, water supply, and recreation and fish and wildlife enhancement is estimated at $119,707,000.

We are pleased to note that you also recommend that advance land acquisition and transportation and utility alterations be authorized as required to preserve the site against incompatible development and avoid increased costs for relocations.

The Bureau of Public Roads reports that the proposed project will affect several Federal-aid primary, Federal-aid secondary, and numerous county and local roads. The estimated cost of road alterations for the Millican Project is $5,258,300; for the Navasota Number Two Project, $7,235,610; a total of $12,493,910. These costs are included in the project cost. The Bureau understands that these alterations are being coordinated with the local highway authorities and assumes that they will be constructed to current standards for current traffic volumes.

The Coast and Geodetic Survey note that no requirements for geodetic control are indicated. Navasota Number Two and Millican Reservoir indicate the need for nautical charting and C & GS recommends that funds for this purpose be included in the project cost.

The Office of Technical Assistance, Economic Development Administration, finds that the area covered by the subject report lies within an EDA designated redevelopment area including Leon, Robertson, Grimes, Limestone, Madison, and Freestone Counties, Texas. Further the proposed improvements would aid in strengthening the agricultural and chemical-producing sectors of the economy, and would be conducive to the development of a water based recreation - tourism industry in those areas where such development has been deterred by the lack of adequate facilities.

The Department concurs in your findings and appreciates the opportunity to review and comment on your report.

Sincerely,

Lowell K. Bridwell
for
Alan S. Boyd

COMMENTS OF THE FEDERAL POWER COMMISSION

FEDERAL POWER COMMISSION
WASHINGTON, D.C. 20426

18 July 1966

Lieutenant General William F. Cassidy
Chief of Engineers
Department of the Army
Washington, D. C. 20315

Reference: ENGCW-PD

Dear General Cassidy:

This is in response to your letter of June 3, 1966, inviting comments by the Commission relative to your proposed report and to the reports of the Board of Engineers for Rivers and Harbors and of the District and Division Engineers on the Navasota River Watershed, Texas.

The cited reports recommend a two-stage plan of development for the Navasota River Watershed in lieu of the presently authorized Ferguson reservoir. The recommended plan would provide for flood control, water supply, recreation, and fish and wildlife enhancement. The first stage of the proposed plan would include the Millican project consisting of an earthfill dam, a reservoir having a total controlled storage capacity of 1,557,400 acre-feet, and a channel improvement downstream from the dam. In the second stage (about the year 2010), the upstream Navasota No. 2 project would be constructed and would consist of an earthfill dam, a reservoir having a total controlled storage capacity of 1,935,600 acre-feet, and a channel improvement downstream of the dam. Also in the second stage, a portion of the flood control storage capacity in the Millican reservoir would be reallocated to the Navasota No. 2 project in order to increase the conservation storage capacity of the Millican project. The total estimated construction cost of the two-stage plan is $119,707,000. The estimated net cost to the United States is $49,414,000 after the required repayments by local interests for costs allocated to water supply, recreation, and fish and wildlife enhancement.

The Commission staff, which has cooperated with your Department in various studies in the Brazos River Basin, has made studies of the recommended projects to determine the possibilities for developing hydroelectric power. These studies show that under the first stage of development, the Millican project could include a power installation of about 6,500 kilowatts capable of generating, on the average, about 17 million kilowatt-hours of energy annually. Based on specific power costs, the power development would have a benefit-cost ratio of about 0.5 to 1.0. In the second stage, the Navasota No. 2 project could include a power installation of approximately 13,000 kilowatts at ten percent critical period plant factor, which would be capable of generating, on the average, about 24 million kilowatt-hours annually. Such a power development would have a benefit-cost ratio of about 0.8 to 1.0 based on the cost of specific power facilities. In view of the planned construction date of about the year 2010, it appears that a firm conclusion regarding the development of power at Navasota No. 2 should be deferred until the stage of project design. Staff studies indicate that modification of the proposed projects to increase the power potential would not be warranted.

Based on its consideration of the reports of your Department and the studies of its own staff, the Commission concludes that the recommended Millican reservoir would not provide opportunity for the economical development of hydroelectric power. The Commission concludes further that, although power development at the Navasota No. 2 project would not be economically justified under present conditions, any firm decision regarding power facilities at this project should be deferred until the project design stage.

Sincerely,

Lee C. White

Lee C. White
Chairman

NAVASOTA RIVER WATERSHED, TEXAS

REPORT OF THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY

DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20315

IN REPLY REFER TO
ENGCW-PD

29 May 1968

SUBJECT: Navasota River Watershed, Texas

THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress the report of the Board of Engineers for Rivers and Harbors, accompanied by the reports of the District and Division Engineers, on Navasota River Watershed, Texas, in response to a resolution by the Committee on Public Works of the House of Representatives, United States, adopted 1 July 1958, requesting a review of the report on Brazos River and Tributaries, Texas, printed in House Document 535, Eighty-first Congress, second session, and other reports with a view to determining what modifications to the authorized plan for flood control, water conservation, and related water uses in the Navasota River basin are desirable. The report presents the results of an investigation of the problems associated with the water and related land resources of the Navasota River watershed with special emphasis on flood control and water supply in the Navasota River watershed, as well as throughout the lower Brazos River basin.

2. The District and Division Engineers recommend that, in lieu of the authorized Ferguson Reservoir project, a comprehensive plan of stage development, consisting of Millican Reservoir as the initial unit and Navasota No. 2 Reservoir as the future unit, including appurtenant channel improvements and/or flood easements for flood release purposes, be authorized for development of the water resources for purposes of flood control, water supply, and recreation and fish and wildlife enhancement. They estimate the total first cost of the proposed plan of stage development at $119,707,000. The estimated net cost to the United States for construction, after repayment by local interests for construction costs allocated to water supply and recreation and fish and wildlife enhancement, is $36,874,500 for Millican, and $12,540,300 for Navasota No. 2, or $49,414,800 for the total plan. The estimated net cost to the United States for operation, maintenance, and replacements on an average annual basis is $74,800 for Millican, and $49,100 for Navasota No. 2, or $123,900 for the total plan.

3. The Board concurs generally in the findings of the reporting officers and recommends authorization of the proposed improvements, subject to certain requirements of local cooperation.

4. Subsequent to completion of the District Engineer's report and approval by the Board of Engineers, the Department of the Interior made a revised analysis of the wildlife losses which would result from the proposed construction of the Millican and Navasota No. 2 reservoirs on the Navasota River and recommended that provisions be included in the project plans to mitigate these losses. Therefore, the reporting officers in cooperation with the regional office of the Bureau of Sport Fisheries and Wildlife and the Texas Parks and Wildlife Department have given further consideration to this matter.

5. After additional study the reporting officers find the Texas Parks and Wildlife Department will support acquisition of additional lands for wildlife mitigation only on a willing seller basis. Neither the Corps of Engineers nor the Bureau of Sport Fisheries and Wildlife believe this is a practicable or feasible method to accomplish the purpose for which the acquisition of such land might ultimately be authorized. Therefore, the Bureau of Sport Fisheries and Wildlife has withdrawn the supplemental report and the recommendation that additional land should be acquired for partial mitigation of project induced wildlife losses.

6. This further coordination with the Bureau of Sport Fisheries and Wildlife also led to agreement on both the general recreation and the fish and wildlife recreation benefits attributable to the recommended improvements. General recreation benefits are now estimated to be $3,744,000, including casual fishing, and the fish and wildlife recreation benefits are now estimated to be $249,000 before recognizing the fish and wildlife losses which are estimated to be about $126,000. The net annual benefits for recreation and fish and wildlife purposes are now estimated to be about $3,867,000. However, adoption of these revised annual benefits does not significantly affect the evaluation of the proposed Navasota River plan.

7. Because of suggestions made by interested parties that land costs for the proposed Millican Reservoir have been under estimated, I have examined this aspect to determine whether possible increases could alter my recommendations. The most feasible alternative to the plan recommended by the Board of Engineers is a plan in which the Navasota No. 2 Reservoir would be constructed first with the Millican Reservoir to be

constructed in the future. For the purposes of making a comparison and establishing whether Millican Reservoir should be constructed as the first unit in the Navasota River Watershed, an assumption was made that the land costs for Millican Reservoir might be as much as 50 percent higher than the average value estimated by the reporting officers. Amortization of this possible added land cost, based on the same interest rate as used in the recommended plan, might increase the annual charges for Millican Reservoir as the first unit by about $220,000. However, an increase of this magnitude is not sufficient to offset the engineering and economic advantages of constructing Millican Reservoir as the first unit. Furthermore, the Governor of Texas favors the plan as recommended by the Board of Engineers for Rivers and Harbors.

8. I consider the recommended plan to be well formulated in view of the existing and projected future local problems and needs, and clearly a sound economical investment with an annual excess of benefits over costs of nearly five and one-half million dollars, and an overall benefit-cost ratio of 2.1. Use of the currently prescribed interest rate of 3-1/4 percent in computing annual charges and benefits would result in no appreciable change in the benefit-cost ratio.

9. After careful consideration of these reports and the foregoing discussion, I concur generally in the views and recommendations of the Board.

William F. Cassidy

WILLIAM F. CASSIDY
Lieutenant General, USA
Chief of Engineers

REPORT OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
BOARD OF ENGINEERS FOR RIVERS AND HARBORS
WASHINGTON, D.C. 20315

IN REPLY REFER TO

ENGBR

3 May 1966

SUBJECT: Navasota River Watershed, Texas

TO: Chief of Engineers
Department of the Army

1. Authority.--This report is in response to the following resolution adopted 1 July 1958:

> Resolved by the Committee on Public Works of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors be, and is hereby, requested to review the report on Brazos River and Tributaries, Texas, printed in House Document 535, 81st Congress, Second Session, and other reports with a view to determining what modifications to the authorized plan for flood control, water conservation and related water uses in the Navasota River basin are desirable.

The report considers the advisability of modifying the authorized project for Brazos River and tributaries, Texas, by substitution of a more suitable reservoir plan on the Navasota River watershed in lieu of the authorized Ferguson Dam and Reservoir project for flood control, water conservation, and related water uses. The report is limited to investigation of water resource developments on the Navasota River watershed; but includes consideration of water problems and needs of a regional area within the influence of such developments. The study area for this report consists of the Navasota River watershed, the lower Brazos River basin downstream of Whitney Dam, and the contiguous Gulf Coastal Areas, including the area as far east as Galveston and Texas City.

2. <u>Watershed description.</u>--The Navasota watershed is in east-central Texas. It has a length of about 122 miles, a maximum width of 35 miles, and a drainage area of 2,211 square miles. It extends generally in a north-south direction from typical prairie topography and vegetation in the north to the relatively hilly and forested timber belt in the south. The mean annual precipitation over the watershed is about 39 inches, and varies from about 35 inches in the headwater region to about 42 inches near the mouth.

3. The Navasota River, the lowermost major tributary of the Brazos River, flows southeastward for about 72 miles to the Limestone-Robertson County line, then southerly for approximately 125 miles to its confluence with the Brazos River at mile 232.0. The channel capacity of the river within its downstream 80-mile reach varies from 2,500 to 10,000 cubic feet per second. It is affected by backwater from the Brazos River for 24 miles above the mouth.

4. <u>Economic development.</u>--This report is concerned primarily with water problems and demands of a regional study area consisting of 29 counties and containing about 26,128 square miles, or 9.92 percent of the total land of the State of Texas. The population of the study area in 1960 was 2,182,177, of which 226,077 resided in the flood plain. Houston, Galveston, and Waco, three of the State's 21 standard metropolitan statistical areas, are located partially or completely in the study area. The principal manufacturing activities of the area consist of the manufacture of petroleum and associated products, chemicals, lumber, supplies, metal, and food and kindred products. It is a center for oil and gas transmission. The National Aeronautics and Spacecraft Center in the Clearlake area of the contiguous coastal area is headquarters for space exploration. A 55-mile long highly industrialized ship channel connects the Houston area with the Gulf of Mexico. Agriculture occupies an important position among the commodity producing industries in the study area. The principal crops are cotton, corn, grains, grain sorghums, vegetables, fruits, oats, melons, peanuts, rice, and various field crops. Lumber production and sugar processing are of importance. Livestock raised in the area includes beef cattle, dairy cattle, sheep, angora goats, and poultry. Mineral resources include petroleum, natural gas, natural gas liquids, sand and gravel, stone, limestone, clays, graphite, lignite, lime, magnesium chloride, magnesium compounds, salt, bromine, and sulfur.

5. Water resource development.--The principal water resource developments involved in the study area include non-Federal reservoirs such as the existing Lake Mexia, Camp Creek Lake, and Lake Springfield on the Navasota River watershed; the planned long-range Wayland Crossing Reservoir on the upper Navasota River; and the planned Allens Creek Crossing Reservoir in the Brazos Gulf Coastal Area. The principal water resource developments either constructed, under construction, or planned by the Federal Government include: Whitney Dam and Reservoir on the Brazos; Waco Dam and Reservoir on the Bosque River; Aquilla Dam and Reservoir on Aquilla Creek; Proctor and Belton Dams and Reservoirs on the Leon River; Stillhouse Hollow Dam and Reservoir on the Lampasas River; the San Gabriel River projects on the San Gabriel River watershed; Somerville Dam and Reservoir on Yegua Creek; Ferguson Dam and Reservoir on the Navasota, and various systems of flood detention structures on tributary areas of the lower Brazos River basin by the Soil Conservation Service.

6. The only authorized Corps of Engineers project in the Navasota River watershed is the Ferguson Dam and Reservoir project. This project was authorized as an important unit of a comprehensive plan of improvement for the lower Brazos River basin for flood control, water conservation, and allied purposes.

7. The Soil Conservation Service has investigated a potential land-treatment, flood-detention program on the Navasota River watershed. The potential program includes land-treatment measures and 28 flood-detention reservoirs, of which 13 reservoirs would be located on Christmas Creek in Limestone County and 15 reservoirs would be located on Holland Creek in Grimes County and Big Creek in Brazos County. The State Soil Conservation Board has approved the Upper Navasota River Watershed, Limestone and Hill Counties, as feasible for assistance under provisions of Public Law 566. The Big Creek work plan for watershed protection and flood prevention and agricultural water management has been approved for operation.

8. Water resource problems.--Floods occur on the Navasota River at any time of the year and contribute substantially to flooding along the lower Brazos River. During the period of record 1924 to 1963, nine major floods occurred producing peak discharges at the Easterly gage (Navasota River mile 105.7) varying from 30,100 to 60,300 cubic feet per second, and 74 floods exceeding the existing

channel capacity occurred downstream of mile 24.1. The minimum channel capacity along the lower Brazos River is 60,000 cubic feet per second downstream from Richmond. Based on historical records during the period 1903-1962, 26 major floods occurred which produced peak discharges at the Richmond gage ranging from 78,800 to 300,000 cubic feet per second. The part of the Brazos River flood plain affected by floodflows from the Navasota River consists of about 614,400 acres, of which 262,200 are improved agricultural lands, 350,700 are unimproved grazing lands, and 1,500 are in several communities along the reach. The value of property, based on January 1965 prices, is estimated at about $270,000,000. Average annual damages along the Brazos River under present conditions and with the authorized system of Brazos River reservoirs in operation, except for Ferguson Reservoir on the Navasota River, are about $2,668,000. Construction and operation of the Ferguson project would reduce the average annual damages to about $1,670,000.

9. In connection with the studies for this report, the United States Public Health Service prepared a report on the water supply and water quality control needs for the Navasota River watershed and for the lower Brazos River basin. The report shows that the demand for municipal and industrial water in the lower Brazos River basin is expected to increase from the present use of approximately 340 million gallons daily (m.g.d.) to 1,326 m.g.d. in year 2025 and 2,088 m.g.d. in year 2075. The increase is mainly attributable to expected increases in population and industrial growth. In regard to the Navasota River watershed, the principal municipal and industrial water requirements are expected to increase from a present use of about 7 m.g.d. to 83.4 m.g.d. in year 2025 and 167.7 m.g.d. in year 2075.

10. Improvements desired.--During the course of the report studies, public hearings were held at Bryan, Texas, on 16 December 1958, and at College Station on 1 March 1962 and 16 March 1965. Most of the local interests agreed on the urgent need for a multiple-purpose reservoir on the Navasota River for flood control, water supply, and recreation purposes. Certain landowners, represented by the Navasota River Improvement Association have expressed opposition to an initial reservoir project on the Navasota River at the Ferguson and Millican sites, but have expressed approval of a

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reservoir at the Navasota No. 2 site upstream at about stream mile 83.4, with the second-stage unit at Millican if needed in the future. The cities of Bryan, College Station, and Navasota, and Brazos River Authority, the State of Texas, and many individuals have indicated approval of a reservoir project at the Millican site. Opposition to any dam on the Navasota River was expressed by about 400 residents in the middle portion of the Navasota River watershed. The State of Texas requested consideration of the following plans for flood control, water supply, water quality control, fish and wildlife, and general recreation: (a) Millican Reservoir, containing not less than 2,300,000 acre-feet of water conservation storage; (b) stage development at the Millican Reservoir site in order to reduce the immediate obligation of the Brazos River Authority to contract with the Federal Government for the approximately 2,300,000 acre-feet of conservation storage space; and (c) consideration of stage development involving the optimum plan at the Millican site, or the site designated as Navasota No. 2, or a combination of the two, taking into account the most feasible sequence of construction. Approval of a plan of stage development with Millican Reservoir as the initial unit was expressed by local officials of Bryan, College Station, and Navasota, counties along the Brazos River, the Brazos River Authority, Texas A&M University, Millican Dam Development Association, civic organizations, and representatives of businesses and industries. Approval of Navasota No. 2 Reservoir as the initial unit in a plan of stage development, or as the only unit, was expressed by the Navasota River Improvement Association, by local officials or civic organizations of the cities of Hearne, Calvert, Bremond, and Franklin, the Robertson County Commissioners Court, and individual landowners.

11. Investigated plans.--The report of the District Engineer includes preliminary investigations and analyses of various prospective dam and reservoir sites on the Navasota River in the reach from mile 24.1 to mile 83.4, including that of the authorized Ferguson project. It includes detailed investigations and analyses of the three most favorable sites: Millican Dam at mile 24.1; Ferguson No. 3 Dam at mile 41.5; and Navasota No. 2 Dam at mile 83.4, providing for the multiple purposes of flood control, water supply, and recreation and fish and wildlife enhancement. The investigated multiple-purpose plans include: (a) single reservoir plans to provide optimum-economical-to-maximum development of the water supply resources upstream of each damsite; and (b) stage development plans involving the Millican and

Navasota No. 2 Reservoirs--with equal consideration to each as the initial unit--to develop approximately the total water supply resources of the Navasota River watershed. In regard to the flood control function, each reservoir plan includes necessary channel improvements and/or flood easements for making releases to empty the flood control pools within a reasonable period of time.

12. Recommended plan.--The District Engineer finds that the most suitable plan to satisfy the needs of the regional study area would be one of stage development, consisting of a multiple-purpose Millican Dam and Reservoir as the initial unit to be completed about year 1975 and a multiple-purpose Navasota No. 2 Dam and Reservoir as a future unit to be completed when additional water supply is needed, presently estimated at about year 2010. The District Engineer finds that the plan of stage development with Millican Dam and Reservoir as the initial unit would be more favorable than with Navasota No. 2 as the initial unit, on the basis of the amount of excess benefits over costs, the magnitude of the flood control benefits and the optimum-economical development of water supply resources, during the initial stage of development. The reservoir storages and estimated dependable water supply yields for the plan of improvement are as follows:

Item	First-Stage: Millican Reservoir	Second-Stage: Millican Reservoir	Second-Stage: Navasota No. 2 Reservoir	Second-Stage: Total
Reservoir storage, 1,000 acre-feet:				
Flood control	784.8	359.6	550.7	910.3
Water supply	680.2	1,125.8	1,315.4	2,441.2
Sediment	92.4	72.0	69.5	141.5
Total	1,557.4	1,557.4	1,935.6	3,493.0
Dependable water supply yield:				
Cubic feet per second	300	175	300	475
Million gallons daily	194	113	194	307

13. Using January 1965 prices, the District Engineer estimates the total first costs at $58,620,000 for Millican Dam and Reservoir and $61,087,000 for Navasota No. 2 Dam and Reservoir, or a total first cost for the Navasota River plan of $119,707,000, initially all Federal. The net Federal construction costs are estimated at $36,874,500 for the Millican unit and $12,540,300 for the Navasota No. 2 unit, or $49,414,800 for the total plan, after repayment by non-Federal interests of construction costs allocated to water supply and to recreation and fish and wildlife enhancement. The District Engineer estimates the total annual costs of operation, maintenance, and replacement at $286,000 for Millican and $257,700 for Navasota No. 2, or $543,700 for the total plan of stage development. The annual operation and maintenance costs include Federal costs of $108,000 for Millican and $121,000 for Navasota No. 2, or $229,000 for the total plan. The net Federal annual operation and maintenance costs are $74,800 for Millican and $49,100 for Navasota No. 2, or $123,900 for the total plan after reimbursement by non-Federal interests of annual costs allocated to water supply; non-Federal interests will bear all operation and maintenance costs for recreation estimated at $314,700, annually. The economic evaluation of the plan of stage development is as follows:

Item	Millican	Navasota No. 2
Period of evaluation	1975-2075	2010-2110
First cost	$58,620,000	$61,087,000
Annual charges	2,404,500 (1)	2,484,200 (1)
Annual benefits	6,648,400	3,648,000
Benefit-cost ratio	2.8	1.5

(1) Future recreation facilities discounted to present value at year 1975 for Millican, and at year 2010 for Navasota No. 2.

14. The District Engineer recommends authorization of the Millican and Navasota No. 2 projects, in lieu of the authorized Ferguson project, and construction of the units in accordance with the plan of stage development, subject to certain local cooperation for water supply and recreation and fish and wildlife enhancement. The Division Engineer concurs.

15. Public notice.--The Division Engineer issued a public notice stating the recommendations of the reporting officers and affording interested parties an opportunity to present additional information to the Board. Careful consideration has been given to the communications received.

Views and Recommendations of the Board of Engineers for Rivers and Harbors.

16. Views.--The Board of Engineers for Rivers and Harbors concurs in general in the views and recommendations of the reporting officers. It notes that the Millican site alone could be economically scaled to develop the total practical water-management potentials of the Navasota River basin; however it further notes that the construction cost of the two-stage plan is less than Millican alone by about $10 million on a present worth basis at year 1975. The Board recognizes the need for immediate authorization of the second-stage Navasota No. 2 Reservoir--although not required until the year 2010--in order to permit acquisition of such interest in lands required as to preserve the site against incompatible developments. The Board concludes that the recommended plan is suitable for the intended purposes, is scaled for timely development of the water-management needs of the area, and is economically justified.

17. Recommendations.--Accordingly, the Board recommends:

a. That the authorized project for the Brazos River and tributaries be modified to provide for authorization of two-stage development on the Navasota River, consisting of a dam and reservoir at the Millican site as the initial unit and another at the Navasota No. 2 site as a future unit, for the purposes of flood control, water supply, and recreation and fish and wildlife enhancement in lieu of the authorized Ferguson Dam and Reservoir;

b. That the Millican and Navasota No. 2 Reservoirs include, as integral parts for flood-release purposes, appurtenant channel improvements and/or flowage easements on the Navasota River downstream from the dams;

c. That the foregoing be accomplished, with such changes and modifications as in the discretion of the Chief of Engineers may be advisable, at an estimated cost to the United States of $119,707,000 for construction and $229,000 for annual operation and maintenance, or at increases of $95,707,000 for construction and $146,100 for annual operation and maintenance over the presently estimated costs of the authorized project: Provided that, prior to initiation of construction of each reservoir unit, responsible local interests give assurances satisfactory to the Secretary of the Army that they will:

(1) Obtain without cost to the United States all water rights necessary for operation of the project in the interest of water supply;

(2) Hold and save the United States free from damages due to water-rights claims resulting from construction and operation of the project;

(3) Reimburse the United States for the project costs allocated to water supply on terms which will permit paying out the costs allocated thereto as determined by the Chief of Engineers, in accordance with the provisions of the Water Supply Act of 1958, as amended, and with such modification of the following presently estimated allocated water supply costs as may be necessary to reflect adjustments in the storage capacity for water supply and other purposes:

Water Supply Costs Allocated to Local Interests

Plan unit	Construction first costs	Average annual operation and maintenance costs
Millican Reservoir	$19,215,500	$ 33,200
Navasota No. 2 Reservoir	46,771,700	71,900
Total plan	$65,987,200	$105,100

(4) In accordance with the Federal Water Project Recreation Act:

(a) Administer project land and water areas for recreation and fish and wildlife enhancement;

(b) Pay, contribute in kind, or repay (which may be through user fees) with interest, one-half of the separable cost of the project allocated to recreation and fish and wildlife enhancement, the amounts involved being currently estimated at $2,530,000 for the Millican Reservoir, and $1,775,000 for the Navasota No. 2 Reservoir, or $4,305,000 for the total plan; and

(c) Bear all costs of operation, maintenance, and replacement of recreation and fish and wildlife lands and facilities, the amounts involved being currently estimated on an average annual basis at $178,000 for the Millican Reservoir, and $136,700 for the Navasota No. 2 Reservoir, or $314,700 for the total plan.

Provided further, that the sizing and responsibility for development, operation, maintenance, and replacement of the recreation and fish and wildlife enhancement features of the reservoirs may be modified in accordance with the alternatives provided in the Federal Water Project Recreation Act cited above, dependent upon the intentions of non-Federal interests regarding participation in the costs of these features at the time of reservoir construction and subsequent thereto, and that appropriate adjustments reflecting such modifications may be made in the allocation of costs to other project purposes.

18. The Board further recommends that following authorization of the recommended Millican and Navasota No. 2 Dam and Reservoir projects, detailed site investigations and designs be made for the purpose of accurately defining the project lands required; that, subsequently, advance acquisition be made of such title to such lands as may be required to preserve the sites against incompatible developments; and that the Chief of Engineers be authorized to participate in the construction or reconstruction of transportation and utility facilities in advance of project construction, as required to preserve such areas from encroachment and avoid increased cost of relocations.

19. On the foregoing basis, the net cost to the United States for construction, after repayment by local interests for construction costs allocated to water supply and recreation and fish and wildlife enhancement is $36,874,500 for Millican, and $12,540,300 for Navasota No. 2, or $49,414,800 for the total plan. The net cost to the United States for operation, maintenance, and replacements on an average annual basis is $74,800 for Millican, and $49,100 for Navasota No. 2, or $123,900 for the total plan.

FOR THE BOARD:

R. G. MacDONNELL
Major General, USA
Chairman

REPORT OF THE DISTRICT ENGINEER

REVIEW OF REPORTS
ON
BRAZOS RIVER AND TRIBUTARIES, TEXAS
COVERING
NAVASOTA RIVER WATERSHED

SYLLABUS

The District Engineer finds from his investigations that major floods originating on the Navasota River watershed cause a flood problem within the lower 83.4-mile reach of the Navasota River, and augment appreciably the flood conditions within the lower 236-mile reach of the Brazos River; and that an important water supply problem exists throughout a regional study area consisting of the Navasota River watershed, the lower Brazos River Basin, and the contiguous gulf-coastal areas. He concludes that certain of the flood and water supply problems can best be solved by construction of a plan of stage development, with Millican Reservoir as the initial unit and Navasota No. 2 Reservoir as the future unit, in lieu of the authorized Ferguson Reservoir project. He concludes further that there is an immediate need for the construction of the Millican Reservoir as the initial unit to provide optimum economical development of the water resources of the Navasota River watershed; and, further, that the need for the construction of the Navasota No. 2 Reservoir as the second unit is fully justified at such time additional water supply is needed. The District Engineer concludes that the Millican and Navasota No. 2 Reservoirs are fully justified as units in the system of authorized reservoir projects for flood control, water conservation, and allied purposes in the Brazos River Basin.

The District Engineer recommends that the authorized project for Brazos River and Tributaries, Texas, be modified to provide for the construction of the Millican and Navasota No. 2 Reservoirs with appurtenant channel improvements and/or flowage easements on the Navasota River for flood-release purposes, in lieu of the authorized Ferguson Reservoir project, at an estimated construction cost to the United States of $119,707,000 and an estimated $229,000 for annual operation and maintenance, subject to the conditions that local interests reimburse the United States for the project costs allocated to water supply and to recreation and fish and wildlife enhancement.

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

JULY 2, 1965

SUBJECT: Review of Reports on Brazos River and Tributaries, Texas Covering Navasota River Watershed

THRU: Division Engineer
U. S. Army Engineer Division, Southwestern
Dallas, Texas

TO: Chief of Engineers
Department of the Army
Washington, D. C. 20315

INTRODUCTION

1. AUTHORITY.- This review report is submitted in response to the following resolution adopted July 1, 1958:

> "Resolved by the Committee on Public Works of the House of Representatives, United States, That the Board of Engineers for Rivers and Harbors be, and is hereby, requested to review the reports on Brazos River and Tributaries, Texas, printed in House Document No. 535, 81st Congress, Second Session, and other reports with a view to determining what modifications to the authorized plan for flood control, water conservation, and related water uses in the Navasota River Basin are desirable."

2. SCOPE.- This report presents the results of a comprehensive study of the water and related land resources of the Navasota River watershed with particular emphasis on determining whether the authorized plan (the Ferguson Reservoir project) should be modified at this time. The report is limited to investigation of water resource developments on the Navasota River watershed; but includes consideration of water problems and needs of a regional area within the influence of such developments. Thus, the study area for this report consists of the Navasota River watershed, the lower Brazos River Basin downstream of Whitney Dam, and the contiguous gulf coastal areas, including the area as far east as Galveston and Texas City. The report presents a comprehensive plan for use and control of the runoff from

the Navasota River and its tributaries which has been integrated with existing and proposed local and other Federal improvements within the lower Brazos River Basin and is in consonance with the overall planning of local, State, and Federal interests. The plan presented herein is based upon analysis of detailed technical data and investigations reported upon in the various appendixes of this report.

3. PURPOSE OF THE REPORT.- The Navasota River watershed with a drainage area of 2,211 square miles is located in the east-central portion of Texas, and is a principal tributary area of the lower Brazos River Basin. The watershed is of considerable importance with respect to resolving flood and water supply problems within the regional study area. The primary water problems of the study area have resulted from the experienced extremes of runoff resulting in floods or extended periods of drought without adequate existing control measures to conserve and regulate the water for beneficial use. Local and state officials, having recognized the increasing importance of water conservation and the need for comprehensive planning for all purposes associated with water and related land resources, requested this investigation be made.

4. ARRANGEMENT OF THE REPORT.- The following sections of this report contain the results and conclusions of the study and recommendations of the District Engineer, based on analysis of technical data and investigations reported upon in the following appendixes to this report:

APPENDIX I	- Project Formulation, Analyses, Costs, and Cost Allocation
APPENDIX II	- Hydrology, Water Resources, and Hydraulic Design
APPENDIX III	- Economics
APPENDIX IV	- Recreation and Fish and Wildlife Enhancement
APPENDIX V	- Reports by Other Federal Agencies
APPENDIX VI	- Views and Comments of Other Agencies

5. HISTORY OF INVESTIGATION.- The most recent study submitted to Congress concerning the Navasota River watershed was completed in August 1947 and is printed as House Document No. 535, 81st Congress, 2d Session. This study was the comprehensive "Report on Survey of Brazos River and Tributaries, Texas, Oyster Creek, Texas, Jones Creek, Texas." The reports contained in House Document No. 535 and prior reports on the Brazos River Basin recommended three local flood protection projects and a system of eight reservoirs in a plan for the comprehensive development of the lower Brazos River Basin for flood control and water conservation purposes. The local flood protection projects and the various units of the eight-reservoir system were authorized by the U. S. Congress between the years 1941

and 1954. Four of the reservoir units are in operation: Whitney Reservoir on the Brazos River, Belton and Proctor Reservoirs on the Leon River, and Waco Reservoir on the Bosque River. Two others, Stillhouse Hollow Reservoir on the Lampasas River and Somerville Reservoir on the Yegua Creek, are under construction. Laneport Reservoir on the San Gabriel River, now a unit of the San Gabriel River projects, is in the preconstruction planning stage. The eighth reservoir, Ferguson Reservoir on the Navasota River, is under restudy as part of this survey report investigation. The authorized Ferguson Reservoir is considered to be an important unit in the reservoir plan for reduction of flooding on the lower Brazos River.

6. Subsequent to preparation of the report printed as House Document No. 535, 81st Congress, 2d Session, a report of survey scope entitled "Review of Reports on Brazos River and Tributaries, Texas, Navasota River Watershed," dated October 17, 1960, was prepared and submitted to the Office, Chief of Engineers through the Southwestern Division, pursuant to the authorization cited in paragraph 1. The report contained a restudy of the authorized Ferguson Reservoir and studies of alternative reservoir plans, and recommended the multiple-purpose Millican Reservoir for flood control, water conservation, recreation, and fish and wildlife at river mile 24.1, in lieu of the authorized Ferguson Reservoir at river mile 36.5. The Texas Board of Water Engineers (presently the Texas Water Commission) and the Brazos River Authority expressed a desire that not less than 2,300,000 acre-feet of conservation storage be provided on the Navasota River, and the recommended conservation storage was revised from 674,800 acre-feet to 2,359,800 acre-feet.

7. The Chief of Engineers referred the report to the Governor of Texas and to other interested Federal agencies for their formal views on the report in April 1962. In his comments on the report in August 1962, the Governor of Texas recommended that prior to authorization of the proposed project, a review and revision of the costs allocated to non-Federal interests be made pursuant to the Federal Water Pollution Act Amendment of 1961, a review and reevaluation be made of project costs allocated to recreation and fish and wildlife purposes, and, that a reexamination be made of the project cost allocation in terms of policies set forth in Senate Document 97, 87th Congress, 2d Session. He also recommended that the authorizing legislation provide for possible stage development. The Chief of Engineers returned the report to the Division and District Engineer in November 1962 in order that these additional studies might be made prior to submitting the report to Congress.

8. Subsequent to initiating the restudy, the Governor of Texas was asked to review the comments made in August 1962 on the previous report. Representatives of the Corps met with the Texas Water

Commission; the General Manager, Brazos River Authority; and a representative of the Governor to discuss the restudy. After necessary review and consideration by the various state agencies, the Governor of Texas indicated by letter of March 26, 1964, that the new study should consider the following additional items: (a) the desirability of stage construction in order to reduce the immediate obligation of the Brazos River Authority to contract with the Federal government for the large amount of conservation space at Millican Reservoir site approximating 2,300,000 acre-feet; (b) consideration of stage development involving the optimum plan at the Millican site, or the site designated as Navasota No. 2, or a combination of the two, taking into account what would be the most feasible sequence of any construction recommended; and maintenance of close liaison between the Corps and the Texas Water Commission in regard to the State's problems and policies on inclusion of water quality storage in any recommended reservoir on the Navasota River.

9. Investigations of the Navasota River watershed were also made by the U. S. Study Commission - Texas, created in 1958, by an act of Congress. The U. S. Study Commission published a report in March 1962 which presented a plan for use of existing physical improvements and proposed future improvements to conserve and control the available water resources and supply the projected demands for all the major river basins in Texas, except the Sabine, Red, and Rio Grande. The framework plan developed by the Study Commission for the Brazos River Basin includes a reservoir for flood control and water supply on the Navasota River at the Millican site; a potential system of Soil Conservation Service reservoirs on Christmas, Big, and Holland Creeks, tributaries of the Navasota River; and a potential non-Federal water supply reservoir for the Navasota River at the Wayland Crossing site.

10. The comprehensive plan presented in this report has been developed after fully considering all other investigations and reports described above and the information received as a result of the public hearings and meetings with local interests discussed in the following paragraphs. The plan is generally compatible with the major objectives of plans and investigations developed by local interests and the various agencies concerned with water resource problems in the Navasota River watershed and with the comprehensive aspect of the basinwide Brazos River studies now in progress.

11. PUBLIC HEARINGS AND IMPROVEMENTS DESIRED.- A public hearing was held at Bryan, Texas, on December 16, 1958, in order to obtain the views and desires of local interests, and other Federal agencies during the early phase of the study. The following Federal and State governmental representatives and agencies submitted briefs or

proposals for the record, either before, during, or after the hearing: Honorable Olin E. Teague, United States House of Representatives, sponsor of the subject investigation; Honorable Clark W. Thompson, United States House of Representatives; Honorable John Dowdy, United States House of Representatives; U. S. Bureau of Reclamation; Brazos River Authority; State Highway Department; and State Board of Water Engineers. The Federal and State governmental agencies represented at the hearing were the U. S. Bureau of Reclamation, U. S. Soil Conservation Service, U. S. Department of Agriculture, Federal Power Commission, Brazos River Authority, State Health Department, Texas Water Commission, State Highway Department, State Game and Fish Commission, and Texas Water Conservation Association. Most of the local interest agreed on the urgent need for a multiple-purpose reservoir on the Navasota River to permit development of the municipal, industrial, and agricultural potentialities of the watershed. However, opposition to the authorized Ferguson Reservoir project was expressed by an organization made up of approximately 60 landowners within the Ferguson Reservoir area on the contention that the project would inundate the most highly developed and productive area of the Navasota River watershed, and petitions signed by approximately 400 residents of the watershed objected to construction of any dam on the Navasota River.

12. An hour-long public information panel program, sponsored by Congressman Olin E. Teague, was held at Waco, Texas, on September 10, 1961, and was transmitted by television and radio for the purpose of presenting to the local interests information on the selected plan of improvement and on other plans studied by the District Engineer for the Navasota River watershed. The program panel consisted of Honorable Olin E. Teague, Representative for the U. S. Sixth District of Texas; Mr. Durwood Manford, Chairman of the Texas State Board of Water Engineers; Mr. M. N. Bostick, Vice President and General Manager of KWTX-TV, Waco, as announcer; and Colonel R. Paul West, District Engineer, U. S. Army District, Fort Worth, Texas. Both favorable and unfavorable comments were received concerning the program and the proposed Millican Reservoir. A review of all comments expressed by local interests showed that the persons that would be benefited by the proposed project were favorable to its authorization and that certain landowners whose property would be in the reservoir area were opposed to the project.

13. At the request of local interests, the Board of Engineers for Rivers and Harbors held a public hearing at College Station, Texas, on March 1, 1962, giving interested parties further opportunity to express their views on the plan of improvement recommended in the report which was being reviewed by the Board at that time. Representatives of the Navasota River Improvement Association, a local organization, and other local groups, presented information in substantiation of their support for a dam and reservoir at Navasota River

mile 83.4, indicated in the report as the Navasota No. 2 site, in lieu of the proposed dam and reservoir at the Millican site. City officials and civic groups in the cities of Bryan, College Station, and Navasota presented statements in support of the Millican site. A representative of the Texas Water Commission, formerly the State Board of Water Engineers, restated its view that not less than 2,300,000 acre-feet of conservation storage at the Millican site satisfied the requirements and policies of the State. A representative of the Brazos River Authority restated support of conservation storage at the Millican site, but stated that the Authority might wish to discuss a modification of the amount of such storage at some future date. The Board completed action on the report in March 1962, concurring in general in the views and recommendations of the reporting officers, and forwarded its report to the Office, Chief of Engineers. The report was returned to the field by the Chief of Engineers for additional studies after receiving the formal comments of the Governor of Texas as discussed in paragraph 8.

14. A public hearing was held at College Station, Texas, on March 16, 1965, to present the plan of improvement under consideration by the District Engineer and to obtain the views of local interests. The hearing was attended by 276 persons, of whom 15 persons spoke in favor of the proposed plan of improvement and 5 spoke in opposition to the sequence of construction of the projects in the plan. A total of 83 exhibits were submitted with 58 favoring the plan of improvement, 18 in opposition to the plan as presented, and 7 noncommittal. Proponents of the plan included local officials of Bryan, College Station, Navasota, and the counties along the Brazos River below the mouth of the Navasota River, Brazos River Authority, Texas A&M University, Millican Dam Development Association, civic organizations, representatives of businesses and industries, landowners and interested individuals. All of the purposes in the multiple-purpose projects were supported by one or more of the above proponents. Representatives of the Navasota River Improvement Association expressed opposition to the plan to build Millican Dam first; but would support the stage construction if Navasota No. 2 Dam is constructed first, since it was felt that this would provide all of the perceivable need for water conservation and 90 percent of the downstream flood control benefits that would be accomplished by constructing Millican Dam first. Support for Navasota No. 2 Dam as the first or the only project on the Navasota River was presented by local officials or civic organizations of the towns of Hearne, Calvert, Bremond, and Franklin, Robertson County Commissioners Court, businesses in the town of Hearne, and individual landowners. The opposition to Millican Dam is based mainly on the contention that the project would inundate the most highly developed and productive area of the Navasota River watershed in order to benefit interests outside the watershed, and that the Navasota No. 2 Dam will best serve the interest of the Navasota River valley until such time as the need for additional water conservation develops.

WATERSHED DESCRIPTION

15. LOCATION AND SIZE.- The Navasota River watershed is located in the east-central portion of Texas, approximately between 30°20' and 31°50' north latitude and 95°55' and 97°00' west longitude. The Navasota River watershed is a principal tributary area of the lower Brazos River Basin. The watershed is bounded on the east by the Trinity River Basin and on the west by lateral tributary areas of the main stem of the Brazos River. The Navasota River watershed has a total length of about 122 miles, a maximum width of 35 miles, and an area of about 2,211 square miles. The watershed includes portions of Hill, Limestone, Freestone, Robertson, Leon, Brazos, Madison, and Grimes Counties. The Navasota River watershed extends generally southward from the southeast corner of Hill County to the confluence of the Navasota and the Brazos Rivers in Grimes and Brazos Counties, about 27 miles southeast of Bryan, Texas. The Navasota River, for over 50 percent of its length, serves as the county line between adjoining counties; namely, Robertson and Leon, Brazos and Madison, and Brazos and Grimes. The principal urban areas within the Navasota River watershed include Bryan, College Station, Navasota, Mexia, Groesbeck, Teague, and Kosse. The location and extent of the Navasota River watershed are shown on plate A (adjacent to the rear cover of this report). The relative location of the Navasota River watershed within the Brazos River Basin is shown on plate 1. The component drainage areas of the Navasota River watershed are shown on plate 2.

16. PHYSICAL CHARACTERISTICS OF THE WATERSHED.- The Navasota River watershed lies within the West Gulf Coastal Plain section of the Coastal Plain physiographic province. The flood plain areas along the Navasota River are composed of typical bottom land and terrace fluvial sediments consisting of variable combinations of gravels, sands, silts, and clays. The upstream area of the watershed is covered by the generally marly clay residual soils of the underlying Upper Cretaceous rocks and lies in the Blackland Prairie belt of the West Gulf Coastal Plain physiographic section. Proceeding downstream from the Blackland Prairie belt, the residual soils become increasingly sandy and merge into the East Texas Timber belt. The watershed changes gradually from the typical prairie topography and vegetation in the north portion to the relatively hilly and forested East Texas Timber belt in the south portion. The general land elevations of the watershed vary from about 650 feet mean sea level at the headwater divide to about 185 feet near the mouth of the Navasota River.

17. GEOLOGY.- The watershed lies within the outcrops of the Upper Cretaceous, Eocene, Oligocene, and Miocene strata. From its upper reaches to its confluence with the Brazos River, the Navasota

River traverses formations of decreasing ages as follows: the Taylor and Navarro Groups of the Upper Cretaceous; the Midway, Wilcox, Claiborne, and Jackson Groups of the Eocene; the Catahoula of the Oligocene; and the Oakville and Lagarto Groups of the Miocene epoch. The outcrops consist principally of consolidated marls, soft limestones, sands, clays, silty clays, and sandy clays.

18. STREAMS.- The Navasota River originates in the southeastern portion of Hill County and flows southeastward for about 72 river miles to the Limestone-Robertson County line; thence southerly for approximately 125 river miles to its confluence with the Brazos River at river mile 232.0 near Washington, Texas. The average slope of the streambed is 2.6 feet per mile. From river mile 197 to 125 the Navasota River is generally well defined, including a small but irregular flood plain; whereas, from river mile 125 to river mile 83 the flood plain widens into a large well-defined area and the streambed changes from moderately straight course into a meandering direction. Downstream from river mile 83, in the vicinity of Normangee, Texas, the valley floor, generally covered with trees and brush, becomes wider and more level with many sloughs, lakes, and swamps. At the same time, the river channel becomes more tortuous with a relatively flat streambed gradient and a well-defined flood plain. This flat streambed gradient makes it possible for a large area of the Navasota River and flood plain to become inundated by flood waters from the main stem of the Brazos River when at flood stage although no rainfall may have occurred in the Navasota River watershed. The Brazos River floodflows have been known to inundate the Navasota River and flood plain with backwater for approximately 24 river miles. The principal tributaries of the Navasota River are Christmas, Big, Steel, Lake, Clear, Camp, Cedar, Wickson, Carters, Lick, Gibbons, Peach, Holland, and Big Creeks in descending order from the source to the mouth of the Navasota River. The relative location of the Navasota River with its principal tributaries is shown on plate 2. Pertinent data for selected reaches of the Navasota River are shown in the tabulation below. The profiles of the Navasota River for these reaches are shown on plate 3.

	Average for reach (river mile)		
	0-10	10-41.5	41.5-83.4
Streambed gradient, feet per mile	1.4	1.2	1.4
Height of banks, feet	42	14	13
Bankfull width, feet	250	150	100
Bankfull capacity, cfs	10,000	4,000	2,500

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19. CLIMATOLOGY.- The Navasota River watershed has a generally mild climate with a wide range of annual and daily temperatures. In summer, the days are usually hot and the nights moderately warm. Generally the winters are moderate; however, freezing temperatures and snowfall are occasionally experienced during the passage of cold high-pressure air masses from the northwestern polar regions and the continental western highlands.

20. The mean annual temperature for the watershed is about 67 degrees Fahrenheit. Temperatures in and near the watershed have ranged from a maximum of 114 degrees to a minimum of minus 7 degrees. January, the coldest month, has an average minimum daily temperature of about 37 degrees; August, the warmest month, has an average maximum daily temperature of about 97 degrees. The average length of growing season between killing frosts is about 250 days.

21. The mean annual precipitation over the Navasota River watershed is about 39 inches and varies from about 35 inches in the headwater region to about 42 inches near the mouth. Snowfall is an insignificant portion of the total precipitation. Annual precipitation at the Anderson gage has ranged from a maximum of 65.46 inches in 1919 to a minimum of 17.69 inches in 1917. The normal seasonal distribution of rainfall over the watershed is generally favorable for agricultural purposes, with the heaviest rainfall occurring during the period April through June.

22. The average annual runoff on the Navasota River watershed has been measured at two stream gaging stations. Annual runoff data for the stations, both of which are on the main stem of the Navasota River, are summarized in the following tabulation.

Gaging Station	Drainage area (sq. mi.)	Period of record			Annual runoff (in.)		
		From	To	Length (yr.-mo.)	Maximum (1)	Minimum (1)	Mean
Easterly (2)	940	4/24	9/63	40-6	14.75	0.23	5.94
Bryan (3)	1,429	1/51	9/63	12-9	13.08	0.46	4.48

(1) Water year.
(2) Recording gage installed in 1932.
(3) Recording gage entire period.

23. FLOODS AND DROUGHTS.- The amounts of average annual precipitation and runoff indicate that the Navasota River watershed receives a substantial amount of fresh water through rainfall and runoff. However,

extremes in rainfall and runoff have caused flood and water supply problems on the watershed. The history of the watershed shows a recurring pattern of long to moderate droughts and periods of heavy rainfall. The most severe drought period, based on dependable yield studies made for the reservoirs, extended from June 1947 through March 1957.

24. Floods occur frequently and at almost any time of the year on the Navasota River watershed. The maximum known flood in the vicinity of the gaging station near Easterly, as determined by the U. S. Geological Survey, occurred in June 1899. This flood produced a peak stage and discharge of about 24 feet and 90,000 second-feet, respectively. The maximum flood during the period of record at the Easterly gage (1924-1963) was that of May 1944, with a peak discharge of 60,300 second-feet and a maximum stage of 22.13 feet. The following tabulation gives the peak discharges for the larger floods occurring during the period of record at the Easterly gage.

Flood Date	Peak Discharge (CFS)
May 1929	49,400
May 1930	30,100
Jan 1932	35,500
Sep 1932	53,200
Dec 1935	41,700
Nov 1940	34,300
May 1944	60,300
Apr 1957	37,700
Dec 1960	33,000

25. The maximum flood during the period of record (1951-1963) at the Bryan gage on the Navasota River was that of April 1957 with a peak discharge of 35,800 second-feet.

ECONOMIC DEVELOPMENT

26. INTRODUCTION.- This study is concerned primarily with water problems and demands associated with the water resources of the Navasota River that can be solved by the construction of water resource improvements having as project purposes flood control, water supply, and recreation-fish and wildlife. Figure 1 shows the composite base study area for all purposes including the flood control area. The economy of the flood control area was used as a guide in planning for flood plain improvements. The water supply area includes Austin, Bell, Brazoria, Brazos, Burnet, Burleson, Falls, Fort Bend, Galveston, Grimes, Hill, Lee, Leon, Limestone, McLennan, Madison, Milam, Robertson, Waller, Washington, and Williamson Counties. The area selected for the economic base study comprises 29 counties and contains about 26,128 square miles, 9.92 percent of the total land area of the State of Texas. The economic base study presented in appendix III contains a detailed analysis of current and historical economic conditions and projections of industrial development, population, employment and income for the study area.

27. POPULATION.- The population of the study area in 1960 was 2,182,177, of which 226,077 resided within the flood control area. The comparative rates of growth for the periods 1890 to 1960 and 1960 to 2025 for the United States, Texas, study area, and flood control area are shown below.

	Average annual percent of change in population	
	1890-1960	1960-2025
United States	1.50	1.72
Texas	2.10	1.88
Study area	1.91	1.68
Flood control area	0.84	2.18
Residual area	2.22	1.62

28. Houston, Galveston and Waco, three of the state's 21 standard metropolitan statistical areas, are located partially or completely within the study area. For the period from 1890 to 1960, the residual area (study area less flood control area) experienced quite a rapid growth. The activity, which has occurred in the deep water ports of Houston and Galveston, has benefited the economy of this residual area. The larger urban centers are influencing the nearby counties of the flood control area to a greater extent than they have in the past. This is particularly noticeable in the flood control counties which are

adjacent to Harris County. The Houston standard metropolitan statistical area was recently enlarged by the addition of Montgomery, Liberty, Brazoria, and Fort Bend Counties. (Liberty County lies outside the study area.) The future population growth rate of the flood control area is expected to outpace that of the residual area as the urban centers expand into areas of lower population density. Growth of business and industry in these recently added counties of the Houston SMSA will create additional employment and increase population.

29. The population of the study area is projected to increase at the average annual rate of 1.68 percent to the total of 6,465,100 in 2025 as compared with an average annual rate of 2.18 percent to the total of 917,700 in 2025 for the flood control area.

30. REAL PERSONAL INCOME.- Real personal income is the most comprehensive available measure of economic activity and bears a close and generally constant relationship with the gross national product over the long run. At the national level it has been found that personal income exhibits the same rate of increase that characterizes the gross national product. Personal income, when reduced by taxes, becomes disposable personal income, that portion of the income most representative of the economic condition of an area. In 1960, the disposable personal income of the 2,182,177 persons in the study area and the 226,077 persons in the flood control area was $3,927,932,000 and $318,824,000 respectively. On the basis of a 1960 per capita total, this amounted to $1,800 for the study area and $1,410 for the flood control area. The 1960 per capita disposable income for the nation was $1,937.

31. MANUFACTURING.- Prior to 1940, manufacturing in Texas was greatly dependent on agriculture and forestry for raw materials and furnished the farmer with the tools of his livelihood. There was the beginning of a mineral-oriented industrial expansion but nothing like the upsurge that followed the advent of World War II.

32. During the war years, the national policy of industrial dispersion and development and the availability of large quantities of mineral resources combined to give impetus to the growth of the refining industry, established the aircraft industry, and gave the state a tremendous boost in the chemical field. The state's income originating in the chemical industry is about 16 percent of the total, nearly double the 9 percent which was derived from manufacturing in 1940.

33. For the study area, manufacturing is quite important. In 1960, about 31 percent of the total income was derived from manufacturing. The study area rate of expansion exceeded that of the state for the period 1939 to 1958. Measured in terms of the value added by

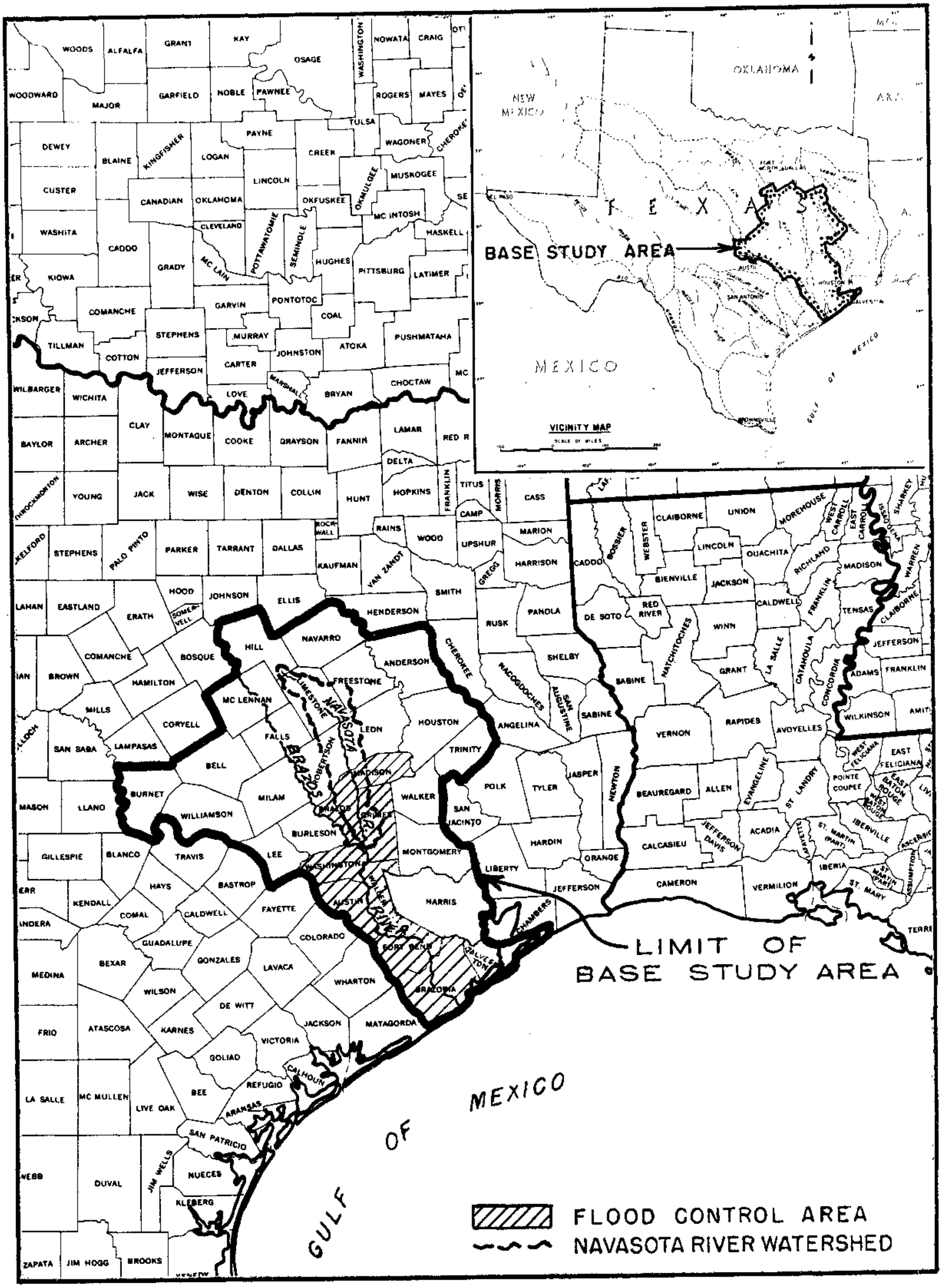

FIGURE I. NAVASOTA RIVER BASE STUDY AREA manufacture, the study area gained from about 27.1 percent in 1929 to about 36.1 percent of the state's total value added in 1958.

34. Over 63 percent of the study area manufacturing is produced in Harris County which has a very important influence on the study area's economy. It is a rapidly growing commercial and industrial center. A 55-mile long highly industrialized ship channel connects the Houston area with the Gulf of Mexico. This is a major port for oil, petrochemicals, sulfur, cotton, forest products, livestock and other farm-ranch-mining raw materials and processed goods. Manufactures include petroleum and associated products, chemicals, lumber, supplies, metals and various others. It is a center for oil and gas transmission. The National Aeronautics and Spacecraft Center in the Clearlake area is headquarters for space exploration.

35. The Aluminum Corporation of America operates an alumina reduction plant in Milam County.

36. The remaining 37 percent of the study area's value added by manufacture is distributed among the other counties of the study area, and of this percentage, greater concentrations develop in and near urban centers such as Waco, Galveston and Texas City.

37. Manufacturing in the counties of the flood control area is very heavily oriented to chemicals and allied products. Employment in chemical and allied products category represented one-half of the 1960 manufacturing employment. The next two largest manufacturing employment categories were food and kindred products (13.29 percent) and other nondurable products (11.48 percent).

38. The relative importance of manufacturing expressed as manufacturing employment is illustrated in table 1 which shows employment in the various manufacturing categories as a percent of the total manufacturing employment for the United States, Texas, study area, and flood control area. The table was prepared from information given in the U. S. Bureau of the Census, U. S. Census of Population: 1960.

39. AGRICULTURE.- Agriculture occupies an important position even though it ranks third among the commodity producing industries in the study area. Crops and livestock provide livelihood for operators of about 44,800 farms and ranches in the study area and 11,551 farms and ranches in the flood control area. The 1960 income in agriculture was slightly over 2.8 percent of the total for the study area and about 10.2 percent of the total for the flood control area. The total land in farms represented 75 percent of the total land area in the study area.

40. In 1959, the total value of all farm products sold was $224.2 million for the study area and $63.7 million for the flood

control area. Sale of livestock and livestock products represented 53.9 percent of the study area total and 52.6 percent of the flood control area total. The 1959 value of farm products sold in Harris County represented 8.8 percent of the study area total value of farm products sold. The 1959 value of all livestock and livestock products sold in Harris County represented about 9.0 percent of the study area total value of livestock and livestock products sold. This higher proportion of livestock and livestock products sold can probably be attributed to beef feed-lot operations, dairies, and poultry farms that so frequently are situated near large urban centers. According to the 1959 census of agriculture, Harris County is the top county in number of head of cattle. Brazoria County, also in the study area, is third in cattle population.

41. Varieties of crops produced in the study area include: cotton, corn, grains, grain sorghums, vegetables, fruits, oats, melons, peanuts, rice, sugar processing, fruits and various field crops. Lumber production is important in several study area counties. Beef cattle, sheep and wool production, angora goats, dairy products and poultry production are significant parts in the agricultural economy of the study area. Most of these crops and livestock are also produced in the flood control area.

42. MINERAL PRODUCTION.- About 10 percent of the state's value of mineral production came from the study area in 1960. The minerals produced in the study area include petroleum, natural gas, natural gas liquids, sand and gravel, stone, limestone, clays, graphite, lignite, lime, magnesium chloride, magnesium compounds, salt, bromine and sulfur. Over 53.3 percent of the study area's value of mineral production came from the flood control area in 1960.

43. A wide array of organic and inorganic chemicals, feedstocks and intermediates were produced by chemical companies in the study area. Important chemicals were ammonia, acetylene, and actyl chemicals, acrylonitrile, benzene, butanol, caprolactam, ethylene, propylene, the poly derivatives and styrene. There are a number of petroleum refineries in the study area. Portland and masonry cements were produced at the four cement plants in the study area. In Milam County, lignite was mined from open pits by Industrial Generating Company and used for fuel to generate electric power. The Aluminum Company of America operated its Rockdale aluminum reduction works near full capacity during 1964. Alumina from its Point Comfort alumina refinery supplied feed for the reduction plant. Lignite will become more important as a fuel and will occupy a greater proportion of the value of mineral production in the future.

44. GOVERNMENT.- The economy of the study area is influenced by the effect of government employment. Over six percent of the

TABLE 1

EMPLOYMENT IN MANUFACTURE-1960

	United States	Texas	Study area	Flood Control area
	Percent of manufacturing employment			
Furniture, lumber and wood products	6.09	6.11	5.57	5.05
Primary metal industries	6.99	4.99	5.74	2.14
Fabricated metal industries	7.38	5.79	7.35	2.05
Machinery except electrical	8.95	8.68	13.48	4.31
Electrical machinery	8.49	4.08	2.03	0.49
Motor vehicles and motor vehicle equipment	4.81	1.25	0.46	0.15
Transportation equipment except motor vehicle equipment	5.58	9.09	2.20	1.06
Other durable goods	7.83	6.34	6.70	2.29
Total durable goods	56.12	46.33	43.53	17.54
Food and kindred products	10.41	14.77	10.74	13.29
Textile mill products	5.48	1.44	1.38	2.38
Apparel and other fabricated textiles	6.62	6.16	3.47	0.94
Printing, publishing and allied products	6.52	7.46	6.14	4.30
Chemical and allied products	4.92	8.70	15.58	50.07
Other nondurable products	9.93	15.14	19.16	11.48
Total nondurable products	43.88	53.67	56.47	82.46
Total	100.00	100.00	100.00	100.00

total employment in the study area was from government in 1960. According to the census, approximately 55 percent of the 1960 government employment was civilian in the study area. There is a U. S. Veterans Hospital at Waco. A part of Fort Hood, a large military establishment, near Killeen, is within the study area. It is expected that government will continue to occupy an important role in the economy of the study area.

WATER RESOURCE DEVELOPMENTS

45. GENERAL.- The study area, including the Navasota River watershed, the lower Brazos River Basin, and the contiguous gulf coastal areas, involve water resource developments which have been constructed or planned by both Federal and non-Federal interests. The principal water resource developments by local interests include water-supply reservoirs such as the existing Lake Mexia, Camp Creek Lake, and Lake Springfield on the Navasota River watershed; the planned long-range Wayland Crossing Reservoir on the upper Navasota River; the planned Allens Creek Reservoir within the Brazos Coastal area. The principal water resource developments either constructed, under construction, or planned by the Federal Government include multiple-purpose reservoirs for flood control, water supply, fish and wildlife, recreation, and siltation purposes, such as Whitney Reservoir on the Brazos River; Waco Reservoir on the Bosque River; Aquilla Creek Reservoir on Aquilla Creek; Proctor and Belton Reservoirs on the Leon River; Stillhouse Hollow Reservoir on the Lampasas River; the San Gabriel River projects on the San Gabriel River watershed; Somerville Reservoir on Yegua Creek; Ferguson Reservoir on the Navasota River; and various systems of flood detention structures on tributary areas of the lower Brazos River Basin by the Soil Conservation Service. Descriptions of the Navasota River watershed developments and a tabular summary of the Brazos River Basin developments are presented in the following paragraphs. The developments on the Navasota River watershed and the Brazos River Basin are shown on plates A (adjacent to rear cover of this report) and 1, respectively.

46. AUTHORIZED FERGUSON RESERVOIR.- The only authorized Corps of Engineers project on the Navasota River watershed is the Ferguson Reservoir project. This project was authorized by the Flood Control Act of September 3, 1954 (Public Law No. 780, 83d Congress, 2d Session), as a part of a comprehensive plan of improvement for the Brazos River Basin for flood control and water conservation purposes. The authorized Ferguson Reservoir area is shown on plate 4.

47. The Ferguson Dam Site is located at river mile 36.5 on the Navasota River, about 12 miles southeast of Bryan, Texas. The flood control portion of the Ferguson Reservoir would provide for the control of major flood flows originating on 1,782 square miles of drainage area upstream from Ferguson Dam. The water conservation portion of the authorized project would provide part of the water required for municipal water supply to cities within the lower Brazos River Basin. The authorized project would provide for a dam about 8,855 feet in length, including 904 feet of gate-controlled spillway and 7,951 feet of rolled-fill earth embankment. The spillway would consist of a broadcrested weir with crest at elevation 212.0. The spillway would have a gross length of 904 feet and would be controlled by nineteen 40 by 24 foot tainter gates. Below top of flood-control pool, elevation 236.0, the authorized

Ferguson Reservoir project would provide for a total storage capacity of 619,200 acre-feet, including 516,400 acre-feet for flood control, 62,200 acre-feet for conservation storage and 40,600 acre-feet for sedimentation. The authorized Ferguson Reservoir project has an approved first cost estimate of $24,000,000, and an estimated annual operation and maintenance cost of $82,900, based on July 1960 prices.

48. SOIL CONSERVATION SERVICE PROGRAM.- The Soil Conservation Service has investigated a potential land-treatment flood-detention program on the Navasota River watershed. The potential program is covered in the report of the U. S. Study Commission - Texas, dated March 1962. The potential program includes land-treatment measures and 28 flood-detention reservoirs, of which 13 reservoirs would be located on Christmas Creek in Limestone County within the northwestern portion of the Navasota River watershed, and 15 reservoirs would be located on Holland Creek in Grimes County and Big Creek in Brazos County, within the extreme southern or downstream portion of the watershed. Based on preliminary studies, the 13 structures on Christmas Creek would have a total floodwater capacity of about 13,820 acre-feet, providing annual benefits of $33,250 at an annual cost of $26,150; 5 structures on Holland Creek would have a total floodwater capacity of 7,070 acre-feet, providing annual benefits of $22,970 at an annual cost of $10,560; and 10 reservoirs and 8.6 miles of channel improvements on Big Creek would have a total floodwater capacity of 3,460 acre-feet, providing annual benefits of $51,920 at an annual cost of $26,270.

49. The Soil Conservation Service has initiated work plan studies on the Navasota River watershed. The State Soil Conservation Board has approved the Upper Navasota River Watershed, Limestone and Hill Counties, as feasible for assistance under provisions of Public Law 566. Structural measures, consisting of floodwater retarding structures, supplementing land treatment in the watershed, will provide watershed protection and flood prevention to agricultural lands. Also, the Brazos-Robertson Soil Conservation District and the Brazos County Water Control and Improvement District have received the assistance of the Soil Conservation Service in development of a work plan for Big Creek, Brazos County, Texas, under provisions of Public Law 566. The Big Creek work plan for watershed protection and flood prevention and agricultural water management has been approved for operation. The plan of improvement consists of land treatment measures and structural measures consisting of six floodwater retarding structures and 24.4 miles of channel improvement, including 111 grade-stabilization structures.

50. WAYLANDS CROSSING RESERVOIR.- Waylands Crossing Reservoir is included in the plan of the U. S. Study Commission - Texas report as a potential long-range water supply project to be constructed by local interests. As presently planned, Waylands Crossing Dam would be located on the Navasota River about 11 miles southeast of Groesbeck, Texas. The reservoir would have a total storage capacity of 44,200

acre-feet, of which 33,000 acre-feet would be for water supply, and 11,200 acre-feet would be for sedimentation. The water supply storage would provide an estimated dependable yield of about 21 cubic feet per second, or about 13.6 million gallons daily. The drainage area above the dam site is about 211 square miles. The future project has an estimated first cost of about $3,990,000, based on the 1961 price level.

51. LAKE MEXIA.- Lake Mexia, formed by Bistone Dam, is located in Limestone County, 7 miles southwest of Mexia on the Navasota River. Lake Mexia project was constructed by the Bistone Municipal Water Supply District for municipal and industrial water supply purposes. The project was completed on June 5, 1961. Water is sold to Mexia and Mexia State School, with future delivery to Groesbeck expected. The lake has a capacity of 10,000 acre-feet and a surface area of 1,200 acres at spillway elevation of 448.3 feet above mean sea level. The drainage area above the dam is about 198 square miles.

52. CAMP CREEK LAKE.- Camp Creek Lake is located on Camp Creek in Robertson County about 13 miles east of Franklin, Texas. Camp Creek Lake project was constructed by the Camp Creek Water Company of Bryan, Texas, for recreation purposes. The project was completed on January 3, 1949. The lake has a capacity of 8,550 acre-feet and a surface area of 750 acres at spillway elevation 310.0 feet above mean sea level. The dam has a top elevation of 325.0. Drainage area above the dam is about 40 square miles.

53. LAKE SPRINGFIELD.- Lake Springfield is located on the Navasota River in the Fort Parker State Park in Limestone County, about 4.5 miles north of Groesbeck, Texas. The lake was constructed by the Texas State Parks and Wildlife Commission and is used for municipal and industrial water supply and recreation purposes. The lake has a capacity of 4,200 acre-feet at spillway elevation.

54. OTHER RESERVOIRS.- The Navasota River watershed includes numerous other small reservoirs constructed by local interests for recreation and various water supply purposes. A few of these include Holman Reservoir and Teague Lake, constructed by the City of Teague for municipal water supply purposes; and Lake Normangee, constructed in Normangee City Park area for recreation purposes.

55. LOWER BRAZOS BASIN.- Other principal water resource developments in the lower Brazos River Basin are shown in the following tabulation:

Project	Location	Controlled storage (ac-ft)	Status
Whitney Reservoir	Brazos River	1,999,500	In operation
Belton Reservoir	Leon River	1,097,600	In operation
Proctor Reservoir	Leon River	374,200	In operation
Waco Reservoir	Bosque River	726,400	In operation
Stillhouse Hollow Reservoir	Lampasas River	630,400	Under construction
Somerville Reservoir	Yegua Creek	507,500	Under construction
San Gabriel River projects (Laneport, North Fork, South Fork Reservoirs)	San Gabriel River	692,000	Advance planning
Aquilla Creek Reservoir	Aquilla Creek	199,300	Under study
Allens Creek Reservoir	Allens Creek	575,000	U. S. Study Commission

56. INTRODUCTION.- The aim of river-basin and watershed programs is to satisfy human needs and provide solutions to the various water problems. A basic principle in this investigation is that the water and related land resources developments have value only to the extent that they are needed. The magnitude of the demands for water resources development and control in the study area is based on the past and present uses as related to the economic activities of the study area and the broad projections of future economic growth. In the evaluation of the demands for water resources, including resolution of various water problems, consideration was given to all available information on present and projected needs as developed by the State of Texas and by Federal agencies, the desires of local interests as expressed at public hearings, and the directives from Congress for this investigation.

57. The study area considered in evaluating the various water problems that would be affected by water resource developments on the Navasota River is a regional area that includes the influence areas of the several project purposes. The study area for the flood control problems consists of the flood plain of the Navasota River downstream of river mile 83.4 and the flood plain of the Brazos River below the mouth of the Navasota River. The study area for water supply consists of the lower Brazos River Basin downstream of Whitney Dam and the contiguous gulf coastal areas east and west of the basin since all developments and needs within this area are so interdependent. The study area for recreation and fish and wildlife consists of a general regional area that would be served by developments on the Navasota River. Other water problems and needs were studied in a similar manner.

58. FLOOD PROBLEM ON THE NAVASOTA RIVER.- The flood problem on the Navasota River is the result of frequent floods caused by heavy and frequent storm rainfall and inadequate channel capacities. During the period of record from 1924 to 1963, nine major floods occurred producing peak discharges at the Easterly gage (mile 105.7) varying from 30,100 to 60,300 second-feet. Also during this period of record, a total of 74 floods exceeding the existing channel capacity occurred in the Navasota River below river mile 24.1. Prior to the period of record, the maximum known flood occurred in June 1899, producing a peak discharge of about 90,000 second-feet. The channel capacity of the Navasota River is insufficient to contain these floods, being about 10,000 second-feet downstream from river mile 10.0 and varying from 4,000 to 2,500 second-feet between river miles 10.0 and 83.4. The lower Navasota River flood plain, as far upstream as river mile 24.0, is subject to varying degrees of flooding due to the backwater effects of major flood flows on the Brazos River, as well as to a combination of coincident flood conditions on the

Navasota and Brazos Rivers. As a result of these conditions, the 24.0-mile reach is considered to be a portion of the Brazos River flood plain area. The flood problem area on the Navasota River investigated for this report is the flood plain of the Navasota River from its mouth upstream to an investigated dam site at about river mile 83.4. The problem area is an agricultural area composed principally of improved and unimproved pasture lands and devoted principally to the production of beef and dairy products. It contains pipelines, highways, and railroads, but no urban development. Within the investigated problem area, exclusive of the 24-mile backwater reach, the estimated value of physical property is about $9,389,700, and the estimated average annual damages are about $249,400, under present conditions and development.

59. FLOOD PROBLEM ON THE BRAZOS RIVER.- In addition to the flood problem on the Navasota River, the need for the reduction of flood flows on the main stem of the lower Brazos River is an important flood problem to be considered in conjunction with the investigation of flood control improvements on the Navasota River watershed. The numerous major floods which originate on the Navasota River watershed contribute appreciably to the flood problem on the Brazos River. As the result of prior investigations covering the flood problems in the Brazos River Basin, a system of eight reservoirs, including the Ferguson Reservoir on the Navasota River, was recommended and authorized by the Federal government to facilitate control of floods originating on the Brazos River and its principal tributaries and to provide principally for the protection of urban development and highly-developed agricultural lands within the flood plains of the lower Brazos River. The flood problem area on the Brazos River investigated for this report is the lower 236.0-mile flood plain reach which is affected by flood flows from the Navasota River. The minimum channel capacity of the Brazos River below Waco is 60,000 second-feet at East Columbia, about 61 miles downstream from Richmond, Texas. Based on historical records during the period 1903-1962, 26 major floods have occurred on the Brazos River producing peak discharges ranging from 78,800 to 300,000 second-feet at the Richmond gage. The Brazos River problem area contains urban and highly-developed agricultural areas, as well as numerous transportation facilities, utilities, and rural non-agricultural properties. Within the investigated Brazos River problem area below the mouth of the Navasota River, the estimated value of physical property is about $270,000,000, and the estimated average annual damages are about $2,667,500, under present conditions of development.

60. WATER SUPPLY PROBLEMS.- At the public hearing held by the Corps of Engineers at Bryan, Texas, on December 16, 1958, local interests stated the need for conservation of water for municipal, industrial, and agricultural purposes in the lower Brazos River Basin, including the Navasota River watershed. These statements have been reiterated in studies by the State and Federal agencies

since 1958. The State of Texas published a report in May 1961 setting forth a plan to meet the 1980 water requirements that includes a project at the Millican site with 2,400,000 acre-feet of conservation storage. The U. S. Study Commission - Texas published a report in March 1962 that also shows that there will be an increasing demand for water supply in the lower Brazos River Basin, and includes development of the resources of the Navasota River in its proposed plan of development. The Brazos River Authority has requested consideration of the inclusion of water conservation storage in any Federally constructed reservoirs. The State has requested that the optimum conservation storage be investigated in any proposed reservoir project on the Navasota River.

61. The United States Public Health Service, in cooperation with the Corps of Engineers, has prepared a report covering the water supply and water quality control needs for the Navasota River watershed and for the lower Brazos River Basin, which is presented in appendix V. The anticipated needs for municipal and industrial, irrigation, and water quality control purposes are discussed in the following subparagraphs:

a. Domestic, municipal, and industrial.- The demand for municipal and industrial water in the lower Brazos River Basin is expected to increase from the present use of approximately 340 million gallons daily to 1,326 mgd in year 2025 and 2,088 mgd in year 2075. The increase is mainly attributable to expected increases in population and industrial growth. The area's population is expected to more than double by year 2025 and more than quadruple by year 2075. Significant industrial growth is expected in the study area, particularly in the petrochemical industry. The major water-using industries are chemicals and allied products, food and kindred products. In regard to the Navasota River watershed, the principal municipal and industrial water requirements in million gallons daily are shown in the following tabulation.

	1960	1975	2025	2075
Bryan-College Station	5.7	8.8	74.9	150.0
Navasota	1.0	1.2	4.5	9.4
Mexia	1.2	1.3	4.0	8.3

b. Water quality control.- The organic quality of the waters of the lower Brazos River Basin can be described as good at the present time, and is expected to remain satisfactory in the future for municipal, industrial, recreational, fish and wildlife, and agricultural uses. The mineral quality of the main stem of the Brazos River below Whitney Reservoir is considered poor. This condition is due primarily to extensive natural brine pollution in the upper Brazos River Basin, and undesirable concentrations of total

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dissolved solids can be expected until the natural brine pollution of the upper basin is controlled. Current studies being made by the Corps of Engineers, the United States Geological Survey, and the United States Public Health Service in connection with the comprehensive study of the entire Brazos River Basin indicate that adequate control of the brine emission areas may be possible. If control does prove to be feasible, the mineral quality of the waters of lower Brazos River will be greatly improved.

c. Irrigation.- The investigation of the water supply problems included consideration of the existing and potential water requirements for irrigation. The Bureau of Reclamation, Department of the Interior, was consulted early in the study to determine if there was a need and justification for inclusion of storage for irrigation in any reservoir project proposed on the Navasota River. By letter dated October 23, 1959, the Bureau indicated that no large scale irrigation development is expected on the Navasota River watershed under present economic conditions and legislation. However, the Bureau pointed out that there are large acreages of land well-suited for irrigation development located in the Brazos River Basin below the mouth of the Navasota River. Water for irrigation is presently obtained from surface water sources, such as pumping directly from the Brazos River, and from hundreds of wells located in the flood plain of the Brazos River. Therefore, water requirements for irrigation needs should be included in any fully integrated water supply plan for the lower Brazos River Basin.

62. HYDROELECTRIC POWER AND NAVIGATION.- Investigations indicate that the development of hydroelectric power on the Navasota River watershed is not economically attractive. Preliminary estimates show that the low head and small flow would produce a benefit-cost ratio for the specific power facilities alone of less than unity, even when utilizing the conservation storage for generation of power. The navigation needs for the Brazos River Basin are being investigated in connection with the comprehensive study currently being made of the entire basin. The study of navigation has not progressed far enough to permit definite conclusions at this time; however, proper development of the water resources of the Navasota River watershed will not adversely affect navigation, since navigation of the Navasota River itself is considered improbable.

63. RECREATION AND FISH AND WILDLIFE ENHANCEMENT.- The majority of people seeking outdoor recreation wish to be near water areas and to engage in water-associated activities such as swimming, fishing, boating, hunting, camping, and picnicking. Our expanding population, with more leisure time, more purchasing power, and more mobility, continues to seek more opportunities to enjoy the outdoors. The demand for outdoor recreation consequently has become greater each year and future population projections indicate this demand

will continue to increase. With the addition of a considerable water surface in this area, which has been lacking in the past, the recreational potential will be greatly increased. The warm climate is ideal for all types of water-oriented recreation.

64. The Navasota River is a small intermittent stream, especially in its upper reaches, in which fishing has been of minor importance in the past. In the lower portion of the river (about 100 miles) the stream becomes larger and fishing is of more importance. The principal fish species are catfish, carp, freshwater drum, and bluegill. Wildlife species of importance in the project area are white-tailed deer, squirrel, mourning dove, bobwhite, raccoon, and fox. Approximately 65 percent of the project area is excellent habitat for deer, fox, raccoon, and squirrel. The white-tailed deer is the most sought after wildlife species in the project area. The recreational value of fish and wildlife is of profound significance to the well-being of people, possibly even more so than the food value of this resource. The opportunity to hunt and fish will not automatically remain, and fish and wildlife resources must be considered in the overall plan of improvement for the Navasota River watershed area. The recommendations of the Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Service, will be given every consideration in the development of projects in this area.

65. GENERAL.- Many water resource developments have been constructed or planned by both Federal and non-Federal interests for purposes of water supply, prevention of flood damages, recreation, and fish and wildlife on the Navasota River and in the lower Brazos River Basin, as described in previous sections of the report. A comprehensive plan of development must take into account the existing and planned improvements that affect the total needs for all purposes; then, provide for additional improvements or modifications of existing facilities as required to bring the overall program into balance and satisfy the present and future needs in the most economical manner.

66. OBJECTIVES.- The basic objective in the formulation of a plan of development for the water resources of the Navasota River watershed is to provide the best use, or combination of uses, of the water and related land resources of the watershed to meet all foreseeable short- and long-term needs within the study area. Plan formulation studies require the consideration of all water problems and the interrelation of all purposes and projects to fully develop the potentials of the watershed, to add impetus to economic development, and to enhance the conditions of health and welfare of the people.

67. After adequate analyses of the water problems and consideration of views expressed by various interested agencies and individuals, plans of improvement were formulated and investigated with a view to achieving the following principal objectives: (a) to provide substantial reductions in flood damages in the lower Brazos River Basin; (b) to provide adequate water supply for the projected population and industrial growth of the study area; (c) to provide for the development and recreation and fish and wildlife potentials of the Navasota River watershed.

68. PLANNING CONSIDERATIONS.- Broad principles used in accomplishing the above objectives are: (a) that the elements of any plan for further control and development of the water resources of the Navasota River watershed provide a balanced program, that would be compatible with existing improvements on the Navasota River watershed, including a potential Soil Conservation Service program, with the federally authorized system of reservoirs in the lower Brazos River Basin, and with potential projects and developments being considered for the Brazos River Basin; (b) that there is no more economical means, evaluated on a comparable basis, of accomplishing the same purpose or purposes; (c) that the scale of development of each project be such as to provide the maximum excess benefits over costs, insofar as practicable; and (d) that the adopted plan not preclude development of approximately the total resources of the watershed, since the water

demand within the study area is expected to exceed available resources within the next 100 years, and in order to allow some flexibility to meet changing conditions in the future.

69. INVESTIGATED GENERAL PLANS.- In order to consider the existing and potential needs of the Navasota River watershed, the lower Brazos River Basin, and the contiguous gulf coastal area, many multiple-purpose reservoir plans involving flood control, water supply, and recreation and fish and wildlife enhancement, were studied. After a review and study of possible dam sites on the Navasota River between miles 24.1 and 83.4, five prospective dam sites were studied initially on a preliminary benefit-cost analysis basis. The location of the dam sites are shown on plate A. The Ferguson No. 3 site was selected in lieu of the authorized Ferguson Dam site since it was more favorable at greater storage capacity levels and would eliminate the need for relocation of State Highway 30.

70. The three most favorable sites were selected for detailed study on the basis of benefit-cost ratios and excess benefits over costs. The three dam sites selected include the Millican site (river mile 24.1), the Ferguson No. 3 site (river mile 41.5), and the Navasota No. 2 site (river mile 83.4).

71. The detailed investigation of the three selected reservoir sites and maximization studies for flood control established that the reservoir plans should contain sufficient flood storage to control 100-year-frequency floods originating upstream of the dam sites. The flood control studies determined that such flood control storage would be sufficient to contain the maximum flood of record on the Navasota River watershed. The maximum flood of record with respect to flood volume occurred in May-June 1929. The May-June 1929 flood approximates a 100-year-frequency flood, based on a regional analysis for flood-control storage requirements.

72. The requirements for water supply and water quality control within the study area have been evaluated by the United States Public Health Service. Data furnished indicates that the Brazos River Basin is a water-deficient basin for our planning period. The formulation of plans has proceeded on the basis that the full watershed resources will be required to fulfill the Brazos River Basin demands for water supply. Water quality control studies by the U. S. Public Health Service indicate that the total resources of the Navasota River watershed could not improve the mineral quality on the Brazos River to Public Health Service drinking water standards of 500 ppm of total dissolved solids. Therefore, storage for water quality control probably would not be recommended.

73. The detailed studies indicate that the water supply storage provided in the investigated plans would adequately serve the potential water-based recreational needs of the area, and that specific storage for recreation and fish and wildlife enhancement purposes would not be needed.

74. The plans for detailed study involved multiple-purpose reservoirs to provide optimum-economical to maximum water resource development by construction of a dam on the Navasota River at each of the three most favorable sites -- the Millican site, the Ferguson No. 3 site, and the Navasota No. 2 site. Also, the plans involved the Millican and Navasota No. 2 sites in stage development to develop approximately the total water resources upstream of the Millican Dam site. In the investigated plans for stage development, the Millican and Navasota No. 2 Reservoirs were given equal consideration as first-stage projects. In regard to the flood control function, each reservoir plan includes channel-improvement and/or flood-easement requirements for making flood releases from the investigated reservoir projects.

75. With a view to approximately full development of the water supply resources upstream from the Millican Dam site, the following most favorable alternate plans were selected for comparison: Plan I, a Federal multiple-purpose Millican Reservoir operating alone; Plan II, a Federal multiple-purpose plan of stage development, with the Millican Reservoir as the initial unit and Navasota No. 2 Reservoir as the future unit; Plan VI, a Federal multiple-purpose plan of stage development, with Navasota No. 2 Reservoir as the intial unit and Millican Reservoir as the future unit; and Plan IX, a Federal-non-Federal multiple-purpose plan of stage development, with Millican Reservoir as a Federal first-stage unit, and Navasota No. 2 Reservoir as a non-Federal future unit. Economic analysis of investigated single-reservoir plans and the investigated stage-development plans are presented in appendix 1. A brief summary of the four stage-development plans selected for comparison is presented in table 2. The economic analyses are based on a 100-year evaluation period extending from year 1975 to year 2075. The first reservoir unit of a plan is assumed to be completed by year 1975. The second unit is assumed to be completed at the time additional water supply is needed.

76. The basic objective of project formulation is to provide the best use, or combination of uses, of water and land resources to meet all foreseeable short- and long-term needs. The most effective use of the economic resources required for a project is made if they are utilized in such a way that the amount by which benefits exceed costs is at a maximum. The summary shown in table 2 indicates that Plan II, which involves Millican Reservoir as the initial unit, is the most favorable plan for the regional study area on the basis that it provides the maximum amount of excess annual benefits over the annual costs.

TABLE 2

SUMMARY OF ECONOMIC AND COST ANALYSES
INVESTIGATED RESERVOIR PLANS
WITH 100-YEAR-FREQUENCY FLOOD STORAGE
NAVASOTA RIVER WATERSHED

Item	Plan I	Stage-Development Plan II			Stage-Development Plan VI			Stage-Development Plan IX		
	Millican Reservoir only	First Stage Millican Reservoir	Second Stage Navasota No. 2 Reservoir	Total	First Stage Navasota No. 2 Reservoir	Second Stage Millican Reservoir	Total	First Stage Millican Reservoir	Second Stage Navasota No. 2 Reservoir	Total
1. PERTINENT DATA Purposes (1)	FC-WS-R	FC-WS-R	FC-WS-R	FC-WS-R	FC-WS-R	FC-WS-R	FC-WS-R	FC-WS-R	WS-R	FC-WS-R
Total controlled storage, acre-feet	3,287,100	*1,557,400	1,935,600	*3,493,000	1,291,400	2,317,800	3,609,200	1,557,400	1,613,800	3,171,200
Flood control storage, acre-feet	(786,400)	(784,800)	(550,700)	(910,300)	(543,200)	(364,100)	(907,300	(784,800)	(-)	(784,800)
Water supply storage, acre-feet	(2,408,300)	(680,200)	(1,315,400)	(2,441,200)	(678,700)	(1,881,700)	(2,560,400)	(680,200)	(1,544,300)	(2,224,500)
Sediment storage, acre-feet	(92,400)	(92,400)	(69,500)	(141,500)	(69,500)	(72,000)	(141,500)	(92,400)	(69,500)	(161,900)
Additional dependable water supply yield, second-feet	480	300	175	475	232	238	470	300	160	460
Assumed year of completion	1975	1975	2010	-	1975	2005	-	1975	2010	-
2. TOTAL FIRST COST OF PROJECT (Based on actual dollar expenditures):	91,260,000	58,620,000	61,087,000	119,707,000	55,487,000	68,400,000	123,887,000	58,620,000	52,250,000	110,870,000
3. TOTAL FIRST COST OF PROJECT (With future expenditures discounted to 1975 worth):	88,160,000	57,480,000	20,577,000	78,057,000	53,897,000	26,907,000	80,804,000	57,480,000	17,480,000	74,960,000
4. TOTAL ANNUAL CHARGES (Based on average annual equivalent values for the period 1975 to 2075):	3,652,200	2,404,500	837,400	3,241,900	2,290,800	1,076,700	3,367,500	2,404,500	882,200	3,286,700
5. TOTAL ANNUAL BENEFITS (Based on average annual equivalent values for the period 1975 to 2075):	8,891,300	6,648,400	2,282,400	8,930,800	5,160,900	3,410,400	8,571,300	6,648,400	2,192,900	8,841,300
Prevention of damages:	3,111,500	3,111,500	49,500	3,161,000	2,054,000	764,500	2,818,500	3,111,500	-	3,111,500
Navasota River watershed	(-)	(-)	(49,500)	(49,500)	(184,000)	(-)	(184,000)	(-)	(-)	(-)
Brazos River Basin	(3,111,500)	(3,111,500)	(-)	(3,111,500)	(1,870,000)	(764,500)	(2,634,500)	(3,111,500)	(-)	(3,111,500)
Water supply	1,980,000	1,320,000	650,000	1,970,000	890,000	1,063,000	1,953,000	1,320,000	610,000	1,930,000
Recreation and fish and wildlife enhancement	3,799,800	2,216,900	1,582,900	3,799,800	2,216,900	1,582,900	3,799,800	2,216,900	1,582,900	3,799,800
6. RATIO OF BENEFITS TO COSTS:	2.43	2.76	2.73	2.75	2.25	3.17	2.55	2.76	2.47	2.69
7. EXCESS BENEFITS OVER COSTS:	5,239,100	4,243,900	1,445,000	5,688,900	2,870,100	2,333,700	5,203,800	4,243,900	1,310,700	5,554,600

(1) FC - flood control
WS - water supply
R - recreation and fish and wildlife enhancement

* Millican Reservoir storage reallocated upon completion of future Navasota No. 2 Reservoir unit.

SELECTED PLAN OF IMPROVEMENT

77. SELECTED PLAN.- The plan of improvement selected as the most feasible for water resource development on the Navasota River watershed and for satisfying the needs of the study area is a stage-development plan consisting of a multiple-purpose Millican Reservoir as the initial unit to be completed about year 1975 and a multiple-purpose Navasota No. 2 Reservoir as a future unit to be completed when additional water supply is needed, presently estimated at about year 2010. The selected plan would be constructed in lieu of the authorized Ferguson Reservoir project, and would operate for purposes of flood control, water supply, and recreation and fish and wildlife enhancement.

78. The Millican Dam would be located about 12 miles downstream from the authorized Ferguson Dam site, about 18 miles southeast of Bryan, Texas, and about 7 miles north of Navasota, Texas. The project would involve an earth embankment at river mile 24.1 on the Navasota River, a gate-controlled ogee-type saddle spillway, 1,557,400 acre-feet of controlled storage, and channel improvements and/or flood easements on the Navasota River downstream from Millican Dam for flood-release purposes.

79. The Navasota No. 2 Dam would be located about 60 river miles upstream of Millican Dam, about 23 miles generally north of Bryan, Texas, and about 43 miles north of Navasota, Texas. The project would involve an earth embankment at river mile 83.4 on the Navasota River, a gate-controlled ogee-type saddle spillway, 1,935,600 acre-feet of controlled storage, and channel improvements on the Navasota River downstream from Navasota No. 2 Dam for flood-release purposes.

80. The general locations of the improvements in the selected plan are shown on plate A (adjacent to the rear cover of this report). Pertinent data on the earth embankments, spillways, reservoir storages, surface areas, land requirements, and relocations are presented in table 3 and in appendix I. The reservoir areas, and the details of dams, spillways, and flood-release channels are shown on plates 9 through 14.

81. The reservoir units of the selected plan would be provided with sufficient facilities such as lands, access roads, parking areas, boat ramps, and picnic areas to serve the various recreational activities. Zoning plans to insure adequate use of reservoir lands and waters for the various types of recreation activities would be developed during the advanced planning stages.

82. MILLICAN RESERVOIR.- The total controlled storage of 1,557,400 acre-feet to be provided in the Millican Reservoir unit

would be allocated as follows: Flood control, 784,800 acre-feet; water supply, 680,200 acre-feet; and sedimentation, 92,400 acre-feet. The flood-control storage would be sufficient to control 100-year frequency floods originating above the dam site, and to control a recurrence of the maximum flood of record (May-June 1929) on the Navasota River watershed. The water supply storage would provide for optimum economical development of the water supply resources of the Navasota River watershed and would provide a total dependable water supply yield at the site of about 193.9 million gallons daily (mgd), or about 300 cubic feet per second (cfs), based on maximum drought conditions (June 1947 through March 1957). The sediment storage would allow for deposition of sediment for at least a 100-year period, in the event the future reservoir unit is not constructed.

83. NAVASOTA NO. 2 RESERVOIR.- The total controlled storage of 1,935,600 acre-feet to be provided in the Navasota No. 2 Reservoir unit would be allocated as follows: flood control, 550,700 acre-feet; water supply, 1,315,400 acre-feet; and sediment storage, 69,500 acre-feet. On completion of the Navasota No. 2 Reservoir unit, the fulfillment of the flood-control and water-supply objectives of the selected plan of improvement would require reallocation of total controlled storage in the Millican Reservoir project as follows: flood-control storage reduced from 784,800 acre-feet to 359,600 acre-feet; water-supply storage increased from 680,200 acre-feet to 1,125,800 acre-feet; and sediment storage reduced from 92,400 acre-feet to 72,000 acre-feet. The flood-control storage in the Millican-Navasota No. 2 Reservoir system would maintain the same degree of protection for the area downstream of Millican Dam as provided by Millican Reservoir operating alone. In addition, the flood-control storage in Navasota No. 2 Reservoir would extend flood protection on the Navasota River upstream to the Navasota No. 2 Dam site. The total water-supply storages to be provided in Millican and Navasota No. 2 Reservoirs would provide a total dependable water-supply yield of about 307 mgd, or 475 cfs. Thus, the addition of the Navasota No. 2 Reservoir results in a net increase in dependable water-supply yield of about 113.1 mgd or 175 cfs. The sediment storages allocated to the Navasota No. 2 and Millican Reservoirs would allow for deposition of sediment for a 100-year period of second-stage operation under projected conditions of upstream development.

84. FLOOD-RELEASE CHANNELS.- The selected plan includes provisions for improving and straightening the existing Navasota River channel and/or for flood-flowage easements for a total length of about 33,000 feet between river mile 9.5 and 22.4 below Millican Dam. This would permit unrestricted releases from Millican Reservoir up to 10,000 second-feet with a total flow of 30,000 second-feet in the Brazos River downstream from the mouth of the Navasota River, and up to 6,000 second-feet with 60,000 second-feet control at Richmond. The plan

TABLE 3

PERTINENT DATA
SELECTED PLAN OF IMPROVEMENT
STAGE DEVELOPMENT
NAVASOTA RIVER WATERSHED

Item	First Stage: Millican Reservoir	Second Stage: Navasota No. 2 Reservoir	Second Stage: Millican Reservoir With Reallocated Storage
MISCELLANEOUS			
Dam location, river mile	24.1	83.4	24.1
Drainage area, square miles	2,120	1,341	2,120
Yield, cfs	300	300	175
Million gallons daily	193.9	193.9	113.1
SPILLWAY DESIGN FLOOD			
Peak inflow, cfs	466,300	420,800	762,500
Volume, acre-feet	2,523,600	1,725,200	2,558,500
Volume, inches	22.53	24.39	22.84
Peak outflow, cfs	302,900	290,000	371,800

RESERVOIR	First Stage Millican: Elev. (1) (feet)	Area (acres)	Capacity (acre-feet)	Capacity (inches)	Navasota No. 2: Elev. (1) (feet)	Area (acres)	Capacity (acre-feet)	Capacity (inches)	Millican Reallocated: Elev. (1) (feet)	Area (acres)	Capacity (acre-feet)	Capacity (inches)
Sediment storage	-	-	92,400	0.82	-	-	69,500	0.97	-	-	72,000	0.64
Spillway crest	204.0	22,700	276,500	2.47	312.0	28,600	723,500	10.12	204.0	22,700	276,500	2.47
Top of conservation storage	219.0	42,400	754,400	6.74	330.0	44,540	1,378,600	19.28	228.0	55,500	1,193,500	10.66
Five-year pool	225.0	50,900	1,034,000	9.23	336.0	50,870	1,664,100	23.27	233.0	64,200	1,492,300	13.32
Top of flood control pool	234.0	66,000	1,557,400	13.91	341.0	58,180	1,935,600	27.06	234.0	66,000	1,557,400	13.91
Guide taking line	237.0	72,000	1,764,400	15.75	344.0	63,780	2,118,200	29.62	237.0	72,000	1,764,400	15.75
Maximum design water surface	237.9	73,800	1,830,000	16.34	346.4	69,440	2,277,600	31.85	242.6	83,300	2,199,100	19.63
Top of dam	250.0	-	-	-	354.0	-	-	-	250.0	-	-	-

Item	First Stage: Millican Reservoir	Second Stage: Navasota No. 2 Reservoir	Second Stage: Millican Reservoir With Reallocated Storage
STORAGE SUMMARY			
Water conservation, acre-feet	680,200	1,315,400	1,125,800
Flood control, acre-feet	784,800	550,700	359,600
Sediment, acre-feet	92,400	69,500	72,000
Total, acre-feet	1,557,400	1,935,600	1,557,400
DAM			
Type of dam	Concrete and earth fill	Concrete and earth fill	Concrete and earth fill
Total length, feet	25,300	16,100	25,300
Embankment section:			
Type	Compacted earth fill	Compacted earth fill	Compacted earth fill
Total length, feet	24,393	15,361	24,493
Height above streambed, feet	83	111	83
Freeboard, feet	12.1	7.6	7.4
Crown width, feet	30	30	30
Sides slopes:			
Upstream	1 on 3 and 1 on 3.5	1 on 2.5 and 1 on 3.5	1 on 3 and 1 on 3.5
Downstream	1 on 2.5 and 1 on 3	1 on 2.5 and 1 on 3	1 on 2.5 and 1 on 3
Non-overflow section			
Type	Concrete gravity	Concrete gravity	Concrete gravity
Total length, feet	335	315	335
Height above apron, feet	77	124	77
Top width, feet	16	16	16
Spillway section:			
Type	Concrete ogee	Concrete ogee	Concrete ogee
Gross length, feet	472	424	472
Net length, feet	400	360	400
Gates:			
Type	Tainter	Tainter	Tainter
Number	10	9	10
Size (width x height)	40'x 30'	40' x 29'	40' x 30'
Spillway discharge, cfs:			
Maximum design water surface	302,900	290,000	371,800
OUTLET WORKS			
Type	Gate-controlled sluices through spillway piers	Gate-controlled sluices through spillway piers	Gate-controlled sluices through spillway piers
Number of sluices	2	2	2
Dimensions (width x height)	2' x 4'	2' x 4'	2' x 4'
Invert elevations, feet (1)	180.0	256.0	180.0
Sluice control	2 - 2'x4' slide gates	2 - 2'x4' slide gates	2 - 2'x4' slide gates
RELOCATIONS			
Highways, miles	10.3	19.9	10.3
County roads, miles	9.4	0.7	9.4
Railroads, miles	None	7.5	None
Power lines, miles	33	35.5	33
Telephone lines, miles	10	12	10
Pipelines, miles	27.8	4.1	27.8
Cemetery Graves	5	None	5
Communities inundated	Piedmont and Peach Creek	None	Piedmont and Peach Creek
LANDS			
Dam and Reservoir:			
Clearing, acres	8,840	8,900	8,840
Land acquisition:			
Fee simple, acres	80,800	70,220	80,800
(Top control elevation)(1)	(237.0)	(344.0)	(237.0)
Flood easement, acres	3,000	3,780	3,000
Channel:			
Clearing, acres	260	315	260
Land acquisition:			
Fee simple, acres	260	315	260
Flood easement, acres	1,100	-	1,100
Recreation:			
Clearing, acres	22,200	17,800	22,200
Land acquisition:			
Fee simple, acres	1,820	1,300	1,820

(1) All elevations refer to mean sea level.

layout and profile of the channel improvement are shown on plate 11.

85. In connection with construction of the Navasota No. 2 Reservoir, the selected plan includes improvement of the existing channel of the Navasota River from the Navasota No. 2 Dam site downstream to the headwater of Millican Reservoir for flood-storage-release purposes. The improved channel, extending from stream mile 67.9 to mile 82.9, would have a total length of about 49,000 feet, and would contain flood releases up to 6,000 second-feet within banks. The plan layout and profile of the channel improvement are shown on plate 14.

PHYSICAL EFFECTS OF THE SELECTED PLAN

86. FLOOD CONTROL.- The proposed Millican Reservoir would provide for the control of the 100-year frequency flood originating upstream from the dam site. The reservoir would provide flood protection within the flood plain area along the main stem of the Brazos River, including the 24-mile backwater reach of the lower Navasota River, against floods originating on the Navasota River watershed. The authorized Ferguson Reservoir was considered an important element of the authorized eight-reservoir system, designed to provide substantial flood protection to the lower Brazos River Basin. However, Millican Reservoir would adequately replace Ferguson Reservoir in this system, particularly since it would afford greater control of Navasota River floods. Millican Reservoir would eliminate more than 40 percent of the residual average annual damages in the reaches below the Navasota River, when considered as the last constructed project of the Brazos River Reservoir system.

87. The selected plan involves reallocation of the storage in Millican Reservoir at the time the Navasota No. 2 Reservoir project is constructed, as shown in table 3, in order to develop the total water supply resources. The transfer of flood storage upstream to the Navasota No. 2 site makes available additional water supply storage in the Millican site, thus allowing full development of the water supply resources from the incremental drainage area between the Millican and Navasota No. 2 Dams. With the Millican Reservoir project in operation, flood-control storage to afford protection to the incremental area between the Navasota No. 2 and Millican Dam sites could not be justified; however, through the reallocation of storage in the reservoir system it was possible to afford flood protection to this reach of the Navasota River. The flood protection provided to the flood plain reaches below Millican Dam would not be changed.

88. The channel improvement and/or flood flowage easements downstream from the Millican and Navasota No. 2 Reservoirs would prevent one or more of the following: (a) damaging overflows of long duration by flood-storage releases from the reservoirs; (b) use of an excessive length of time for evacuation of the flood control storage; and (c) the need for additional storage and lands above the dam. The capacities of the improved channel and flowage easement provisions were established to reduce the time required to evacuate the total flood storage capacities of the reservoirs from about 98 to 116 days under existing channel conditions to about 39 to 46 days under improved channel conditions. These improvements would insure sound and flexible operation of the reservoir for flood control and would be a necessary functional segment of the reservoirs.

89. WATER SUPPLY.- Development of the water conservation resources of the Navasota River watershed would play an important

part in satisfying the projected future requirements of the lower Brazos River Basin during the period 1975 through 2075, since these resources represent a substantial portion of the remaining undeveloped surface water in the study area. The selected plan of improvement provides for the orderly development of the water conservation resources of the Navasota River watershed. Millican Reservoir as the initial unit would provide for optimum economical development of the water supply resources of the Navasota River watershed. Navasota No. 2 Reservoir as a future unit would complete the plan for approximately full development of the water supply resources. The Navasota No. 2 Reservoir would be constructed to provide an additional increment of water supply if determined to be the most economical and logical alternative at the time additional water supply is needed.

90. Millican Reservoir as the initial unit would provide a dependable water supply yield of about 193.9 mgd (300 cfs). The study indicates that Millican Reservoir will be needed for water supply by year 1980, and that the demand will gradually increase until the total yield of the reservoir is required about year 2010. At this time, the Navasota No. 2 Reservoir would increase the dependable water supply yield from 193.9 mgd (300 cfs) for Millican Reservoir alone to about 307.0 mgd (475 cfs) for Millican and Navasota No. 2 Reservoirs. These reservoirs, together with the potential water resources of the lower Brazos River Basin are sufficient to satisfy the projected water requirements within the study area until about year 2028; however, Millican and Navasota No. 2 Reservoirs are more than adequate to supply the water requirements of the Navasota River watershed for the period 1975 through 2075.

91. After considering the location and magnitude of the future water requirements, the existing available water supplies, and the potential water supplies, the resources of the Navasota River have been determined to be the next logical increment of water supply development in the lower Brazos River system. The Public Health Service report, appendix V, shows the relationship of the proposed Millican and Navasota No. 2 Reservoirs to the existing and planned sources of water supply for the lower Brazos River Basin.

92. OTHER PHYSICAL EFFECTS.- The proposed plan of improvement would greatly increase the water-oriented outdoor recreation opportunities in the lower Brazos River Basin. The first-stage Millican Reservoir project would have a surface area of about 42,000 acres at top of water conservation pool level. This surface area would have an upstream reach of about 24 miles and a shoreline distance of about 167 miles. Likewise, the Navasota No. 2 Reservoir would have a surface area of about 45,000 acres, an upstream reach of about 30 miles, and a shoreline distance of about 215 miles. Thus, reservoirs of such size and with adequate facilities will afford abundant

opportunities for sight-seeing, camping, picnicking, boating, skiing, swimming, hunting, and fishing, and are expected to attract an average annual visitation of 6,000,000 persons during the period 1975-2075.

93. Millican and Navasota No. 2 Reservoirs would provide highly productive game fish habitat in an area where the interest in sport fishing is very high. Many people travel as far as 100 miles to fish. Although the opportunities for hunting would be reduced by permanent inundation of wildlife habitat in the reservoir areas, the net result of the reservoirs would be a significant increase in the recreation and fish and wildlife opportunities.

PROJECTS RECOMMENDED FOR AUTHORIZATION

94. GENERAL.- Millican and Navasota No. 2 Reservoirs, as units in the selected plan of stage development, are recommended for authorization to provide full development and beneficial public use of the water resources of the Navasota River watershed. In order to satisfy the existing and immediately prospective needs for flood control, water supply, recreation and fish and wildlife, the Millican Reservoir unit of the selected plan of improvement is recommended as the initial unit for immediate construction. As discussed in prior sections of this report, Millican Reservoir will adequately provide for the water resource needs of the study area for many years. Should the water needs of the study area develop as estimated in the study, the dependable water supply yield in Millican Reservoir will meet the needs of the study area until year 2010. Thence, completion of construction of Navasota No. 2 Reservoir by year 2010 will extend flood protection on the Navasota River upstream to the Navasota No. 2 Dam site and will complete development of approximately the total water supply resources of the Navasota River watershed. Also, the flood control, recreation and fish and wildlife needs will be adequately satisfied by the Millican project until the second reservoir unit is constructed. Millican Reservoir, as the initial unit, will develop about 63 percent of the water supply resources and about 98 percent of the flood control advantages to be expected of the selected overall plan of improvement during the economic-evaluation period 1975-2075.

95. Economic studies of the recommended Millican and Navasota No. 2 Reservoirs were made to determine that (a) the average annual benefits exceeded the average annual charges for each reservoir unit; (b) that each separable purpose provides benefits at least equal to its costs; (c) the scope of development is such as to provide maximum net benefits to the extent practicable after taking intangible considerations into account; and (d) there is no more economical means, evaluated on a comparable basis, of accomplishing the same purpose or purposes. The costs, benefits, and economic justification of the recommended reservoir units of the selected plan of improvement are fully presented in the following paragraphs. The project costs and benefits were evaluated on the basis of January 1965 price levels.

96. COSTS.- The first costs of the recommended Millican and Navasota No. 2 Reservoirs comprise all initial expenditures for physical construction, including lands and damages, relocations, reservoir clearing, engineering and design, and supervision and administration. The first costs and annual charges for the Millican and Navasota No. 2 Reservoirs are shown in table 4. Detailed estimates of first cost and annual charges are presented in appendix I. The annual charges for the recommended projects include interest and amortization of the total investments at an interest rate of 3-1/8

percent for a 100-year period, operation and maintenance costs, and annual equivalent costs of major replacements and future recreational facilities.

97. BENEFITS.- Benefits which would be expected to accrue from construction of Millican Reservoir as the initial unit have been estimated for the 100-year period 1975 through 2075, and from construction of Navasota No. 2 Reservoir for the 100-year period 2010-2110. The benefits which are expected to accrue over the 100-year periods have been reduced to an average annual equivalent value by compound interest methods. The estimates of average annual benefits for the Millican and Navasota No. 2 Reservoirs are described below and shown in table 4 by purposes.

a. Reduction in flood damages.- The average annual benefits for reduction of flood damages were determined by use of discharge-damage and discharge-frequency relationships. The proposed Millican and Navasota No. 2 Reservoirs would replace the authorized Ferguson Reservoir project as a unit in the reservoir system consisting of Whitney, Belton, Waco, Proctor, Stillhouse Hollow, Somerville, and Ferguson Reservoirs and the San Gabriel River projects, authorized for flood control and allied purposes in the Brazos River Basin. Ferguson Reservoir is the only project of this system that is not completed, under construction, or in the preconstruction planning stage. Therefore, all of the projects except Ferguson Reservoir were considered to be in operation for computing the benefits for Millican and Navasota No. 2 Reservoirs. The residual average annual damages of $2,667,500 under present conditions of economic development in the flood plain below Millican Reservoir would be reduced to $1,512,400 for benefits of $1,155,100. An allowance to reflect the economic trends and development anticipated in the flood plain during the period 1975 to 2075 would increase these average annual flood-control benefits for Millican Reservoir to a total of $3,111,500. Likewise, average annual flood-control benefits of $156,700 within the flood plains upstream to the Navasota No. 2 Dam during the period 2010 to 2110 would be creditable to the Navasota No. 2 Reservoir unit.

b. Water supply.- Benefits for water supply were computed on the basis of the cost of obtaining the same quantity and quality of water by the cheapest alternative means that would most likely be developed by the potential water users in the absence of the Federal project. The estimated cost of the alternative means was based on non-Federal financing and interest rates for existing private and publicly owned projects. Millican Reservoir has been credited with water supply benefits of $1,320,000 for the period 1975-2075. Navasota No. 2 Reservoir has been credited with water supply benefits of $1,908,400 for the period 2010-2110.

TABLE 4

FIRST COST, ANNUAL CHARGES, ANNUAL BENEFITS, AND BENEFIT-COST RATIO
RECOMMENDED MILLICAN AND NAVASOTA NO. 2 RESERVOIRS
NAVASOTA RIVER WATERSHED
(January 1965 price level)
(Interest rate, 3-1/8% - Amortization period, 100 years)

	MILLICAN RESERVOIR (Period 1975-2075)	NAVASOTA NO. 2 RESERVOIR (Period 2010-2110)
FIRST COST	$57,480,000*	$60,413,000*
ANNUAL CHARGES	2,404,500*	2,484,200*
ANNUAL BENEFITS		
Flood control	3,111,500	156,700
Water supply	1,320,000	1,908,400
Recreation and fish and wildlife enhancement	2,216,900	1,582,900
TOTAL - Benefits	$ 6,648,400	$ 3,648,000
BENEFIT-COST RATIO	2.8	1.5
EXCESS BENEFITS OVER COST	$ 4,243,900	$ 1,163,800

* With future recreation facilities discounted to present worth at year 1975 for Millican Reservoir and at year 2010 for Navasota No. 2 Reservoir.

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c. <u>Recreation and fish and wildlife</u>.- Benefits for recreation and fish and wildlife enhancement were computed on the basis of estimated annual attendance of 3,500,000 visitor-days at Millican Reservoir and 2,500,000 visitor-days at the Navasota No. 2 Reservoir. A unit value of $0.50 per visitor-day was used for a variety of recreational activities, including picnicking, swimming, boating, sightseeing, camping, and other outdoor pursuits. Recreation benefits for sport fishing and hunting were computed on the basis that 30 percent of the total visitation would be for these purposes; 29.70 percent for the purpose of fishing; and 0.30 percent for the purpose of hunting. It was estimated that the unit value for fishing should be $1.00 per visit and that the unit value for hunting should be $1.50. However, it is recognized that construction of the Millican project would reduce the game habitat in this area. resulting in a loss of man-days of hunting. Therefore, the benefits for sport fishing and hunting have been reduced $63,400 and $45,900 for the Millican and Navasota No. 2 projects, respectively. Thus, the total net benefits from these recreation and fish and wildlife enhancement activities are estimated at $2,216,900 and $1,582,900 for the Millican and Navasota No. 2 Reservoirs, respectively. A complete discussion of the recreational potentialities of the selected plan of stage development is presented in appendix IV.

98. ECONOMIC JUSTIFICATION.- The comparison of the annual benefits with annual charges presented in table 4 indicates that the Millican and Navasota No. 2 Reservoirs are economically justified. Although the Millican and Navasota No. 2 Reservoirs have been justified entirely by monetary benefits, the projects would also provide important intangible benefits to the area and to the state.

99. The flood control effects of the reservoirs would reduce the threat to lives and further stabilize the economy of the area subject to flooding downstream from the projects. The recreation and fish and wildlife enhancement aspects of the projects would improve the social well-being of a large segment of the population within the study area. The water supply features would stimulate the general economy of the area. Even though these intangible benefits have not been evaluated in monetary terms, it is evident that they are of major significance and would add materially to the justification of the proposed projects.

100. PROPOSED LOCAL COOPERATION.- Construction of the recommended Millican and Navasota No. 2 Reservoir projects would require local cooperation with respect to the water supply and the recreation and fish and wildlife enhancement functions of the proposed projects. Prior to initiation of construction of each reservoir unit, responsible local interests would be required to give assurances satisfactory to the Secretary of the Army that they will:

a. Obtain without cost to the United States all water rights necessary for operation of the project in the interest of water supply.

b. Hold and save the United States free from water rights claims resulting from construction and operation of the project.

c. Reimburse the United States for the project costs allocated to water supply on terms which will permit paying out the costs allocated thereto as determined by the Chief of Engineers, in accordance with the provisions of the Water Supply Act of 1958, as amended, and with such modification of the presently estimated allocated water supply costs as may be necessary to reflect adjustments in the storage capacity for water supply and other purposes.

d. In accordance with the Federal Water Project Recreation Act of 1965:

(1) Administer project land and water areas for recreation and fish and wildlife enhancement;

(2) Pay, contribute in kind, or repay, which may be through user fees, with interest, one-half of the separable cost of the project allocated to recreation and fish and wildlife enchancement; and

(3) Bear all costs of operation, maintenance, and replacement of recreation and fish and wildlife lands and facilities.

Provided further, that the sizing and responsibility for development, operation, maintenance, and replacement of the recreation and fish and wildlife enhancement features of the reservoirs, involving items (1), (2), and (3) cited above, may be modified in accordance with the alternatives provided in the Federal Water Project Recreation Act cited above, depending upon the intentions of non-Federal interests regarding participation in the costs of these features at the time of reservoir construction and subsequent thereto, and that appropriate adjustments reflecting such modifications may be made in the allocation of costs to other project purposes.

101. The water supply provisions include water that is needed to meet anticipated future needs. Payment is not required with respect to storage for future water supply until such supply is first used except that payments must begin so as to permit paying out the costs allocated to water supply within the life of the project, but

in no event to exceed 50 years after first use. Not more than 30 percent of the total estimated construction cost of each project can be allocated to anticipated future demands. No interest will be charged on the investment costs (construction costs plus interest during construction) allocated to future water supply until use is initiated, but the interest-free period shall not exceed 10 years.

102. The Brazos River Authority is the agency designated by the Texas Water Commission to negotiate with the Corps of Engineers in matters pertaining to water supply storage in Corps projects in the Brazos River Basin. The Brazos River Authority submitted a resolution at the public hearing held on 16 March 1965 indicating approval of the proposed plan of improvement and expressing their willingness to assume the requirements of local cooperation for the water supply portion of the project.

103. Since recreation and fish and wildlife enhancement has been treated as a project purpose and the implementation of the proposed legislation to govern development of recreation at reservoir projects indicates that the costs of recreation are to be shared with non-Federal interests, it follows that major policy and procedural considerations must be undertaken by the State of Texas. Due to the many interests which could become involved from a state-level agency down to the various local interests, the matter of the Federal Water Project Recreation Act (Public Law 89-72 approved July 9, 1965) has been referred to the State of Texas for a policy statement and designation of the responsibility agency to negotiate with the Corps of Engineers in matters pertaining to recreation and fish and wildlife enhancement. This matter is still under consideration by the State of Texas.

104. COST ALLOCATION AND APPORTIONMENT.- Cost allocation studies were made for the recommended Millican and Navasota No. 2 Reservoir projects to determine the equitable distribution of the costs to be chargeable to each project purpose. The allocation of reservoir project costs to the various purposes was based on the Separable Cost-Remaining Benefits method. The total costs of the reservoirs were allocated to purposes of flood control, water supply, and recreation and fish and wildlife enhancement. A summary of allocated costs for the Millican and Navasota No. 2 Reservoirs is presented in table 5.

105. The construction costs and the annual maintenance and operation costs of the Millican and Navasota No. 2 Reservoirs were apportioned to Federal and non-Federal interests in accordance with existing laws, policies, and procedures. A summary of cost apportionment for the Millican and Navasota No. 2 Reservoirs is presented in table 6.

106. The costs allocated to flood control are apportioned to the Federal Government in accordance with the general policy established in the Flood Control Act of 1936, Public Law 738, 74th Congress, as amended. The apportionments are made to the Federal Government because of the widespread and general nature of the benefits associated with the flood control effects of the reservoir projects.

107. The costs allocated to water supply are apportioned to non-Federal interests in accordance with the provisions of the Water Supply Act of 1958, Public Law 580, 85th Congress, as amended.

108. The costs allocated to recreation and fish and wildlife enhancement are apportioned to Federal and non-Federal interests in accordance with Public Law 89-72, cited as the Federal Water Project Recreation Act.

TABLE 5

SUMMARY OF COST ALLOCATION STUDIES
MILLICAN AND NAVASOTA NO. 2 RESERVOIRS
NAVASOTA RIVER WATERSHED
(Interest rate, 3-1/8% - Amortization period, 100-years)

Item	MILLICAN RESERVOIR (1)	NAVASOTA NO. 2 RESERVOIR (1)
	PERTINENT DATA	
Total first cost (dollars)	58,620,000	61,087,000
Total first cost, discounted (dollars)	57,480,000	60,413,000
Average annual charges (dollars)	2,404,500	2,484,200
Average annual maintenance and operation (dollars)	286,000	257,700
Total controlled storage, acre-feet	1,557,400	1,935,600
Flood control storage, acre-feet	784,800	550,700
Water supply storage, acre-feet	680,200	1,315,400
Sediment storage, acre-feet	92,400	69,500
Dependable water supply yield, cfs (mgd)	300 (193.9)	175 (113.1)
	FLOOD CONTROL (2)	
First cost	27,009,900 (46.99)	3,129,400 (5.18)
Annual charges	1,054,000 (43.84)	148,800 (5.19)
Maintenance and operation	58,600 (20.49)	33,500 (13.00)
First cost per acre-foot	34.53	36.83
	WATER SUPPLY (2)	
First cost	19,215,500 (33.43)	46,771,700 (77.42)
Annual charges	741,400 (30.83)	1,795,700 (72.28)
Maintenance and operation	33,200 (11.61)	71,900 (27.90)
First cost per acre-feet	28.25	35.56
Cost per 1,000 gallons (100-year basis)	0.0105	0.0435
Cost per 1,000 gallons (50-year basis)	0.0126	0.0524
	RECREATION AND FISH AND WILDLIFE ENHANCEMENT (2)	
First cost	12,394,600	11,185,900
First cost, discounted	11,254,600 (19.58)	10,511,900 (17.40)
Annual charges	698,100 (25.33)	539,700 (21.73)
Maintenance and operation	194,200 (67.90)	152,300 (59.10)

(1) Cost allocation studies based on total project first cost and annual charges, with future recreation facilities discounted to present worth at year 1975 for Millican Reservoir and at year 2010 for Navasota No. 2 Reservoir.

(2) Allocations by cost and (percentages).

TABLE 6

APPORTIONMENT OF COST
PROPOSED MILLICAN AND NAVASOTA NO. 2 RESERVOIRS
(Costs in thousands of dollars)

Item	Federal	Non-Federal	Total
Millican Reservoir			
First Cost			
1. Flood control	27,009.9	-	27,009.9
2. Water supply	-	19,215.5	19,215.5
3. Optimum Recreation	9,864.6	2,530.0	12,394.6
a. Joint cost	(7,334.6)	-	(7,334.6)
b. Specific cost			
(1) Present value portion	(1,960.0)	(1,960.0)	(3,920.0)
(2) Discounted increment*	(570.0)	(570.0)	(1,140.0)
4. Total	36,874.5	21,745.5	58,620.0
Average Annual Operation and Maintenance			
1. Flood control	58.6	-	58.6
2. Water supply	-	33.2	33.2
3. Optimum recreation	16.2	178.0	194.2
a. Joint cost	(16.2)	-	(16.2)
b. Specific cost	-	(178.0)	(178.0)
4. Total	74.8	211.2	286.0
Navasota No. 2 Reservoir			
First Cost			
1. Flood control	3,129.4	-	3,129.4
2. Water supply	-	46,771.7	46,771.7
3. Optimum Recreation	9,410.9	1,775.0	11,185.9
a. Joint cost	(7,635.9)	-	(7,635.9)
b. Specific cost			
(1) Present value portion	(1,438.0)	(1,438.0)	(2,876.0)
(2) Discounted increment*	(337.0)	(337.0)	(674.0)
4. Total	12,540.3	48,546.7	61,087.0
Average Annual Operation and Maintenance			
1. Flood control	33.5	-	33.5
2. Water supply	-	71.9	71.9
3. Optimum recreation	15.6	136.7	152.3
a. Joint cost	(15.6)	-	(15.6)
b. Specific cost	-	(136.7)	(136.7)
4. Total	49.1	208.6	257.7

*Difference between total cost of recreation facilities and total cost with future facilities discounted to present worth at year 1975 for Millican Reservoir and at year 2010 for Navasota No. 2 Reservoir.

COORDINATION WITH OTHER AGENCIES

109. GENERAL.- The regional offices of other interested Federal agencies were advised by letter dated November 14, 1958, of the general investigation program for fiscal year 1959. The response included statements of interest in the investigations program and information on available basic and general data. The report previously submitted was furnished to the interested agencies for field-level review, and the comments of these agencies were included in the report. During the current preparation of this review report, the coordination with the other interested agencies has been continued.

110. U. S. PUBLIC HEALTH SERVICE.- Estimates of the needs and values of water supply storages on the Navasota River watershed have been coordinated with the U. S. Public Health Service, Department of Health, Education, and Welfare. On the basis of this coordination, the Public Health Service prepared a report presenting information on the value of water supply storage for the proposed plan of improvement and the water requirements in the study area to cover the period of analysis of years 1975 to 2075. The Public Health Service report is presented in appendix V.

111. BUREAU OF SPORT FISHERIES AND WILDLIFE.- In accordance with the Fish and Wildlife Coordination Act, as amended, the Bureau was consulted and various conferences were held regarding the fish and wildlife aspects of the investigated reservoirs on the Navasota River watershed. A detailed report prepared by the Bureau and concurred in by the Texas Parks and Wildlife Department, evaluating the fish and wildlife apsects in investigated reservoir plans on the Navasota River, is presented in appendix V. However, the benefits credited to the selected plan of improvement are based on determinations by the Corps of Engineers as presented in appendix IV.

112. The Bureau estimates that maximum water resource development on the Navasota River watershed would result in benefits of $223,000 annually for sport fishing and of $10,000 annually for commercial fishing. Also, the Bureau indicates that maximum water resource development would result in the loss of about 26,100 man-days annually for upland game and deer hunting, and would result in an increase of about 2,000 man-days of waterfowl hunting annually.

113. NATIONAL PARK SERVICE.- The National Park Service was consulted with respect to the recreational potentialities of the Navasota River watershed. A reconnaissance of the area was made in 1960 by a representative of the Region 3 office, National Park Service, and a report of the findings was submitted. The report contained an appraisal of the recreational potentials and indicated the type of recreational

development and estimated monetary value of recreation benefits applicable to the investigated reservoirs on the basis of planning criteria available at that time. The National Park Service report is presented in appendix V.

114. The service was consulted in June 1964 concerning their participation in the restudy, including review and revision of their report. The general statements of the prior report were felt to be adequate unless a project-grade recreation report was needed in lieu of the reconnaissance report. The recreation benefits utilized in the analysis of the investigated reservoir plans were based on studies of the Corps of Engineers described in appendix IV.

115. SOIL CONSERVATION SERVICE.- During the investigation, the Soil Conservation Service, U. S. Department of Agriculture, furnished information concerning the status of their projects in the Navasota River watershed. The existing and planned improvements in the watershed have been described in previous sections of this report.

116. BUREAU OF PUBLIC ROADS AND STATE HIGHWAY DEPARTMENT.- In accordance with provisions of Public Law No. 562, the Bureau of Public Roads and the State Highway Department were consulted regarding the advisability of providing a highway crossing on the dam projects in the proposed plan of improvement. The State Highway Department has recommended that a highway crossing be considered in design of the Millican Dam since there appears to be definite possibility of connecting FM Highway 244 and State Highway 6 across this dam. Provisions for a highway crossing at the Millican Dam, if later certified to be needed, would be structurally feasible and would not interfere with the proper functioning and operation of the dam. The total estimated cost of the highway crossing would increase the Millican project cost by about $730,000, including costs for roadway base, surfacing, and guard rails, and for increasing the embankment width from 30 to 44 feet, and the spillway bridge width from 16 to 28 feet.

117. BUREAU OF RECLAMATION.- Subsequent to completion of preliminary feasibility studies of five alternative dam and reservoir sites, and prior to initiation of detailed studies of Millican, Ferguson No. 3 and Navasota No. 2 Reservoir sites, the Bureau of Reclamation, Department of the Interior, was consulted to determine if there was a need and justification for the inclusion of irrigation storage space as a Federal purpose in any reservoir project proposed on the Navasota River. By letter dated October 23, 1959, the Bureau indicated that investigations show that under present economic conditions and legislation, no large scale irrigation development is expected on the Navasota River watershed. However, large acreages of land well suited for irrigation development are located in the Brazos River Basin, below the mouth of the Navasota River, which can be

served from the Brazos River with storage on the Navasota River watershed area. Therefore, considering the irrigation development of lands along the Brazos River and future downstream municipal and industrial requirements, the Bureau believes that any reservoir on the Navasota River can justifiably be developed to the full economic capacity of the site for water supply with later allocation to specific use.

118. UNITED STATES GEOLOGICAL SURVEY.- During the investigation the Geological Survey furnished information concerning drainage area determinations in the Navasota River watershed.

119. BUREAU OF MINES.- In response to an inquiry from the Corps of Engineers, the Area IV Bureau of Mines office made a preliminary study of the Millican and Navasota No. 2 Reservoir areas. The Bureau made certain recommendations, in their letters of July 27, 1965, which are shown in Appendix VI, regarding these studies. The Bureau states that it has no objection to the construction of the two reservoirs, provided detailed field examinations are made by a qualified petroleum engineer during preconstruction planning for the purpose of recommending adequate protection measures.

120. REVIEW OF REPORT BY OTHER AGENCIES.- Copies of this report have been forwarded to interested Federal agencies at field level and to the Texas Water Commission for their preliminary views and comments. The reply letters are presented in appendix VI of this report. The comments are summarized briefly in the following subparagraphs:

a. Bureau of Public Roads.- The Bureau of Public Roads noted that they had not received a submission from the State about the possibility of connecting FM Highway 244 and State Highway 6 across the Millican Dam. The Bureau assumed the cost of all highway relocation work would be the responsibility of those as outlined in the report.

b. National Park Service.- The National Park Service stated that their interest was general, relating particularly to the recreational potential which would result from development of the Navasota No. 2 and Millican Reservoirs.

c. Southwestern Power Administration.- The Southwestern Power Administration stated that their interests would not be affected by the recommendations of the District Engineer.

d. Bureau of Outdoor Recreation.- The Bureau of Outdoor Recreation had no comments on the report recommendations.

e. U. S. Geological Survey.- The U. S. Geological Survey indicated concurrence in the project plan to provide for installation and maintenance of hydrologic equipment to measure inflow, outflow, and reservoir contents of each reservoir. The survey noted that the project would help control flooding on the lower Brazos River and would provide needed conservation storage for future water requirements in south Texas.

f. U. S. Public Health Service.- The U. S. Public Health Service indicated that its report adequately stated the views of the Public Health Service with regard to storage of water for municipal and industrial supply, and the storage of dilution waters for pollution control. In addition to the data contained in its report, the Public Health Service made some additional recommendations concerning vector prevention and control, reservoir clearing, the development of recreational areas, and postimpoundage vector control surveys. These recommendations are stated in the U. S. Public Health Service letter dated July 29, 1965, in appendix VI.

g. Federal Power Commission.- The Federal Power Commission concluded that the installation of power features would not be justified at the Millican project but that a final decision regarding power development of the Navasota No. 2 project could not be made at this time. The Commission states that development of the proposed projects will not effect existing or potential hydro projects. An analysis of the Navasota No. 2 project by the Corps of Engineers substantiates the 0.9 benefit-cost ratio for specific power facilities. The Corps study reveals that consideration of the specific power facilities alone shows the power potential in its best light since it does not include costs for the dam and reservoir. The assignment of any portion of the costs of the dam and reservoir would lower the benefit-cost ratio and further prevent any conclusion as to the feasibility of power in the year 2010. The Corps informed the FPC that the power potential of these projects will be examined further during the advance planning stage.

h. Soil Conservation Service.- The Soil Conservation Service suggested certain changes be made in the report in regard to the scope of its program and the effects on water resources. The Service was advised that these changes would be made.

i. Bureau of Sport Fisheries and Wildlife.- The Bureau of Sport Fisheries and Wildlife presented views and comments in regard to visitor days of fishing as estimated by the Corps of Engineers and man-days of fishing as estimated by the Bureau; and suggested that the Bureau's estimates of annual benefits for fishing and hunting be utilized as the basis for project evaluation. In reply, the Corps of Engineers stated that statistical data compiled by the Corps of Engineers at existing projects, and experience gained, do not conform with nor justify the use of the Bureau's data for the Navasota River study.

j. Texas Water Commission.- The Texas Water Commission states that the report reflects a complete analysis of each of the matters in regard to the Commission's recommendations as contained in Order of August 2, 1962, entered subsequent to public hearing held by the Texas Water Commission in 1962. The Water Commission also forwarded the comments of the Texas Highway Department and the Texas Parks and Wildlife Department. The Texas Highway Department stated that the report contained adequate provisions for all highways under jurisdiction of the Department which will be affected by the proposed plan. The Texas Parks and Wildlife Department stated that it concurs in the findings contained in the report.

k. Bureau of Reclamation.- The Bureau of Reclamation had no comments on the report.

l. Bureau of Mines.- The comments in the letters of July 27, 1965 from the Bureau of Mines have already been summarized in paragraph 119 and constitute the field level comments of the Bureau.

DISCUSSION AND CONCLUSIONS

121. DISCUSSION.- This report considers the desirability of modifying the authorized plan of improvement for flood control, water conservation, and related water uses on the Navasota River watershed. The authorized plan consists of a multiple-purpose reservoir project, Ferguson Reservoir, located at river mile 36.5, which is a unit in a system of federally authorized reservoirs in the Brazos River Basin. Each reservoir is planned to function as a unit in the system and to provide maximum reduction of flood stages on the main stem and major tributaries of the lower Brazos River Basin downstream of Whitney Dam.

122. The selected plan of improvement (designated as stage-development Plan II in table 2) accomplishes a balance in the several project purposes in a manner that provides the maximum amount of excess benefits over costs. The projects in the selected plan would adequately replace the authorized Ferguson Reservoir in the system of reservoirs in the lower Brazos River Basin. The flexibility and adaptability of the selected plan of improvement is indicated by the fact that the initial unit of the plan (Millican Reservoir) would still be the optimum economical development of the resources of the watershed in the event the need for the additional water supply to be provided by the future unit (Navasota No. 2 Reservoir) does not materialize because of technological advances or other developments. The Millican Reservoir unit will provide a dependable water supply yield of about 300 cfs, or 193.9 mgd. The water supply will be sufficient to satisfy the projected water supply needs of the regional study area until about year 2010. Thence, the Navasota No. 2 Reservoir unit will provide an additional dependable water supply yield of about 175 cfs, or 113.1 mgd, which will assist in meeting the water supply needs of the study area until about year 2028.

123. The reservoirs in the selected plan would inundate some wildlife habitat; however, comparison of the alternatives for providing for the overall water resource needs shows that the hunting losses are about the same for each of the plans that will satisfy the water resource needs of the study area. For example, the Bureau of Sport Fisheries and Wildlife report shows that the large Millican Reservoir (designated plan 3 in their report), stage-development Plan II (designated plan 12 in their report), and stage-development Plan VIII (designated plan 11 in their report) would result in hunting losses in man-days annually of 26,400; 26,100; and 28,400; respectively. Therefore, the selected plan results in the least amount of hunting losses of the three plans. The net result of the reservoirs would be a significant increase in the recreation and fish and wildlife opportunities.

124. Opposition to the sequence of construction of the reservoir projects was expressed by several individuals and organizations at the public hearing held March 16, 1965. Several plans of stage development beginning with Navasota No. 2 Reservoir as the initial unit and Millican Reservoir as the future unit were evaluated and are presented in appendix I. The variation in excess benefits over costs for plans with Navasota No. 2 Reservoir as the initial unit is small; however, the most favorable plan utilizing Navasota No. 2 Reservoir as the initial unit is stage-development Plan VI. A brief summary of this plan is presented in table 2. This table shows, however, that the excess benefits over costs are materially reduced for plans with Navasota No. 2 Reservoir as the initial unit, in comparison to plans with Millican Reservoir as the initial unit.

125. The selected plan of improvement (Plan II) with Millican as the initial unit, is considered the best and most practical plan, in comparison to the most favorable alternate plan (Plan VI) with Navasota No. 2 Reservoir as the initial unit, for the following reasons:

a. Plan II provides $485,100 more excess-benefits-over-costs than Plan VI; and during first-stage conditions, Millican Reservoir provides $1,373,800 more excess-benefits-over-costs than Navasota No. 2 Reservoir.

b. Millican Reservoir as the initial unit provides 98 percent of the total flood control advantages to be expected of the selected plan of improvement during the economic-evaluation period 1975-2075, compared to about 65 percent afforded by Navasota No. 2 Reservoir as the initial unit.

c. In regard to total water supply resources upstream of the Millican Dam site, Millican Reservoir as the initial unit develops 63 percent, in comparison to 49 percent by Navasota No. 2 Reservoir. Also, Millican Reservoir provides the maximum optimum economical development of the available water supply resources of Navasota River watershed in the event the second unit is not constructed.

d. Development of Navasota No. 2 as the initial unit under Plan VI would necessitate construction of an $8,400,000 channel for flood-release purposes, of which a $5,000,000 portion would be inundated by the future Millican Reservoir unit, and results in the allocated flood control cost to the Federal Government being about $5,500,000 greater, in comparison to Plan II.

126. Cost allocation studies for Millican Reservoir as the initial unit under the selected Plan II indicate that local interest would be required to make an initial payment of about $1,629,500

of the total allocated water supply cost. Cost allocations made for Navasota No. 2 Reservoir as the initial unit under Plan VI indicates no initial payment would be required until the water supply is needed. However, cost allocation studies made for a Millican unit providing a dependable water supply yield equivalent to that provided by the Navasota No. 2 unit under Plan VI indicate that (1) no initial payment would be required, and (2) the unit cost of water supply would be less.

127. After the plan of improvement had been formulated and scaled, consideration was given to the area redevelopment effects of the investigated plans. The evaluation of area redevelopment benefits is discussed in appendix III. The average annual equivalent area redevelopment benefits for using unemployed persons from the ARA counties in the area as part of the on-site construction and operation and maintenance were estimated at $85,800 if Millican Reservoir were the initial project constructed and $104,300 if Navasota No. 2 Reservoir were the initial project constructed. The additional benefits to be gained by starting with Navasota No. 2 Reservoir as the initial unit are very minor when compared to the excess benefits-advantage of the selected plan over the best plan with Navasota No. 2 Reservoir as the first unit and would not justify modifying the selected plan of improvement.

128. Additional information on the plan of improvement called for by Senate Resolution 148, 85th Congress, adopted January 28, 1958 is contained in Supplement A to this report.

129. CONCLUSIONS.- The District Engineer concludes that:

a. A flood problem exists on the Navasota River within the investigated 83.4-mile reach between the mouth and the investigated Navasota No. 2 Dam site where an agricultural area, devoted principally to the production of beef and dairy products, is subject to frequent damage by floodflows originating on the Navasota River watershed.

b. A serious flood problem exists along the main stem of the lower Brazos River where damages to urban and highly-developed agricultural areas are considerably increased during flood stages on the Brazos River by major floodflows discharging from the Navasota River.

c. Existing surface and ground water supplies within the regional study area will not be sufficient to provide for the future water supply requirements, and that the development of water resources of the Navasota River is essential to assist in meeting these requirements.

d. The investigation of single-reservoir plans with a view to optimum economical development of the water supply resources of the Navasota River watershed indicates that Millican Reservoir is the most favorable for flood control and water supply purposes by providing the maximum amount of excess benefits over costs in comparison to the Ferguson and Navasota No. 2 Reservoirs.

e. The investigation of stage-development plans with a view to approximate full development of the water supply resources of the Navasota River watershed indicates that Millican Reservoir as the initial unit, in comparison to Navasota No. 2 Reservoir as the initial unit, establishes the most favorable plan of stage development for flood control and water supply purposes by providing the maximum amount of excess benefits over costs.

f. The authorized plan for flood control, water conservation, and related water uses on the Navasota River should be modified to provide for authorization of the investigated Millican and Navasota No. 2 Reservoirs in lieu of the authorized Ferguson Reservoir project.

g. There is an immediate need for construction of Millican Reservoir as the initial project to function as an important element in the system of authorized reservoir projects for flood control, water conservation, and other allied purposes within the lower Brazos River Basin, and in a plan of stage development on the Navasota River watershed for purposes of flood control, water supply, and recreation and fish and wildlife enhancement within the regional study area.

RECOMMENDATIONS

130. RECOMMENDATIONS.- On the basis of studies and conclusions made for this report, the District Engineer recommends:

a. That a comprehensive plan of stage development, consisting of Millican Reservoir as the initial unit and Navasota No. 2 Reservoir as a future unit, including appurtenant channel improvements and/or flood easements for flood release purposes, be authorized as the plan for full development and beneficial public use of the water resources of the Navasota River watershed.

b. That the authorized project for Brazos River and tributaries, Texas, be modified to provide for authorization of the Millican and Navasota No. 2 Reservoirs, in lieu of the authorized Ferguson Reservoir project, for purposes of flood control, water supply, and recreation and fish and wildlife enhancement.

c. That Millican and Navasota No. 2 Reservoirs be constructed to contain total controlled storages of about 1,557,400 and 1,935,600 acre-feet, respectively, for use of the various purposes.

d. That the Millican and Navasota No. 2 Reservoirs include, as integral parts for flood-release purposes, appurtenant channel improvements and/or flowage easements on the Navasota River downstream from the dams.

e. That the foregoing be accomplished, including such changes and modifications as in the discretion of the Chief of Engineers may be advisable, at an estimated cost to the United States of $119,707,000 for construction and $229,000 for annual operation and maintenance, or at increases of $95,707,000 for construction and $146,100 for annual operation and maintenance over the presently estimated costs of the authorized project, provided that, prior to initiation of construction of each reservoir unit, responsible local interests give assurances satisfactory to the Secretary of the Army that they will:

(1) Obtain without cost to the United States all water rights necessary for operation of the project in the interest of water supply.

(2) Hold and save the United States free from water rights claims resulting from construction and operation of the project.

(3) Reimburse the United States for the project costs allocated to water supply on terms which will permit paying out the costs allocated thereto as determined by the Chief of Engineers,

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in accordance with the provisions of the Water Supply Act of 1958, as amended, and with such modification of the following presently estimated allocated water supply costs as may be necessary to reflect adjustments in the storage capacity for water supply and other purposes.

Water Supply Costs Allocated to Local Interests

Plan unit	Construction first costs	Average annual operation and maintenance costs
Millican Reservoir	$19,215,500	$ 33,200
Navasota No. 2 Reservoir	46,771,700	71,900
Total plan	$65,987,200	$105,100

(4) In accordance with the Federal Water Project Recreation Act of 1965:

(a) Administer project land and water areas for recreation and fish and wildlife enhancement;

(b) Pay, contribute in kind, or repay, which may be through user fees, with interest, one-half of the separable cost of the projects allocated to recreation and fish and wildlife enhancement, the amounts involved currently estimated at $2,530,000 for the Millican Reservoir, and $1,775,000 for the Navasota No. 2 Reservoir, or $4,305,000 for the total plan; and

(c) Bear all costs of operation, maintenance, and replacement of recreation and fish and wildlife lands and facilities, the amount involved currently estimated on an average annual basis at $178,000 for the Millican Reservoir, and $136,700 for the Navasota No. 2 Reservoir, or $314,700 for the total plan.

Provided further, that the sizing and responsibility for development, operation, maintenance, and replacement of the recreation and fish and wildlife enhancement features of the reservoirs, involving items (a), (b), and (c) cited above, may be modified in accordance with the alternatives provided in the Federal Water Project Recreation Act cited above, depending upon the intentions of non-Federal interests regarding participation in the costs of these features at the time of reservoir construction and subsequent thereto, and that appropriate adjustments reflecting such modifications may be made in the allocation of costs to other project purposes.

131. On the foregoing basis, the net cost to the United States for construction, after repayment by local interests for construction costs allocated to water supply and recreation and fish

and wildlife enhancement is $36,874,500 for Millican Reservoir, and $12,540,300 for Navasota No. 2 Reservoir, or $49,414,800 for the total plan. The net cost to the United States for operation, maintenance, and replacements on an average annual basis is $74,800 for Millican Reservoir, and $49,100 for Navasota No. 2 Reservoir, or $123,900 for the total plan.

132. The non-Federal costs and responsibilities set forth above with respect to recreation and fish and wildlife enhancement are based on the desirable level of development for these purposes which would be afforded by the plan on which my recommendations are based. However, under the flexibility afforded by the Federal Water Project Recreation Act less extensive development for these purposes would be possible, with attendant reduction in non-Federal costs and responsibilities. As a minimum, it may be possible under the provisions of the Act to limit development to basic provisions for public health and safety and preservation of recreation and fish and wildlife enhancement potentials, without non-Federal participation. The extent to which the scale of development for recreation and fish and wildlife enhancement may be reduced within these limits, without adverse effect on economic justification, remains to be established. I am confident, however, that mutually acceptable arrangements between Federal and non-Federal interests can be worked out in connection with detailed preconstruction planning.

133. The District Engineer further recommends that following authorization of the recommended Millican Reservoir and Navasota No. 2 Reservoir projects, detailed site investigations and design be made for the purpose of accurately defining the project lands required; that, subsequently, advance acquisition be made of such title to such lands as may be required to preserve the site against incompatible developments; and that the Chief of Engineers be authorized to participate in the construction or reconstruction of transportation and utility facilities in advance of project construction, as required to preserve such areas from encroachment and avoid increased cost of relocations.

F P Koisch

F. P. KOISCH
Colonel, CE
District Engineer

[First endorsement]

SWDGA-5
SUBJECT: Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed

United States Army Engineer Division, Southwestern, Dallas, Texas, August 27, 1965

TO: Chief of Engineers, Department of the Army, Washington, D. C.

I concur in the conclusions and recommendations of the District Engineer.

R. H. FREE
Brigadier General, USA
Division Engineer

APPENDIX I

PROJECT FORMULATION, ANALYSES, COSTS, AND COST ALLOCATION

REVIEW OF REPORTS
ON
BRAZOS RIVER AND TRIBUTARIES, TEXAS
COVERING
NAVASOTA RIVER WATERSHED

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APPENDIX I

PROJECT FORMULATION, ANALYSES, COSTS, AND COST ALLOCATION

1. INTRODUCTION.- The selected plan of water resource development on the Navasota River watershed, considered to be the most favorable for flood control, water supply, and recreation and fish and wildlife enhancement purposes within a regional study area, is one of stage development providing for completion of Millican Reservoir as the initial unit about year 1975 and completion of Navasota No. 2 Reservoir as a future unit when additional water supply is needed, probably about year 2010. This appendix presents formulative concepts, restraints, and objectives, comparisons of economical and cost analyses of various investigated plans, detailed cost estimates, and supporting data for cost allocation.

2. GENERAL OBJECTIVES.- This report considers the desirability of modifying the authorized plan of water resource development on the Navasota River watershed for purposes of flood control, water conservation and allied purposes. The report includes a restudy of the authorized Ferguson Reservoir project, an important unit in the authorized system of Brazos River Basin reservoirs designed primarily for the reduction of flood flows on the lower Brazos River Basin. The report includes, also, a study of alternative reservoir plans on the Navasota River for construction in lieu of the authorized Ferguson project. This report recognizes that development of the water resources of the Navasota River watershed is of considerable importance in fulfilling outstanding existing and projected flood control and water supply needs of a regional area, consisting of the Navasota River watershed, the lower Brazos River Basin downstream of Whitney Reservoir, and the contiguous gulf coastal areas. Thus, the general objective of this report is the formulation of a comprehensive plan of water resource development on the Navasota River watershed which will contribute most beneficially in the resolution of existing and projected water problems within the above-defined regional study area.

3. The authorized Ferguson Reservoir project on the Navasota River is a unit in the system of federally authorized reservoirs in the Brazos River Basin. The reservoirs were designed to facilitate control of floods originating on the Brazos River and its major tributaries to provide principally for protection of urban development and highly development agricultural lands within the flood plains of the lower Brazos River Basin from their respective dam sites to the to the mouth of the Brazos River and to provide a source of water supply for municipal, industrial, and other uses. Each reservoir is planned to function as a unit in the system to provide maximum reduction of flood stages on the main stem of the lower Brazos River

and on certain portions of its tributaries. In the investigation of the desirability of modifying the plan for flood control, water conservation, and related water uses on the Navasota River watershed, it was concluded that any project considered as an alternate for the authorized Ferguson Reservoir project should be of a type which could be integrated into the authorized reservoir system; provide for a maximum reduction of flood stages in the Brazos River Basin downstream from Waco to the mouth with resultant flood control benefits equal to or in excess of the benefits to be afforded by the system as now authorized; and, in view of the apparent future water-supply-deficiency status of the regional study area, provide for the maximum economical development of the water supply resources of the Navasota River watershed.

4. SUMMARY OF WATER PROBLEM STUDIES.- This report includes a study of all possible water problems within the influence of water resource developments on the Navasota River watershed. The studies determined that the purposes of flood control, municipal and industrial water supply, and recreation and fish and wildlife enhancement should be included for analyses in plans for water resource development on the Navasota River watershed. Other purposes considered but excluded as project purposes were water quality control, irrigation, hydroelectric power, and navigation.

5. The flood problem is of primary importance within the study area. Major floods originating on the Navasota River watershed cause appreciable damages along the Navasota River and, in addition, augment considerably the flood problems along the Brazos River. The investigated Navasota River flood plain, which includes about 53,100 acres between river miles 24.1 to 83.4, is an agricultural area composed principally of improved and unimproved pasture lands and devoted principally to the production of beef and dairy products. The flood plain of the Brazos River affected by Navasota River floods extends from Brazos River mile 236.0 to the mouth, includes the lower 24.1-mile reach of the Navasota River, and has a total area of about 614,400 acres. The subject Brazos River flood plain is highly developed, containing considerable agricultural and urban developments, as well as numerous transportation facilities and utilities. The Brazos River flood plain is considerably more developed than the investigated Navasota River flood plain. The value of physical property under present-day development averages about $440 per acre for the subject Brazos River flood plain, compared to about $180 per acre for the Navasota River flood plain. Under conditions that the authorized system of Brazos River reservoirs are in operation, except for Ferguson Reservoir on the Navasota River, the estimated average annual damages under present-day development within the subject Brazos River and Navasota River flood plains are $2,667,500 and $249,400, respectively. Flood control studies indicate that 100-year flood storage on the Navasota River, located to

provide maximum effects, could prevent average annual damages within the subject Brazos River and Navasota River flood plains of $1,155,000 and $147,300, respectively. Within the economic evaluation period 1975-2075, the value of physical property, and the amount of average annual damages without a project on the Navasota River, are expected to increase almost threefold. Thus, the flood control as a project purpose is an essential consideration in the formulation of plans for water-resource development on the Navasota River watershed.

6. The water supply problem, like the flood problem, is of primary importance within the regional study area. Periods of prolonged drought, upward trends in population, and expansion of industrial and municipal development within the study area have made evident the increasing need for the conservation of surface runoff for all beneficial purposes. The need for including water supply in a project on the Navasota River has been recognized for many years, as evidenced by the fact that water supply storage was included in the authorized Ferguson Reservoir project under the more limited criteria available prior to the Water Supply Act of 1958. Local interests stated the need for conservation of water at the public hearing held at the beginning of this study in December 1958. Prior studies were made without the benefit of a comprehensive study of the future water supply requirements of the region. Several comprehensive reports have been published since initiation of the investigation connected with this report that include a study of water supply. The State of Texas published a report in May 1961 setting forth a plan to meet the 1980 water requirements that includes a project at the Millican site with 2,400,000 acre-feet of conservation storage. The U. S. Study Commission - Texas published a report in March 1962 indicating that there will be an increasing demand for water supply in the lower Brazos River Basin, and includes reservoirs on the Navasota River to develop the water resources of the watershed. The U. S. Public Health Service, in cooperation with the Corps of Engineers, has prepared a report covering the water supply and water quality control needs for the Navasota River watershed and the lower Brazos River Basin. In its report, the U. S. Public Health Service indicates that the regional study area will eventually become a water-deficient area. The report indicates that the municipal and industrial water supply needs will increase from the present use of 340 million gallons daily (mgd) to an estimated 1,326 mgd in year 2025 and 2,088 mgd in year 2075; that the total water supply needs for all purposes will be a minimum of 2,026.2 mgd by year 2025 and 2,908.1 mgd by year 2075; that the aggregate of existing and planned surface water storage, uncontrolled runoff, and ground water developments from "in-basin" sources will be sufficient only to meet the water supply needs of the regional study area until about year 2028; and that additional water supply development on the Navasota River watershed will be needed for the regional study area by year 1980. The lower Brazos River Basin above the confluence of the Navasota River, including the Navasota

River watershed, has resources adequate to meet requirements through the entire study period of 1975 to 2075; however, the greatest needs for water supply are now and can in the future be expected to be concentrated in the area downstream from the confluence of the Navasota River. The water resources of the Navasota River involved are considered to be the most favorable undeveloped source of good quality water supply within the Brazos River Basin and should be developed to the maximum economical amount to assist in meeting the projected water supply needs of the regional study area. Thus, water supply as a project purpose is an essential consideration in the formulation of plans for water-resource development on the Navasota River watershed.

7. Recreation and fish and wildlife enhancement is a purpose which should be included for consideration in all plans for surface water storage. Our expanding population, with more leisure time, more purchasing power, and more mobility, continues to seek more opportunities to enjoy the outdoors by participating in such recreational activities as swimming, boating, skiing, camping, picnicking and sight-seeing, sport fishing, and hunting. Based on the availability of adequate water surface and shoreline areas and on the magnitude of projected populations within the areas of influence, the Corps of Engineers estimates that the average annual recreation visitation to water-resource developments on the Navasota River watershed would be about 6,000,000 persons during the economic evaluation period 1975-2075. Based on studies by the Corps of Engineers, including classification of visits to existing Corps of Engineers projects in Texas, it is estimated that the total average annual visitation of 6,000,000 would provide total annual benefits of $3,799,800, including $1,699,800 for sport fishing and hunting activities.

8. Water quality control as a project purpose has been considered in connection with water-resource development on the Navasota River watershed. The report of the U. S. Public Health Service contained in appendix V indicates that the organic quality of the waters of the lower Brazos River Basin can be described as good at the present time, and is expected to remain satisfactory in the future for municipal, industrial, recreational, fish and wildlife, and agricultural uses. The mineral quality of the main stem of the Brazos River below Whitney Reservoir is considered poor. This condition is due primarily to extensive natural brine pollution in the upper Brazos River Basin, and undesirable concentrations of total dissolved solids can be expected until the natural brine pollution of the upper basin is controlled. Current studies being made by the Corps of Engineers, U. S. Public Health Service, and the U. S. Geological Survey indicate that adequate control of the brine-emission areas may be possible. The Public Health Service report indicates that the total resources of the Navasota River watershed could not improve the mineral quality of Brazos main-stem waters to U. S. Public Health Service drinking water standards of 500

parts per million (ppm) of total dissolved solids; but that the normal municipal and industrial water supply releases from investigated Navasota River water-resource developments will reduce the total dissolved solids concentration under 98 percent low-flow conditions from 1115 ppm to 888 ppm in year 2015 and from 1300 ppm to 976 ppm in year 2075. This incidental reduction, however, is not considered sufficient to create significant benefits to water users in the lower Brazos River Basin. Based upon the above-mentioned findings, storage for water quality control has been excluded in the formulation of reservoir plans on the Navasota River.

9. Irrigation as a project purpose is excluded in the formulation of water-resource development plans on the Navasota River. The Bureau of Reclamation indicated that no large-scale irrigation development is expected on the Navasota River watershed under present economic conditions and legislation. However, the Bureau pointed out that there are large acreages of land well-suited for irrigation development located in the Brazos River Basin downstream from the mouth of the Navasota River. Water for irrigation is presently obtained from surface water, such as pumping directly from the Brazos River, and from hundreds of wells located in the flood plain of the Brazos River. It is expected that irrigation water for future uses will be acquired from like sources. The U. S. Public Health Service report indicates the trend in irrigation usage within the study area as follows: 1958, about 327.0 mgd; 1980, about 740 mgd; and 2025 to 2075, about 747 mgd. The water supply to be provided in a water-resource development plan on the Navasota River watershed will ultimately be utilized for meeting the higher priority demands of municipal and industrial water supply.

10. Hydroelectric power and navigation as project purposes are excluded in the formulation of water resource development plans on the Navasota River. Preliminary estimates show that the low head and small flow would produce a benefit-cost ratio for the specific power facilities alone of less than unity, even when utilizing the conservation storage for generation of power. The navigation needs for the Brazos River Basin are being investigated in connection with the comprehensive study currently being made of the entire basin. The study of navigation has not progressed far enough to permit definite conclusions at this time; however, proper development of the water resources of the Navasota River watershed will not adversely affect navigation, since navigation of the Navasota River itself is considered improbable.

11. The U. S. Public Health Service, the Bureau of Sport Fisheries and Wildlife, and the National Park Service, at the request of the Corps of Engineers, furnished reports pertaining to the water supply, fishing, hunting, wildlife, and recreation aspects of the

investigated plans of improvement. The reports of the three Federal agencies are presented in appendix V. The results of the Public Health Service study have been summarized in previous paragraphs. The Corps of Engineers' study of the recreation and fish and wildlife enhancement aspects of water-resource developments in the Navasota River watershed is presented in appendix IV, and the results of the study have been summarized in previous sections of this appendix. Pertinent data, reservoir capacities and surface areas, and estimates of cost for the investigated plans as needed for the various analyses were furnished the other Federal agencies.

12. FORMULATION CONCEPTS.- The ultimate aim of the plan of improvement for the Navasota River watershed, in common with all other productive activities, is to satisfy human needs and desires within the study area. The broad principles and objectives followed in the formulation of projects or plans herein are (a) that the goods or services to be produced by a recommended project have value only to the extent that there will be a need and demand for the product, (b) that the overall plan includes consideration of the expanding needs and well being of all the people and provides for a balanced program with the least investment in water and related land resources and funds, (c) that the scale of development is such as to provide, where practicable, the maximum excess benefits over cost, and (d) that the program of development be devised so as to permit ultimate development of the full natural resources of the basin when and if the need arises within or beyond the economic time basis used in this study. The first of these principles and objectives required the appraisal of the existing and future water resources needs and problems of the study area and established a planning criteria for selection of projects which are capable of meeting the residual needs and the solutions of multiple water resources problems in a timely manner. The second principle required the selection of the most favorable projects for a balanced plan after full consideration of all alternatives. Inherent in this principle was the goal to insure maximum flexibility and adaptability of recommended projects should actual conditions in the future differ from estimated projections obtained by the imperfect techniques now available to project conditions that are expected to prevail in the next 50 years or so. The third principle required the determination of costs and benefits of individual projects of various dimensions and sizes in order to determine the limits, where practicable, of the optimum development.

13. BASIC CONSIDERATIONS IN PROJECT FORMULATION.- Within the framework of the above-recorded formulation concepts there were certain physical, legal, and design objectives that were adopted as goals or constraints to consider in the formulation process that led to the selection of a project or plan herein. No single principle, objective, criteria or constraint is the sole determinant of projects to be included or excluded as desirable adjuncts to the Navasota River developments. All of these concepts, goals, and objectives were used in the rationale

for selection of a project or plan. The project or plan selected must have a favorable benefit cost ratio and otherwise promote economic efficiency in water resources development even though it was not practicable in each economic test to provide maximum excess benefits over cost. A comparison of various investigated plans, particularly stage-development plans, must be based on utilization of the 100-year annual equivalent values of costs and benefits to be experienced within the 100-year period of analysis 1975-2075. The more important physical, legal, and design objectives and constraints for adopted project purposes are presented below.

a. Flood control.-

(1) To provide for reduction of flood flows within the Brazos River flood plain to the maximum extent practicable in keeping with the flood-control intent of the authorized system of Brazos River reservoirs.

(2) To provide flood protection to the agricultural flood plains against a recurrence of at least a 50-year flood, or possibly greater floods to the extent practicable within reasonable economic efficiency as determined by the maximization of excess benefits over cost.

(3) To provide channel improvements and/or flood easements as necessary to allow efficient operation of investigated reservoir projects by evacuation of flood control storages within a reasonable period of time.

(4) To give full cognizance to the long-range waterflow retardation and land conservation programs of the Soil Conservation Service to the extent such programs relate to hydrologic and economic aspects of the affected project or plan selected in this report.

(5) To determine economic justification of flood control storage on the Navasota River on a last-added basis in the authorized system of Brazos River reservoirs and as a last-added increment in any investigated multiple-purpose project on the Navasota River.

b. Water supply.-

(1) To make maximization studies of excess benefits over costs and to determine optimum economical water supply storage conditions in one-reservoir and two-reservoir plans investigated for water resource development on the Navasota River.

(2) To meet the demands for water supply in the Brazos River Basin study area to the extent possible with "in-basin" supplies, including ground water.

(3) To fully coordinate water supply development on the Navasota River watershed with the plans of affected municipalities, the Brazos River Authority, and the Texas Water Commission.

(4) To consider the requests of the State of Texas for possible optimum to maximum economical development of the Navasota River water resources by plans of stage development at the one most favorable reservoir site, or at two such sites, with a view to providing water supply as needed and to reducing the finaicial burden of the responsible party designated to bear the project costs allocated to water supply.

(5) To determine dependable water supply yields on a net basis, recognizing prior water rights within the study area, existing watershed developments, and a potential system of flood detention reservoirs by the Soil Conservation Service as reported in the U. S. Study Commission - Texas plan.

c. Recreation and fish and wildlife enhancement.-

(1) To provide facilities for recreation and fish and wildlife enhancement purposes to the maximum practicable extent for satisfying expected visitor demands.

(2) To determine the economic justification of the recreation purpose on the basis of: utilizing a reasonable average annual visitation for the basis of benefits and facility needs; establishing a reasonable schedule for installation of facilities in accordance with expected increases in visitor demands; and utilizing present value of first cost and average annual equivalent charges for recreation facilities, based on the schedule of installation.

14. SOLUTIONS CONSIDERED.- After review and study of possible dam sites on the Navasota River, five dam and reservoir sites were considered initially for satisfying the water resource needs of the study area. The names of these reservoirs and the location of their respective dam sites are as follows: Millican Reservoir, river mile 24.1; Ferguson No. 3 Reservoir, river mile 41.5; Iola Reservoir, river mile 53.8; Bundic Crossing Reservoir, river mile 73.7; and Navasota No. 2 Reservoir, river mile 83.4. The above dam and reservoir sites were considered to be the most favorable with respect to physical possibilities, economy in construction, and available storage capacity for flood control and water conservation purposes. For purposes of the analyses made for this study the authorized Ferguson project site was moved upstream about five miles to utilize a dam site which

is more favorable at greater storage levels and to eliminate the need for relocation of State Highway 30 which was constructed subsequent to authorization of the Ferguson project. The investigated dam site locations are shown on plate A (adjacent to the rear cover of this report).

15. PRELIMINARY STUDIES.- Preliminary design, cost, and economic studies were made on the five reservoir sites to determine economic feasibility and to select the more favorable sites for further detailed field investigation and office studies. The preliminary evaluations of the five sites were made on the basis of multiple-purpose reservoirs containing flood control storage adequate to provide effective downstream control from a 50-year frequency flood and a range of conservation storages. These preliminary studies indicated that a multiple-purpose reservoir would be economically justified at each of the dam sites, but that Millican, Ferguson No. 3, and Navasota No. 2 Reservoirs are the most favorable on the basis of excess benefits over costs. Therefore, subsequent studies were confined to the Millican, Ferguson No. 3, and Navasota No. 2 Reservoirs. Reservoir maps of the Millican, Navasota No. 2, and Ferguson No. 3 sites are shown on plates 9, 12, and 27, respectively.

16. DETAILED STUDIES.- The final or detailed stage of the studies involved hydrologic, hydraulic, and structural design studies; economic field and office studies; and cost studies. The detailed investigations included subsurface explorations to determine foundation conditions at the three dam sites, topographic surveys to establish reliable reservoir mapping data, and topographic surveys to obtain channel and valley cross sections for hydraulic, economic, and plan of improvement studies.

17. The reservoir sites selected for detailed study were investigated in a wide range of plans formulated for purposes of flood control, water supply, and recreation and fish and wildlife enhancement. Studies were made to determine the best plan of development for these purposes within the objectives, formulation concepts, and basic formulation considerations outlined in previous paragraphs. The detailed studies and investigations included economic and cost analyses of the reservoir units to determine the most favorable amounts of controlled storage for flood control and for water supply. The detailed studies involved single-reservoir plans to provide optimum-economical to maximum water-resource development by construction of a dam at the Millican site, at the Ferguson No. 3 site, and at the Navasota No. 2 site. Also, the detailed studies involved the Millican and Navasota No. 2 sites in plans of stage development to develop approximately the total water resources of the watershed upstream of the Millican site.

18. Project formulation, economic analysis, and cost allocation studies of the alternative plans involved investigations and studies of single-purpose projects for flood control, water supply, and recreational purposes. Single-purpose reservoirs for flood control were investigated as dry-pool reservoirs containing no permanent pool capacity.

19. BENEFITS AND COSTS.- An economic base study has been made to evaluate recent economic growth and to estimate future growth in the lower Brazos River Basin. These projections have been made to assist in measurement of the probable increase in water resource requirements, development within the flood plains and thus the need for flood protection, and the potential recreation demands within the influence areas of projects on the Navasota River. The economic base study is presented in appendix III, Economics. Economic studies were made to determine the costs, benefits, and economic justification of the alternative plans. The project costs and benefits were evaluated on the basis of January 1965 price levels.

a. Costs.- The first cost of the investigated projects comprise all initial expenditures for construction, including lands and damages, relocations, reservoir clearing, engineering and design, and supervision and administration. The cost of future recreation facilities required for the expected recreation development is included in the project costs. The annual charges for the investigated projects include interest and amortization of the total investments at an interest rate of 3-1/8 percent for a 100-year period, operation and maintenance costs, and annual equivalent cost of major replacements and future recreation facilities.

b. Flood control benefits.- The average annual benefits for reduction of flood damages were determined by use of discharge-damage and discharge-frequency relationships as described in appendix III. Each investigated plan was considered as a substitute for the authorized Ferguson Reservoir in the reservoir system consisting of Whitney, Belton, Waco, Proctor, Stillhouse Hollow, Somerville, and Ferguson Reservoirs, and the San Gabriel River projects, authorized for flood control and allied purposes in the Brazos River Basin. Ferguson Reservoir is the only project of this system that is not completed, under construction, or in the advance planning stage. Therefore, all of the projects in this system except Ferguson Reservoir were considered to be in operation for computing the benefits for the investigated plans. In the case of stage-development plans, the flood control benefits attributed to the second project were the incremental damages prevented by adding the second project. Pertinent data concerning the flood plains below the investigated projects are presented in appendix III.

c. Water supply benefits.- Benefits for water supply were computed on the basis of the cost of obtaining the same quantity and quality of water by the cheapest alternative means that would most likely be developed by the potential water users in the absence of the Federal project. The estimated cost of the alternative means was based on non-Federal financing and interest rates. The benefits used in this report were computed by the Corps of Engineers; however, the method of computation used is the same as that used by the Public Health Service in arriving at the benefits for the selected plan of improvement, with the exception of the assumption used by Public Health Service that the alternative projects would be completed 10 years prior to the time the water is first needed.

d. Recreation and fish and wildlife enhancement benefits.- The recreation and fish and wildlife enhancement has been evaluated on the basis of studies by the Corps of Engineers. The benefits for the investigated plans were determined by estimating the potential recreational demand within the influence area of the projects and then assigning unit values for the various activities to the estimated annual visitation for each project on a visitor-day basis. The complete analysis of recreation and fish and wildlife enhancement is presented in appendix IV.

20. RESERVOIR STORAGE STUDIES.- Reservoir storage studies for the various investigated plans are summarized as follows:

a. Flood control storage.- Analyses of each reservoir were made to determine the flood control storage conditions which would provide the maximum amount of excess flood control benefits over costs. The flood control analyses were made on the basis of flood control storage requirements for the frequency range of once in 30 years to once in 150 years as a part of a multiple-purpose reservoir under three different conditions of constant conservation storage. In this manner, the relationships between excess benefits over costs and flood-frequency control were established for each reservoir as shown in figure 1. The curves shown in figure 1 indicate that flood control storage capacities which would control flood volumes having a frequency of occurrence of once in 30 years or once in 100 years would provide the maximum amount of excess benefits over costs in the three reservoirs depending on the amount of conservation storage included. In those cases where the 30-year storage provides the maximum excess benefits over costs, the excess benefits for 100-year storage are only slightly less. In no case would the excess benefits be reduced by more than two percent by providing 100-year flood control storage. Although the curves shown in figure 1 are not based on the latest cost and benefit estimates, checks made using current detailed cost and benefit data indicate that these relationships are reasonable. Based on the analyses described above,

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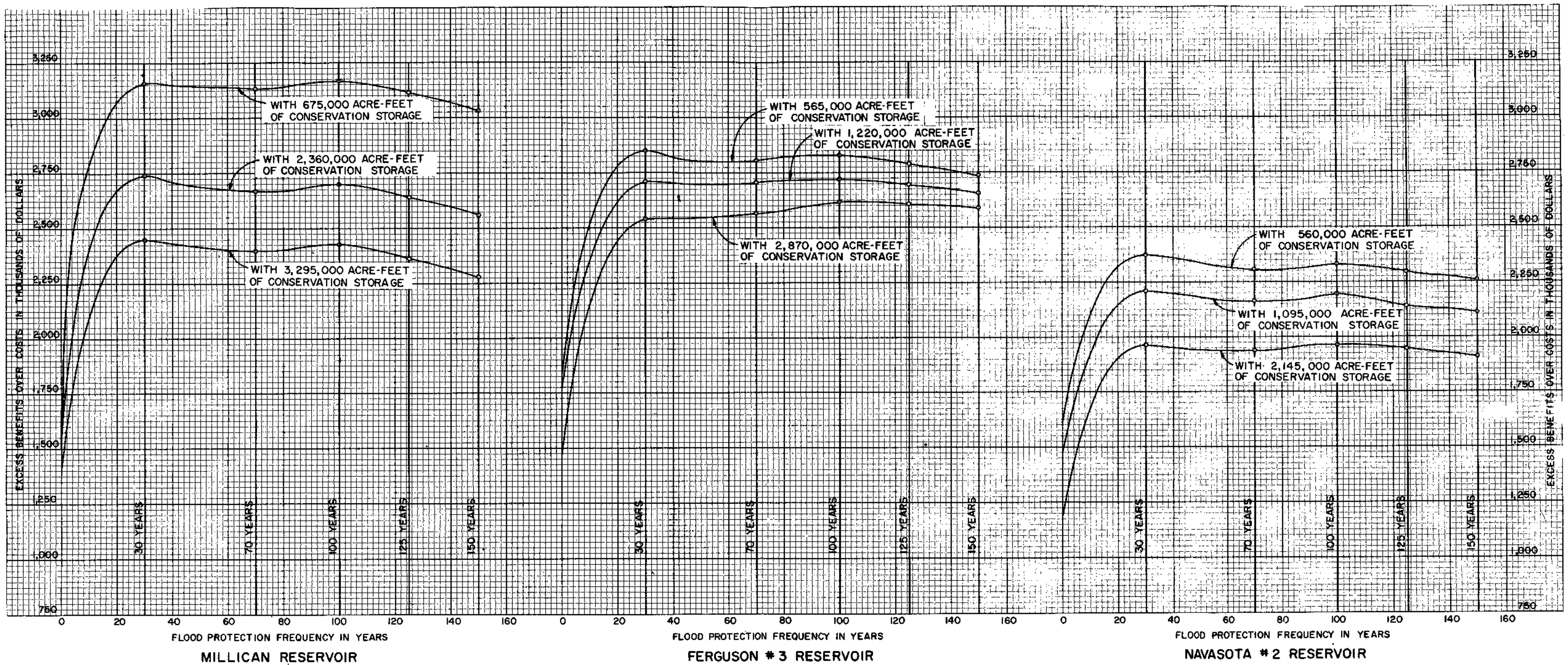
the volume of flood control storage adopted for the formulation studies approximates that required for 100-year flood control as based on a regional analysis of flood control storage requirements, and is sufficient to control the maximum flood of record (May-June 1929) with respect to flood control storage required. The economic analysis of single-purpose flood control projects at the three sites is presented in table 1.

b. Channel improvements.- During the flood control studies, the channel capacities below the investigated reservoirs were found to be inadequate to provide for a reasonable emptying time of the flood control storage without sustained releases exceeding the downstream channel capacities. Water covers a wide area when the discharge in the river exceeds the minimum channel capacity because of the comparatively low and flat flood plain of the Navasota River. The area below the Millican Dam site is also affected by backwater during medium and high flows on the Brazos River. Existing channel capacities of the Navasota River are as follows: 10,000 second-feet from the mouth to river mile 10.0; 4,000 second-feet from river mile 10.0 to river mile 41.5; and 2,500 second-feet from river mile 41.5 to river mile 83.4 at the Navasota No. 2 Dam site. In consideration of the objective of reducing the emptying time, various plans for improving conditions downstream from the dam site were investigated with a view to reducing the emptying time from about 98 to 116 days under existing conditions to 39 to 46 days under improved conditions with a minimum of damage due to valley flooding. The investigated plans of improvement included increasing the capacity of the channel, acquiring flood flowage easements and providing additional storage space over and above that required to control the 100-year frequency flood. The cost of providing an excavated channel with sufficient within bank capacity below Millican Dam was found to be excessive because of the disproportionate size channel that would be required and the impracticability of eliminating backwater from the Brazos River. Preliminary comparisons indicated that the additional reservoir storage would be several times more costly than comparable channel improvement and/or flowage easements. Therefore, channel improvement works and/or flood flowage easements were considered the best method to reduce the time required to evacuate the flood storage capacities of the investigated reservoirs. These improvements would insure sound and flexible operation of the reservoirs for flood control. The channel provisions would be a necessary integral part of flood-control operation in each multiple-purpose reservoir plan, and therefore, are not considered in any sense to be a local flood protection project. The costs of the appurtenant channel improvement works and flowage easements have been included in the overall costs of the investigated reservoir plans. The determination as to whether to provide an improved channel and flowage easement or flowage easement only will be made in connection with the preconstruction studies when complete detailed information will be available on the flood plain downstream from the dam.



NOTE: Based on preliminary estimates of costs and benefits.

NAVASOTA RIVER WATERSHED

MAXIMIZATION OF EXCESS FLOOD CONTROL BENEFITS OVER COSTS

FLOOD PROTECTION FREQUENCY VS. EXCESS BENEFITS

FIGURE 1

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TABLE 1

SUMMARY OF ECONOMIC AND COST ANALYSES
INVESTIGATED SINGLE-RESERVOIR PLANS
WITH 100-YEAR-FREQUENCY FLOOD STORAGE
NAVASOTA RIVER WATERSHED

Item	MILLICAN RESERVOIR				
	Plan A-1	Plan A-2	Plan A-3	Plan A-4	Plan A-5(Plan I)
1. PERTINENT DATA					
Purpose, flood control (FC), water supply (WS), recreation and fish and wildlife enhancement (R)	FC	FC WS R	FC WS R	FC WS R	FC WS R
Elevations, feet msl					
Top of dam	235.0	242.0	246.0	255.0	264.0
Top of flood control pool	222.0	230.0	234.0	244.0	254.0
Top of water supply pool	-	212.0	219.0	233.0	246.0
Surface area, acres					
Top of flood control pool	46,600	58,800	66,000	86,100	108,400
Top of water supply pool	-	32,100	42,400	64,200	90,200
Total controlled storage, acre-feet	887,900	1,307,800	1,557,400	2,317,800	3,287,100
Flood control storage, acre-feet (100-year)	(795,500)	784,800	784,800	815,000	786,400
Water supply storage, acre-feet	(-)	430,600	680,200	1,410,400	2,408,300
Sediment storage, acre-feet	(92,400)	92,400	92,400	92,400	92,400
Dependable flow, water supply yield					
Second-feet (cfs)	-	240	300	380	480
Million gallons daily (mgd)	-	155.1	193.9	245.6	310.2
2. TOTAL FIRST COST OF PROJECT (Based on actual dollar expenditures):	34,600,000	57,500,000	61,670,000	74,060,000	91,260,000
Reservoir	(32,780,000)	(47,030,000)	(51,200,000)	(63,590,000)	(80,790,000)
Channel rectification	(1,820,000)	(1,820,000)	(1,820,000)	(1,820,000)	(1,820,000)
Recreation	(-)	(8,650,000)	(8,650,000)	(8,650,000)	(8,650,000)
3. TOTAL FIRST COST OF PROJECT (With future expenditures discounted to 1975 worth):	34,600,000	54,400,000	58,570,000	70,960,000	88,160,000
Reservoir	(32,780,000)	(47,030,000)	(51,200,000)	(63,590,000)	(80,790,000)
Channel rectification	(1,820,000)	(1,820,000)	(1,820,000)	(1,820,000)	(1,820,000)
Recreation	(-)	(5,550,000)	(5,550,000)	(5,550,000)	(5,550,000)
4. TOTAL ANNUAL CHARGES (Based on average annual equivalent values for the period 1975 to 2075):	1,327,700	2,300,000	2,486,600	2,956,200	3,652,200
Annual investment	1,239,700	1,977,000	2,158,600	2,615,200	3,294,200
Reservoir	(1,174,500)	(1,709,200)	(1,887,000)	(2,343,600)	(3,018,800)
Channel rectification	(65,200)	(66,100)	(67,100)	(67,100)	(68,000)
Recreation	(-)	(201,700)	(204,500)	(204,500)	(207,400)
Annual maintenance and operation	88,000	323,000	328,000	341,000	358,000
Reservoir	(80,000)	(95,000)	(100,000)	(113,000)	(130,000)
Channel rectification	(8,000)	(8,000)	(8,000)	(8,000)	(8,000)
Recreation	(-)	(220,000)	(220,000)	(220,000)	(220,000)
5. TOTAL ANNUAL BENEFITS (Based on average anneul equivalent values for the period 1975 to 2075):	3,111,500	7,841,300	8,231,300	8,604,300	8,891,300
Prevention of damages	3,111,500	3,111,500	3,111,500	3,111,500	3,111,500
Navasota River watershed	(-)	(-)	(-)	(-)	(-)
Brazos River Basin	(3,111,500)	(3,111,500)	(3,111,500)	(3,111,500)	(3,111,500)
Water conservation	-	930,000	1,320,000	1,693,000	1,980,000
Recreation and fish and wildlife enhancement	-	3,799,800	3,799,800	3,799,800	3,799,800
6. RATIO OF BENEFITS TO COSTS:	2.34	3.41	3.31	2.91	2.43
7. EXCESS BENEFITS OVER COSTS:					
FC, WS, and R	1,783,800	5,541,300	5,744,700	5,648,100	5,239,100
FC, or FC and WS	1,783,800	2,163,200	2,369,500	2,272,800	1,866,700

Item	FERGUSON RESERVOIR				
	Plan B-1	Plan B-2	Plan B-3	Plan B-4	Plan B-5
1. PERTINENT DATA					
Purpose, flood control (FC), water supply (WS), recreation and fish and wildlife enhancement (R)	FC	FC WS R	FC WS R	FC WS R	FC WS R
Elevations, feet msl					
Top of dam	259.0	269.0	271.0	282.0	289.0
Top of flood control pool	249.0	258.0	262.0	273.0	281.0
Top of water supply pool	-	238.5	245.0	261.5	271.5
Surface area, acres					
Top of flood control pool	35,750	61,500	53,220	68,800	81,650
Top of water supply pool	-	26,030	31,590	52,530	66,580
Total controlled storage, acre-feet	762,500	1,137,100	1,339,000	2,008,700	2,610,100
Flood control storage, acre-feet (100-year)	685,000	677,100	695,300	687,800	696,900
Water supply storage, acre-feet	-	382,500	566,200	1,243,400	1,835,700
Sediment storage, acre-feet	77,500	77,500	77,500	77,500	77,500
Dependable flow, water supply yield					
Second-feet (cfs)	-	200	250	325	383
Million gallons daily (mgd)	-	129.3	161.6	210.1	247.5
2. TOTAL FIRST COST OF PROJECT (Based on actual dollar expenditures):	29,490,000	53,939,000	57,590,000	72,690,000	82,590,000
Reservoir	(25,600,000)	(41,449,000)	(45,100,000)	(60,200,000)	(70,100,000)
Channel rectification	(3,890,000)	(3,890,000)	(3,890,000)	(3,890,000)	(3,890,000)
Recreation	(-)	(8,600,000)	(8,600,000)	(8,600,000)	(8,600,000)
3. TOTAL FIRST COST OF PROJECT (With future expenditures discounted to 1975 worth):	29,490,000	50,839,000	54,490,000	69,590,000	79,490,000
Reservoir	(25,600,000)	(41,449,000)	(45,100,000)	(60,200,000)	(70,100,000)
Channel rectification	(3,890,000)	(3,890,000)	(3,890,000)	(3,890,000)	(3,890,000)
Recreation	(-)	(5,500,000)	(5,500,000)	(5,500,000)	(5,500,000)
4. TOTAL ANNUAL CHARGES (Based on average annual equivalent values for the period 1975 to 2075):	1,157,700	2,181,700	2,319,400	2,916,700	3,332,300
Annual investment	1,056,700	1,847,700	1,980,400	2,564,700	2,970,300
Reservoir	(917,300)	(1,506,400)	(1,639,100)	(2,218,700)	(2,619,400)
Channel rectification	(139,400)	(141,400)	(141,400)	(143,300)	(145,400)
Recreation	(-)	(199,900)	(199,900)	(202,700)	(205,500)
Annual maintenance and operation	101,000	334,000	339,000	352,000	362,000
Reservoir	(77,000)	(90,000)	(95,000)	(108,000)	(118,000)
Channel rectification	(24,000)	(24,000)	(24,000)	(24,000)	(24,000)
Recreation	(-)	(220,000)	(220,000)	(220,000)	(220,000)
5. TOTAL ANNUAL BENEFITS (Based on average anneul equivalent values for the period 1975 to 2075):	2,954,500	7,514,300	7,739,300	8,224,300	8,459,300
Prevention of damages	2,954,500	2,954,500	2,954,500	2,954,500	2,954,500
Navasota River watershed	(271,200)	(271,200)	(271,200)	(271,200)	(271,200)
Brazos River Basin	(2,683,300	(2,683,300)	(2,683,300)	(2,683,300)	(2,683,300)
Water conservation	-	760,000	985,000	1,470,000	1,705,000
Recreation and fish and wildlife enhancement	-	3,799,800	3,799,800	3,799,800	3,799,800
6. RATIO OF BENEFITS TO COSTS:	2.55	3.44	3.34	2.82	2.54
7. EXCESS BENEFITS OVER COSTS:					
FC, WS, and R	1,796,800	5,332,600	5,419,900	5,307,600	5,127,000
FC, or FC and WS	1,796,800	1,952,700	2,040,000	1,930,500	1,752,700

Item	NAVASOTA NO. 2 RESERVOIR					
	Plan C-1	Plan C-2	Plan C-3	Plan C-4	Plan C-5	Plan C-6
1. PERTINENT DATA						
Purpose, flood control (FC), water supply (WS), recreation and fish and wildlife enhancement (R)	FC	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R
Elevations, feet msl						
Top of dam	325.0	337.0	341.0	348.0	354.0	358.0
Top of flood control pool	308.0	321.0	328.0	334.0	341.0	345.0
Top of water supply pool	-	301.0	312.5	321.0	330.0	335.5
Surface area, acres						
Top of flood control pool	25,600	36,340	42,600	48,600	58,180	66,000
Top of water supply pool	-	21,130	29,000	36,340	44,540	49,100
Total controlled storage, acre-feet	615,300	1,015,200	1,291,400	1,564,700	1,935,600	2,183,100
Flood control storage, acre-feet (100-year)	545,800	546,200	543,200	541,100	550,700	539,500
Water supply storage, acre-feet	-	399,500	678,700	954,100	1,315,400	1,574,100
Sediment storage, acre-feet	69,500	69,500	69,500	69,500	69,500	69,500
Dependable flow, water supply yield						
Second-feet (cfs)	-	200	232	265	300	325
Million gallons daily (mgd)	-	129.3	149.9	171.3	193.9	210.1
2. TOTAL FIRST COST OF PROJECT (Based on actual dollar expenditures):	33,776,000	53,210,000	58,587,000	64,155,000	72,717,000	78,905,000
Reservoir	(25,376,000)	(36,370,000)	(41,747,000)	(47,315,000)	(55,877,000)	(62,065,000)
Channel rectification	(8,400,000)	(8,400,000)	(8,400,000)	(8,400,000)	(8,400,000)	(8,400,000)
Recreation	(-)	(8,440,000)	(8,440,000)	(8,440,000)	(8,440,000)	(8,440,000)
3. TOTAL FIRST COST OF PROJECT (With future expenditures discounted to 1975 worth):	33,776,000	50,110,000	55,484,000	61,055,000	69,617,000	75,805,000
Reservoir	(25,376,000)	(36,370,000)	(41,747,000)	(47,315,000)	(55,877,000)	(62,065,000)
Channel rectification	(8,400,000)	(8,400,000)	(8,400,000)	(8,400,000)	(8,400,000)	(8,400,000)
Recreation	(-)	(5,340,000)	(5,340,000)	(5,340,000)	(5,340,000)	(5,340,000)
4. TOTAL ANNUAL CHARGES (Based on average annual equivalent values for the period 1975 to 2075):	1,337,200	2,186,100	2,390,500	2,600,900	2,954,800	3,186,900
Annual investment	1,210,200	1,821,100	2,016,500	2,218,900	2,565,800	2,793,900
Reservoir	(909,200)	(1,321,800)	(1,517,200)	(1,719,600)	(2,059,300)	(2,2[illegible]7,400
Channel rectification	(301,000)	(305,300)	(305,300)	(305,300)	(309,600)	(309,600)
Recreation	(-)	(194,000)	(194,000)	(194,000)	(196,900)	(196,900)
Annual maintenance and operation	127,000	365,000	374,000	382,000	389,000	393,000
Reservoir	(65,000)	(83,000)	(92,000)	(100,000)	(107,000)	(111,000)
Channel rectification	(62,000)	(62,000)	(62,000)	(62,000)	(62,000)	(62,000)
Recreation	(-)	(220,000)	(220,000)	(220,000)	(220,000)	(220,000)
5. TOTAL ANNUAL BENEFITS (Based on average anneul equivalent values for the period 1975 to 2075):	2,298,000	6,857,800	6,987,800	7,177,800	7,417,800	7,567,800
Prevention of damages	2,298,000	2,298,000	2,298,000	2,298,000	2,298,000	2,298,000
Navasota River watershed	(428,000)	(428,000)	(428,000)	(428,000)	(428,000)	(428,000)
Brazos River Basin	(1,870,000)	(1,870,000)	(1,870,000)	(1,870,000)	(1,870,000)	(1,870,000)
Water conservation	-	760,000	890,000	1,080,000	1,320,000	1,470,000
Recreation and fish and wildlife enhancement	-	3,799,800	3,799,800	3,799,800	3,799,800	3,799,800
6. RATIO OF BENEFITS TO COSTS:	1.72	3.14	2.92	2.76	2.51	2.37
7. EXCESS BENEFITS OVER COSTS:						
FC, WS, and R	960,800	4,671,700	4,597,300	4,576,900	4,463,000	4,380,900
FC, or FC and WS	960,800	1,285,900	1,211,500	1,191,100	1,080,100	998,000

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c. Water supply storage.- Studies and analyses were made to determine the water supply storage to be included in the various investigated reservoir plans. The studies involved: (1) the determination of optimum water supply storage at each of the investigated sites; and (2) the determination of the most economical placement of water supply storage to develop the approximately maximum water supply resources of the Navasota River watershed. In regard to item (1), studies were made to determine the optimum economical water supply storage conditions in various single-reservoir plans on the Navasota River. A range of water supply storage capacities up to that required to develop the maximum dependable yield at the site were included in multiple-purpose reservoirs at the three dam sites selected for detailed study. Each of the multiple-purpose reservoir projects was based on 100-year frequency flood control storage conditions. The results of these studies, including economic and cost analyses, and summaries of water supply storages and dependable yields, are presented in table 1. The relationship between excess benefits over costs and dependable water supply yields for the investigated reservoir projects are shown in figure 2. Based on the conditions stated above, the optimum economical water resource development would be realized at the Millican, Ferguson No. 3, and Navasota No. 2 sites by conservation storages of 680,200, 566,200, and 399,500 acre-feet, respectively, which would provide respective estimates in dependable yields of about 300, 250, and 200 cubic feet per second (cfs) or about 193.9, 161.6, and 129.3 million gallons daily (mgd). In regard to item (2) the development of the water supply resources of the Navasota River watershed were confined to those available upstream of the Millican Dam site. The placement of the water supply storage required for maximum development was considered at the Millican site alone, or in the Millican and Navasota units in plans of stage development. The water supply storage requirements in various plans investigated, the distribution of storage between the various stage-development-plan units, and information on dependable water supply yields are summarized in tables 2A and 2B.

d. Recreation storage.- The inclusion of conservation storage for recreation and fish and wildlife enhancement purposes was considered in the early planning stages. However, after determining the water supply requirements and the range of project sizes that could be used to satisfy these requirements, it was concluded that additional conservation storage would not enhance the water-based recreational aspects of projects significantly. Therefore, specific reservoir storage for the recreation purposes was not included in the reservoir plans studied.

21. PLAN-COMPARISON STUDIES.- The objective at this point in the studies was to determine the most efficient plan of improvement in the interest of flood control, full development of the water

supply resources of the watershed, and recreation and fish and wildlife enhancement. With a view to approximately full development of the water resources upstream from the Millican Dam site, the following plans were selected for analyses and comparison: A multiple-purpose Millican Reservoir operating alone; multiple-purpose plans of stage development, with Millican Reservoir as the intial unit and Navasota No. 2 as the future unit; multiple-purpose plans of stage development, with Navasota No. 2 Reservoir as the initial unit and Millican Reservoir as the future unit; and a plan of stage development consisting of Millican Reservoir as the initial unit for purposes of flood control, water supply, and recreation and fish and wildlife enhancement, and Navasota No. 2 Reservoir as the future unit for water supply and recreation only. The Millican and Navasota No. 2 sites were chosen for the stage-development plans on the basis of their advantages in physical arrangement, construction cost, benefits, and their ability to develop the approximate total water resources of the watershed. Equal and full consideration was given to each of the several alternative plans, and the results of the plan-comparison studies are presented in tables 2A and 2B. The maximization of total excess benefits-over-costs for investigated stage-development plans with Millican Reservoir and with Navasota No. 2 Reservoir utilized as initial units is illustrated in figure 3.

22. SELECTED PLAN OF IMPROVEMENT.- The plan of improvement selected as the most feasible for water resource development on the Navasota River watershed and for satisfying the needs of the study area is a stage-development plan consisting of a multiple-purpose Millican Reservoir as the intial unit to be completed about year 1975 and a multiple-purpose Navasota No. 2 Reservoir as the future unit to be completed when additional water supply is needed, presently estimated at year 2010. The selected plan is designated as stage development Plan II in tables 2A and 2B. Pertinent data on the design characteristics of the selected plan are presented in table 3. Detailed estimates of first costs and annual charges are presented in tables 4 through 7. Reservoir maps, details of the dams, and flood-release channel improvements for the selected plan are shown on plates 9 through 14.

23. The studies showed that a single-purpose flood control reservoir at the Millican Dam site would be justified and that each purpose produces benefits in excess of the cost of adding that purpose to the multiple-purpose projects. The selected plan of stage development accomplishes a balance in the several purposes in a manner that provides the maximum amount of excess benefits over costs.

24. The Millican Reservoir would provide for the control of the 100-year frequency flood originating upstream from the dam site and for development of a dependable water supply yield of about

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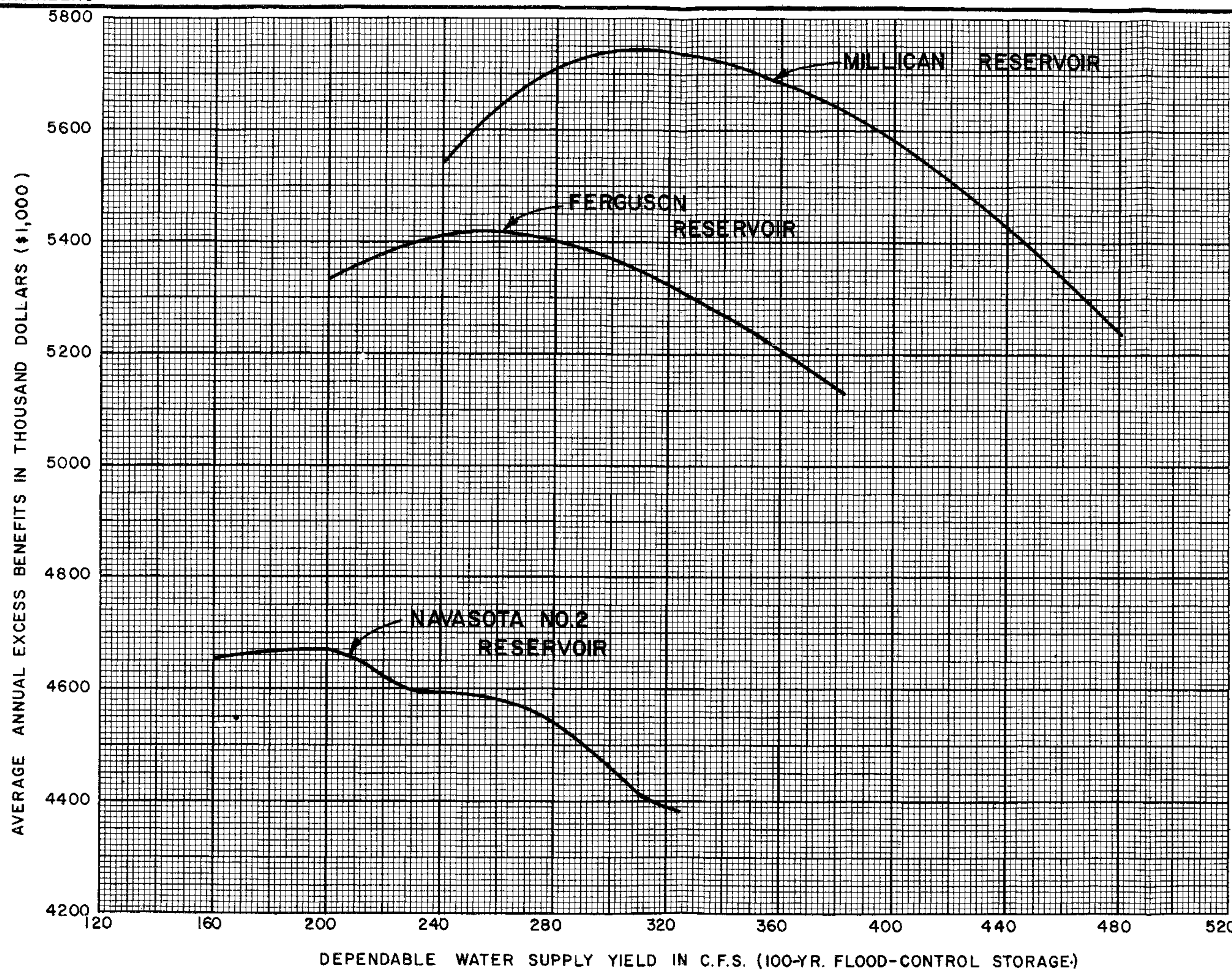

NAVASOTA RIVER WATERSHED

SINGLE PROJECTS

MAXIMIZATION OF EXCESS BENEFITS OVER COSTS

YIELD VS. EXCESS BENEFITS

FIGURE 2

Appendix I

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TABLE 2A

SUMMARY OF ECONOMIC AND COST ANALYSES
INVESTIGATED STAGE-DEVELOPMENT RESERVOIR PLANS
WITH 100-YEAR-FREQUENCY FLOOD STORAGE
NAVASOTA RIVER WATERSHED

Item	PLAN I (A-5)	PLAN V				PLAN II				PLAN X				PLAN IX		
	Millican Reservoir only	Initial Unit Millican Reservoir: First Stage	Initial Unit Millican Reservoir: Second Stage	Future Unit Navasota No. 2 Reservoir: Second Stage	Total: Second Stage	Initial Unit Millican Reservoir: First Stage	Initial Unit Millican Reservoir: Second Stage	Future Unit Navasota No. 2 Reservoir: Second Stage	Total: Second Stage	Initial Unit Millican Reservoir: First Stage	Initial Unit Millican Reservoir: Second Stage	Future Unit Navasota No. 2 Reservoir: Second Stage	Total: Second Stage	Initial Unit Millican Reservoir	Future Unit Navasota No. 2 Reservoir	Total
1. PERTINENT DATA																
Purpose, flood control (FC), water supply (WS), recreation and fish and wildlife enhancement (R)	FC WS R	FC WS R		FC WS R	FC WS R	FC WS R		FC WS R	FC WS R	FC WS R		FC WS R	FC WS R	FC WS R	WS R	FC WS R
Elevations, feet msl																
Top of dam	264.0	249.0	249.0	356.0	-	250.0	250.0	354.0	-	260.0	260.0	341.0	-	250.0	347.0	-
Top of flood control pool	254.0	230.0	230.0	345.0	-	234.0	234.0	341.0	-	244.0	244.0	328.0	-	234.0	-	-
Top of water supply pool	246.0	212.0	223.0	335.5	-	219.0	228.0	330.0	-	233.0	239.5	312.5	-	219.0	335.0	-
Surface area, acres																
Top of flood control pool	108,400	58,800	58,800	66,000	-	66,000	66,000	58,180	-	86,100	86,100	42,600	-	66,000	-	-
Top of water supply pool	90,200	32,100	48,000	49,160	-	42,400	55,500	44,540	-	64,200	72,050	29,000	-	42,400	49,710	-
Total controlled storage, acre-feet	3,287,100	1,307,800		2,183,100	3,490,900	1,557,400		1,935,600	3,493,000	2,317,800		1,291,400	3,609,200	1,557,400	1,613,800	3,171,200
Flood control storage, acre-feet (100-year)	786,400	(784,800	366,500)	(539,500)	(906,000)	(784,800	359,600)	(550,700)	(910,300)	(815,000	364,100)	(543,200)	(907,300)	(784,800)	(-)	(784,800)
Water supply storage, acre-feet	2,408,300	(430,600	869,300)	(1,574,100)	(2,443,400)	(680,200	1,125,800)	(1,315,400)	(2,441,200)	(1,410,400	1,881,700)	(678,700)	(2,560,400)	(680,200)	(1,544,300)	(2,224,500)
Sediment storage, acre-feet	92,400	(92,400	72,000)	(69,500)	(141,500)	(92,400	72,000)	69,500)	(141,500)	(92,400	72,000)	(69,500)	(141,500)	(92,400)	(69,500)	(161,900)
Dependable flow, water supply yield																
Second-feet (cfs)	480	240	150	325	475	300	175	300	475	380	238	232	470	300-135	325	460
Million gallons daily (mgd)	310.2	155.1	96.9	210.1	307	193.9	113.1	193.9	307	245.6	153.9	149.9	303.8	193.9-87.2	210.1	297.3
Assumed year of completion	1975	1975		2005		1975		2010		1975		2013		1975	2010	
2. TOTAL FIRST COST OF PROJECT (Based on actual dollar expenditures):	91,260,000	54,730,000		67,275,000	122,005,000	58,620,000		61,087,000	119,707,000	71,650,000		46,957,000	118,607,000	58,620,000	52,250,000	110,870,000
Reservoir	(80,790,000)	(47,850,000)		(62,065,000)	(109,915,000)	(51,740,000)		(55,877,000)	(107,617,000)	(64,770,000)		(41,747,000)	(106,517,000)	(51,740,000)	(48,700,000)	(100,440,000)
Channel rectification	(1,820,000)	(1,820,000)		(1,660,000)	(3,480,000)	(1,820,000)		(1,660,000)	(3,480,000)	(1,820,000)		(1,660,000)	(3,480,000)	(1,820,000)	(-)	(1,820,000)
Recreation	(8,650,000)	(5,060,000)		(3,550,000)	(8,610,000)	(5,060,000)		(3,550,000)	(8,610,000)	(5,060,000)		(3,550,000)	(8,610,000)	(5,060,000)	(3,550,000)	(8,610,000)
3. TOTAL FIRST COST OF PROJECT (With future expenditures discounted to 1975 worth):	88,160,000	53,590,000		26,419,000	80,009,000	57,480,000		20,577,000	78,057,000	70,510,000		14,376,000	84,886,000	57,480,000	17,480,000	74,960,000
Reservoir	(80,790,000)	(47,850,000)		(24,652,000)	(72,502,000)	(51,740,000)		(19,032,000)	(70,772,000)	(64,770,000)		(12,967,000)	(77,737,000)	(51,740,000)	(16,587,000)	(68,327,000)
Channel rectification	(1,820,000)	(1,820,000)		(659,000)	(2,479,000)	(1,820,000)		(565,000)	(2,385,000)	(1,820,000)		(516,000)	(2,336,000)	(1,820,000)	(-)	(1,820,000)
Recreation	(5,550,000)	(3,920,000)		(1,108,000)	(5,028,000)	(3,920,000)		(980,000)	(4,900,000)	(3,920,000)		(893,000)	(4,813,000)	(3,920,000)	(893,000)	(4,813,000)
4. TOTAL ANNUAL CHARGES (Based on average annual equivalent values for the period 1975 to 2075):	3,652,200	2,231,600		1,059,700	3,291,300	2,404,500		837,400	3,241,900	2,897,600		594,800	3,492,400	2,404,500	882,200	3,286,700
Annual investment	3,294,200	1,950,600		973,700	2,924,300	2,118,500		758,400	2,876,900	2,598,600		522,800	3,121,400	2,118,500	813,200	2,931,700
Reservoir	(3,018,800)	(1,742,000)		(908,600)	(2,650,600)	(1,906,900)		(701,400)	(2,608,300)	(2,387,000)		(471,200)	(2,858,200)	(1,906,900)	(771,700)	(2,678,600)
Channel rectification	(68,000)	(66,100)		(24,300)	(90,400)	(67,100)		(20,800)	(87,900)	(67,100)		(18,800)	(85,900)	(67,100)	(-)	(67,100)
Recreation	(207,400)	(142,500)		(40,800)	(183,300)	(144,500)		(36,200)	(180,700	(144,500)		(32,800)	(177,300)	(144,500)	(41,500)	(186,000)
Annual maintenance and operation	358,000	281,000		86,000	367,000	286,000		79,000	365,000	299,000		72,000	371,000	286,000	69,000	355,000
Reservoir	(130,000)	(95,000)		(39,000)	(134,000)	(100,000)		(33,000)	(133,000)	(113,000)		(26,000)	(139,000)	(100,000)	(27,000)	(127,000)
Channel rectification	(8,000)	(8,000)		(5,000)	(13,000)	(8,000)		(4,000)	(12,000)	(8,000)		(4,000)	(12,000)	(8,000)	(-)	(8,000)
Recreation	(220,000)	(178,000)		(42,000)	(220,000)	(178,000)		(42,000)	(220,000)	(178,000)		(42,000)	(220,000)	(178,000)	(42,000)	(220,000)
5. TOTAL ANNUAL BENEFITS (Based on average annual equivalent values for the period 1975 to 2075):	8,891,300	6,258,400		2,677,900	8,936,300	6,648,400		2,282,400	8,930,800	7,021,400		1,889,100	8,910,500	6,648,400	2,192,900	8,841,300
Prevention of damages	3,111,500	3,111,500		55,000	3.166,500	3,111,500		49,500	3,161,000	3,111,500		46,200	3,157,700	3,111,500	-	3,111,500
Navasota River watershed	(-)	(-)		(55,000)	(55,000)	(-)		(49,500)	(49,500)	(-)		(46,200)	(46,200)	(-)	(-)	(-)
Brazos River Basin	(3,111,500)	(3,111,500)		(-)	(3,111,500)	(3,111,500)		(-)	(3,111,500)	(3,111,500)		(-)	(3,111,500)	(3,111,500)	(-)	(3,111,500)
Water conservation	1,980,000	930,000		1,040,000	1,970,000	1,320,000		650,000	1,970,000	1,693,000		260,000	1,953,000	1,320,000	610,000	1,930,000
Recreation and fish and wildlife enhancement	3,799,800	2,216,900		1,582,900	3,799,800	2,216,900		1,582,900	3,799,800	2,216,900		1,582,900	3,799,800	2,216,900	1,582,900	3,799,800
6. RATIO OF BENEFITS TO COSTS:	2.43	2.80		2.53	2.72	2.76		2.73	2.75	2.42		3.18	2.55	2.76	2.49	2.69
7. EXCESS BENEFITS OVER COSTS:																
FC, WS, and R	5,239,100	4,026,800		1,618,200	5,645,000	4,243,900		1,445,000	5,688,900	4,123,800		1,294,300	5,418,100	4,243,900	1,310,700	5,554,600
FC, or FC and WS	1,866,700	2,130,400		118,100	2,248,500	2,349,500		-59,700	2,289,800	2,229,400		-213,800	2,015,600	2,349,500	-188,700	2,160,800

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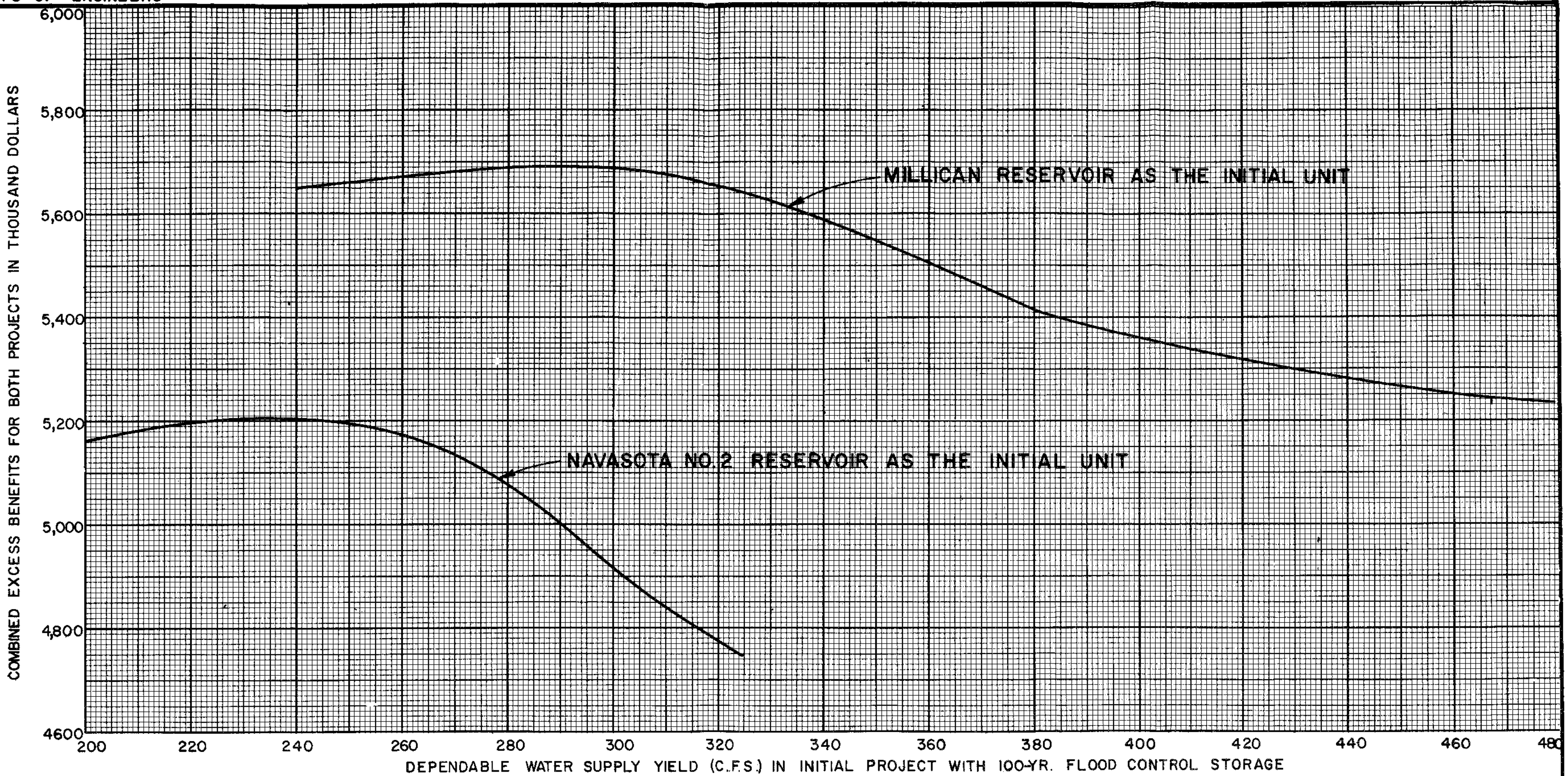
TABLE 2B

SUMMARY OF ECONOMIC AND COST ANALYSES
INVESTIGATED STAGE-DEVELOPMENT RESERVOIR PLANS
WITH 100-YEAR-FREQUENCY FLOOD STORAGE
NAVASOTA RIVER WATERSHED

Item	PLAN VII			PLAN VI			PLAN VIII			PLAN IV			PLAN III		
	Initial Unit Navasota No. 2 Reservoir	Future Unit Millican Reservoir	Total	Initial Unit Navasota No. 2 Reservoir	Future Unit Millican Reservoir	Total	Initial Unit Navasota No. 2 Reservoir	Future Unit Millican Reservoir	Total	Initial Unit Navasota No. 2 Reservoir	Future Unit Millican Reservoir	Total	Initial Unit Navasota No. 2 Reservoir	Future Unit Millican Reservoir	Total
1. PERTINENT DATA															
Purpose, flood control (FC), water supply (WS), recreation and fish and wildlife enhancement (R)	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R	FC WS R
Elevations, feet msl															
Top of dam	335.0	263.0	-	341.0	260.0	-	348.0	256.0	-	354.0	250.0	-	356.0	249.0	-
Top of flood control pool	321.0	248.0	-	328.0	244.0	-	334.0	239.0	-	341.0	234.0	-	345.0	230.0	-
Top of water supply pool	301.0	244.0	-	312.5	239.5	-	321.0	234.0	-	330.0	228.0	-	335.5	223.0	-
Surface area, acres															
Top of flood control pool	36,340	94,600	-	42,600	86,100	-	48,600	76,000	-	58,180	66,000	-	66,000	58,800	-
Top of water supply pool	21,130	86,100	-	29,000	77,050	-	36,340	66,000	-	44,540	55,500	-	49,160	48,000	-
Total controlled storage, acre-feet	1,015,200	2,679,000	3,694,200	1,291,400	2,317,800	3,609,200	1,564,700	1,912,400	3,477,100	1,935,600	1,557,400	3,493,000	2,183,100	1,307,800	3,490,900
Flood control storage, acre-feet (100 years)	(546,200)	(358,300)	(904,500)	(543,200)	(364,100)	(907,300)	(541,100)	(351,300)	(892,400)	(550,700)	(359,600)	(910,300)	(539,500)	(366,500)	(906,000)
Water supply storage, acre-feet	(399,500)	(2,248,700)	(2,648,200)	(678,700)	(1,881,700)	(2,560,400)	(954,100)	(1,489,100)	(2,443,200)	(1,315,400)	(1,125,800)	(2,441,200)	(1,574,100)	(869,300)	(2,443,400)
Sediment storage, acre-feet	(69,500)	(72,000)	(141,500)	(69,500)	(72,000)	(141,500)	(69,500)	(72,000)	(141,500)	(69,500)	(72,000)	(141,500)	(69,500)	(72,000)	(141,500)
Dependable flow, water supply yield															
Second-feet (cfs)	200	270	470	232	238	470	265	205	470	300	175	475	325	150	475
Million gallons daily (mgd)	129.3	174.5	303.8	149.9	153.8	303.8	171.3	132.5	303.8	193.9	113.1	307.0	210.1	96.9	307.0
Assumed year of completion	1975	2000		1975	2005		1975	2008		1975	2010		1975	2011	
2. TOTAL FIRST COST OF PROJECT (Based on actual dollar expenditures):	49,660,000	75,130,000	124,790,000	55,037,000	68,470,000	123,507,000	60,605,000	61,260,000	121,865,000	69,167,000	55,440,000	124,607,000	75,355,000	51,550,000	126,905,000
Reservoir	(36,370,000)	(71,430,000)	(107,800,000)	(41,747,000)	(64,770,000)	(106,517,000)	(47,315,000)	(57,560,000)	(104,875,000)	(55,877,000)	(51,740,000)	(107,617,000)	(62,065,000)	(47,850,000)	(109,915,000)
Channel rectification	(8,400,000)	(-)	(8,400,000)	(8,400,000)	(-)	(8,400,000)	(8,400,000)	(-)	(8,400,000)	(8,400,000)	(-)	(8,400,000)	(8,400,000)	(-)	(8,400,000)
Recreation	(4,890,000)	(3,700,000)	(8,590,000)	(4,890,000)	(3,700,000)	(8,590,000)	(4,890,000)	(3,700,000)	(8,590,000)	(4,890,000)	(3,700,000)	(8,590,000)	(4,890,000)	(3,700,000)	(8,590,000)
3. TOTAL FIRST COST OF PROJECT (With future expenditures discounted to 1975 worth):	48,520,000	34,496,000	83,016,000	53,897,000	26,935,000	80,832,000	59,465,000	21,944,000	81,409,000	68,027,000	18,654,000	86,681,000	74,215,000	16,805,000	91,020,000
Reservoir	(36,370,000)	(33,094,000)	(69,464,000)	(41,747,000)	(25,733,000)	(67,480,000)	(47,315,000)	(20,848,000)	(68,163,000)	(55,877,000)	(17,623,000)	(73,500,000)	(62,065,000)	(15,805,000)	(77,870,000)
Channel rectification	(8,400,000)	(-)	(8,400,000)	(8,400,000)	(-)	(8,400,000)	(8,400,000)	(-)	(8,400,000)	(8,400,000)	(-)	(8,400,000)	(8,400,000)	(-)	(8,400,000)
Recreation	(3,750,000)	(1,402,000)	(5,152,000)	(3,750,000)	(1,202,000)	(4,952,000)	(3,750,000)	(1,096,000)	(4,846,000)	(3,750,000)	(1,031,000)	(4,781,000)	(3,750,000)	(1,000,000)	(4,750,000)
4. TOTAL ANNUAL CHARGES (Based on average annual equivalent values for the period 1975 to 2075):	2,086,400	1,382,900	3,469,300	2,290,800	1,076,700	3,367,500	2,491,200	885,800	3,377,000	2,849,800	760,600	3,610,400	3,081,900	681,800	3,763,700
Annual investment	1,763,400	1,288,900	3,052,300	1,958,800	992,700	2,951,500	2,151,200	808,800	2,960,000	2,502,800	687,600	3,190,400	2,730,900	611,800	3,342,700
Reservoir	(1,321,800)	(1,236,500)	(2,558,300)	(1,517,200)	(948,400)	(2,465,600)	(1,709,600)	(768,400)	(2,478,000)	(2,059,300)	(649,500)	(2,708,800)	(2,287,400	(575,400)	(2,862,800)
Channel rectification	(305,300)	(-)	(305,300)	(305,300)	(-)	(305,300)	(305,300)	(-)	(305,300)	(305,300)	(-)	(305,300)	(305,300)	(-)	(305,300)
Recreation	(136,300)	(52,400)	(188,700)	(136,300)	(44,300)	(180,600)	(136,300)	(40,400)	(176,700)	(138,200)	(38,100)	(176,300)	(138,200)	(36,400)	(174,600)
Annual maintenance and operation	323,000	94,000	417,000	332,000	84,000	416,000	340,000	77,000	417,000	347,000	73,000	420,000	351,000	70,000	421,000
Reservoir	(83,000)	(52,000)	(135,000)	(92,000)	(42,000)	(134,000)	(100,000)	(35,000)	(135,000)	(107,000)	(31,000)	(138,000)	(111,000)	(28,000)	(139,000)
Channel rectification	(62,000)	(-)	(62,000)	(62,000)	(-)	(62,000)	(62,000)	(-)	(62,000)	(62,000)	(-)	(62,000)	(62,000)	(-)	(62,000)
Recreation	(178,000)	(42,000)	(220,000)	(178,000)	(42,000)	(220,000)	(178,000)	(42,000)	(220,000)	(178,000)	(42,000)	(220,000)	(178,000)	(42,000)	(220,000)
5. TOTAL ANNUAL BENEFITS (Based on average annual equivalent values for the period 1975 to 2075)	5,013,300	3,611,400	8,624,700	5,160,900	3,410,400	8,571,300	5,361,100	3,171,400	8,532,500	5,608,400	2,915,700	8,524,100	5,761,500	2,749,400	8,510,900
Prevention of damages	2,036,400	835,500	2,871,900	2,054,000	764,500	2,818,500	2,064,200	715,500	2,779,700	2,071,500	682,800	2,754,300	2,074,600	666,500	2,741,100
Navasota River watershed	(166,400)	(-)	(166,400)	(184,000)	(-)	(184,000)	(194,200)	(-)	(194,200)	(201,500)	(-)	(201,500)	(204,600)	(-)	(204,600)
Brazos River Basin	(1,870,000)	(835,500)	(2,705,500)	(1,870,000)	(764,500)	(2,634,500)	(1,870,000)	(715,500)	(2,585,500)	(1,870,000)	(682,800)	(2,552,800)	(1,870,000)	(666,500)	(2,536,500)
Water conservation	760,000	1,193,000	1,953,000	890,000	1,063,000	1,953,000	1,080,000	873,000	1,953,000	1,320,000	650,000	1,970,000	1,470,000	500,000	1,970,000
Recreation and fish and wildlife enhancement	2,216,900	1,582,900	3,799,800	2,216,900	1,582,900	3,799,800	2,216,900	1,582,900	3,799,800	2,216,900	1,582,900	3,799,800	2,216,900	1,582,900	3,799,800
6. RATIO OF BENEFITS TO COSTS:	2.40	2.61	2.49	2.25	3.17	2.55	2.15	3.58	2.53	1.97	3.83	2.36	1.87	4.03	2.26
7. EXCESS BENEFITS OVER COSTS:															
FC, WS, and R	2,926,400	2,228,500	5,155,400	2,870,100	2,333,700	5,203,800	2,869,900	2,285,600	5,155,500	2,758,600	2,155,100	4,913,700	2,679,600	2,067,600	4,747,200
FC, or FC and WS	1,024,300	740,000	1,764,300	967,500	837,100	1,804,600	967,300	785,100	1,752,400	857,900	652,300	1,510,200	778,900	563,100	1,342,000



NOTE:
Dependable yields for the future unit is the increment needed to develop the total resources of about 470-480 C.F.S.

NAVASOTA RIVER WATERSHED
STAGE DEVELOPMENT PLANS
MAXIMIZATION OF EXCESS BENEFITS OVER COSTS
YIELD
VS.
EXCESS BENEFITS
FIGURE 3

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TABLE 3

PERTINENT DATA
SELECTED PLAN OF IMPROVEMENT
STAGE DEVELOPMENT
NAVASOTA RIVER WATERSHED

Item	First Stage: Millican Reservoir	Second Stage: Navasota No. 2 Reservoir	Second Stage: Millican Reservoir With Reallocated Storage
MISCELLANEOUS			
Dam location, river mile	24.1	83.4	24.1
Drainage area, square miles	2,120	1,341	2,120
Yield, cfs	300	300	175
Million gallons daily	193.9	193.9	113.1
SPILLWAY DESIGN FLOOD			
Peak inflow, cfs	466,300	420,800	762,500
Volume, acre-feet	2,523,600	1,725,200	2,558,500
Volume, inches	22.53	24.39	22.84
Peak outflow, cfs	302,900	290,000	371,800

RESERVOIR	First Stage Elev. (1) (feet)	Area (acres)	Capacity (acre-feet)	Capacity (inches)	Navasota No. 2 Elev. (1) (feet)	Area (acres)	Capacity (acre-feet)	Capacity (inches)	Millican Reallocated Elev. (1) (feet)	Area (acres)	Capacity (acre-feet)	Capacity (inches)
Sediment storage	-	-	92,400	0.82	-	-	69,500	0.97	-	-	72,000	0.64
Spillway crest	204.0	22,700	276,500	2.47	312.0	28,600	723,500	10.12	204.0	22,700	276,500	2.47
Top of conservation storage	219.0	42,400	754,400	6.74	330.0	44,540	1,378,600	19.28	228.0	55,500	1,193,500	10.66
Five-year pool	225.0	50,900	1,034,000	9.23	336.0	50,870	1,664,100	23.27	233.0	64,200	1,492,300	13.32
Top of flood control pool	234.0	66,000	1,557,400	13.91	341.0	58,180	1,935,600	27.06	234.0	66,000	1,557,400	13.91
Guide taking line	237.0	72,000	1,764,400	15.75	344.0	63,780	2,118,200	29.62	237.0	72,000	1,764,400	15.75
Maximum design water surface	237.9	73,800	1,830,000	16.34	346.4	69,440	2,277,600	31.85	242.6	83,300	2,199,100	19.63
Top of dam	250.0	-	-	-	354.0	-	-	-	250.0	-	-	-

Item	First Stage: Millican Reservoir	Second Stage: Navasota No. 2 Reservoir	Second Stage: Millican Reservoir With Reallocated Storage
STORAGE SUMMARY			
Water conservation, acre-feet	680,200	1,315,400	1,125,800
Flood control, acre-feet	784,800	550,700	359,600
Sediment, acre-feet	92,400	69,500	72,000
Total, acre-feet	1,557,400	1,935,600	1,557,400
DAM			
Type of dam	Concrete and earth fill	Concrete and earth fill	Concrete and earth fill
Total length, feet	25,300	16,100	25,300
Embankment section:			
Type	Compacted earth fill	Compacted earth fill	Compacted earth fill
Total length, feet	24,393	15,361	24,493
Height above streambed, feet	83	111	83
Freeboard, feet	12.1	7.6	7.4
Crown width, feet	30	30	30
Sides slopes:			
Upstream	1 on 3 and 1 on 3.5	1 on 2.5 and 1 on 3.5	1 on 3 and 1 on 3.5
Downstream	1 on 2.5 and 1 on 3	1 on 2.5 and 1 on 3	1 on 2.5 and 1 on 3
Non-overflow section			
Type	Concrete gravity	Concrete gravity	Concrete gravity
Total length, feet	335	315	335
Height above apron, feet	77	124	77
Top width, feet	16	16	16
Spillway section:			
Type	Concrete ogee	Concrete ogee	Concrete ogee
Gross length, feet	472	424	472
Net length, feet	400	360	400
Gates:			
Type	Tainter	Tainter	Tainter
Number	10	9	10
Size (width x height)	40'x 30'	40' x 29'	40' x 30'
Spillway discharge, cfs:			
Maximum design water surface	302,900	290,000	371,800
OUTLET WORKS			
Type	Gate-controlled sluices through spillway piers	Gate-controlled sluices through spillway piers	Gate-controlled sluices through spillway piers
Number of sluices	2	2	2
Dimensions (width x height)	2' x 4'	2' x 4'	2' x 4'
Invert elevations, feet (1)	180.0	256.0	180.0
Sluice control	2 - 2'x4' slide gates	2 - 2'x4' slide gates	2 - 2'x4' slide gates
RELOCATIONS			
Highways, miles	10.3	19.9	10.3
County roads, miles	9.4	0.7	9.4
Railroads, miles	None	7.5	None
Power lines, miles	33	35.5	33
Telephone lines, miles	10	12	10
Pipelines, miles	27.8	4.1	27.8
Cemetery Graves	5	None	5
Communities inundated	Piedmont and Peach Creek	None	Piedmont and Peach Creek
LANDS			
Dam and Reservoir:			
Clearing, acres	8,840	8,900	8,840
Land acquisition:			
Fee simple, acres	80,800	70,220	80,800
(Top control elevation)(1)	(237.0)	(344.0)	(237.0)
Flood easement, acres	3,000	3,780	3,000
Channel:			
Clearing, acres	260	315	260
Land acquisition:			
Fee simple, acres	260	315	260
Flood easement, acres	1,100	-	1,100
Recreation:			
Clearing, acres	22,200	17,800	22,200
Land acquisition:			
Fee simple, acres	1,820	1,300	1,820

(1) All elevations refer to mean sea level.

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TABLE 4

DETAILED ESTIMATES OF FIRST COST
SELECTED PLAN OF IMPROVEMENT
NAVASOTA RIVER WATERSHED

Item	Unit quantity	Unit cost	Millican Reservoir (1) Quantity	Millican Reservoir (1) Cost	Navasota No. 2 Reservoir (2) Quantity	Navasota No. 2 Reservoir (2) Cost
PERTINENT DATA						
Top of dam, elevation			250.0		354.0	
Top of gates, elevation			234.0		341.0	
Spillway crest, elevation			204.0		312.0	
Storage capacity (top of gates less sediment), acre-feet			1,465,000		1,866,100	
A. DETAILED ESTIMATE OF FIRST COST - DAM AND RESERVOIR						
(01.1) Lands and damages						
a. Land costs						
(1) Fee simple lands	Acre	-	80,800	$12,902,500	70,220	$10,397,450
(2) Flood easement lands	Acre	-	3,000	260,625	3,780	307,625
(3) Fee severance damage	L.S.	-	-	1,075,000	-	375,000
(4) Easement severance damage	L.S.	-	-	10,000	-	22,500
(5) Fee land improvements	L.S.	-	-	822,500	-	1,227,550
(6) Easement land improvements	L.S.	-	-	21,875	-	14,875
(7) Mineral value	L.S.	-	-	4,075,000	-	1,770,500
(8) Resettlement reimbursement	L.S.	-	-	68,000		115,000
Subtotal - land costs				19,235,500		14,230,500
Contingencies, 25% ±				4,804,500		3,559,500
Total - Land costs				24,040,000		17,790,000
b. Land acquisition expense				820,000		1,000,000
Total - Lands and damages				24,860,000		18,790,000
(02.0) Relocations						
a. Roads						
(1) State Highway 6	L.S.	-	-	1,007,000		
(2) F.M. Highway 30	L.S.	-	-	2,766,250		
(3) F.M. Highway 244	L.S.	-	-	948,200		
(4) County roads	L.S.	-	-	492,650		95,000
(5) State Highway 7	L.S.	-			-	1,804,000
(6) U.S. Highway 79	L.S.	-			-	2,746,000
(7) F.M. Highway 937	L.S.	-			-	58,860
(8) F.M. Highway 977	L.S.	-			-	976,400
(9) F.M. Highway 3	L.S.	-			-	614,100
(10) M.P. Railway	L.S.	-			-	3,350,000
(11) F.M. Highway 1940	L.S.	-			-	626,950
(12) F.M. Highway 2096	L.S.	-			-	249,300
Subtotal - roads				5,214,100		10,520,610
b. Cemeteries and utilities						
(1) Electric lines	Mi.	-	33	387,000	35.5	473,000
(2) Telephone lines	Mi.	$ 1,200.00	10	12,000	12	14,400
(3) Pipelines	Mi.	-	27.8	2,860,500	4.1	386,500
(4) Cemeteries	Graves	-	5	1,000		-
Subtotal - cemeteries and utilities				3,260,500		873,900
Subtotal - relocations				8,474,600		11,394,510
Contingencies, 25% ±				2,118,400		2,844,490
Total - Relocations				10,593,000		14,239,000
(03.0) Reservoirs						
a. Clearing	Acre	75.00	30,700	2,302,500	26,700	2,002,500
Contingencies, 20% ±				460,500		397,500
Total - Reservoirs				2,763,000		2,400,000
(04.0) Dams						
a. Earth embankment						
(1) Diversion and care of water	L.S.	-	-	30,000	-	30,000
(2) Clearing and grubbing	Acre	250.00	98	24,500	152	38,000
(3) Excavation, stripping	C.Y.	0.30	139,800	41,900	232,600	69,800
(4) Excavation, common	C.Y.	0.30	460,400	138,100	429,400	128,800
(5) Excavation, borrow	C.Y.	0.25	1,180,000	295,000	7,775,000	1,943,800
(6) Compacted fill	C.Y.	0.08	3,312,000	265,000	9,218,000	737,400
(7) Drainage blanket	C.Y.	5.00	171,600	858,000	430,000	2,150,000
(8) Riprap	C.Y.	6.50	106,400	691,600	113,200	735,800
(9) Bedding	C.Y.	5.50	39,900	219,500	42,500	233,800
(10) Flexible base	C.Y.	8.00	9,600	76,800	6,500	52,000
(11) Timber guide posts	Each	5.00	1,970	9,900	1,330	6,600
(12) Slope protection, sodding	Acre	600.00	34	20,400	37	40,200
(13) Asphalt treatment	Gal.	0.20	27,900	5,600	18,800	3,800
(14) Aggregate	C.Y.	10.00	530	5,300	350	3,500
(15) Cofferdam (borrow or waste)	L.S.	-	-	5,400	-	9,300
Subtotal - earth embankment				2,687,000		6,182,800
b. Concrete dam and spillway (gated)						
(1) Care of water during construction	L.S.	-	-	140,000	-	140,000
(2) Clearing	Acre	-	46	5,750	70	10,500
(3) Excavation, common	C.Y.	0.40	3,111,000	1,244,400	2,978,000	1,191,200
(4) Backfill, structural	C.Y.	1.00	38,500	38,500	76,300	76,300
(5) Concrete, weir	C.Y.	25.00	16,260	406,500	39,180	979,500
(6) Concrete, non-overflow	C.Y.	24.00	21,140	507,360	17,270	414,500
(7) Concrete, piers	C.Y.	25.00	9,370	234,500	9,010	225,300
(8) Concrete, slab	C.Y.	23.00	8,280	190,440	16,880	388,200
(9) Concrete, wall	C.Y.	35.00	4,380	153,300	8,660	303,100
(10) Concrete, bridge deck	C.Y.	90.00	170	15,300	125	11,300
(11) Cement	Bbl.	5.00	74,500	372,500	113,900	569,500
(12) Steel, reinforcing	Lb.	0.12	3,120,000	374,400	4,716,000	565,900
(13) Steel, structural	Lb.	0.30	131,800	39,000	112,300	33,700
(14) Pipe railing	Lb.	1.50	6,690	10,035	5,840	8,800
(15) Pipe railing, bridge	Lb.	1.50	8,870	13,305	8,280	12,400
(16) Metals, miscellaneous	Lb.	0.50	16,700	8,350	15,000	7,500
(17) Ladders, gratings, and grills	Lb.	0.40	13,300	5,320	12,000	4,800
(18) Walkways	Lb.	0.50	8,800	4,400	39,600	19,800
(19) Water stops, copper	Lb.	1.75	1,530	2,678	1,590	2,800
(20) Water gates, tile	L.F.	14.00	100	1,400	123	1,700
(21) Tainter gates	Lb.	0.26	853,000	221,780	742,500	193,100
(22) Tainter gate hoist, shaft, and hangers	Lb.	1.00	205,000	205,000	180,000	180,000
(23) Trunion anchorages and seals	Lb.	0.30	258,900	77,670	226,100	67,800
(24) Sluice gates and operating equipment	L.S.	-	-	20,000	-	16,000
(25) Trash racks and guides	Lb.	0.40	11,400	4,560	17,160	6,900
(26) Emergency bulkheads	Lb.	0.30	124,200	37,260	103,800	31,100
(27) Precast bridge girders	Each	800.00	30	24,000	27	21,600
(28) Crane	L.S.	-	-	45,000	-	45,000
(29) Electrical facilities	L.S.	-	-	35,000	-	35,000
(30) Standby power unit	L.S.			7,000	-	7,000
(31) Riprap	C.Y.	6.50	8,010	52,065	6,580	42,800
(32) Bedding	C.Y.	5.50	2,850	15,675	2,270	12,500
(33) Slope protection, sodding	Acre	600.00	8	4,800	13	7,800
(34) Piling, sheet	Lb.	0.12	1,164,000	139,680	1,070,000	128,400
(35) Piling, bearing	Lb.	0.12	7,119,000	854,280	8,970,000	1,076,400
Subtotal - concrete dam and spillway				5,511,208		6,838,200
Subtotal - dams				8,198,208		13,021,000
Contingencies, 20% ±				1,639,792		2,604,000
Total - Dams				9,838,000		15,625,000
(08.0) Access road	L.S.			14,200		32,600
Contingencies, 20% ±				2,800		6,400
Total - Access road				17,000		39,000
(19.0) Buildings, grounds, and utilities						
(1) Maintenance facilities	L.S.			100,000		100,000
(2) Water supply	L.S.			30,000		30,000
(3) Power line and substation	L.S.			56,000		64,000
(4) Visitor overlook facilities	L.S.			20,000		20,000
Subtotal - buildings, grounds, and utilities				206,000		214,000
Contingencies, 20% ±				40,000		43,000
Total - Buildings, grounds, and utilities				246,000		257,000
(20.0) Permanent operating equipment						
(1) Radio - telephone equipment	L.S.			4,000		4,000
(2) Boat	L.S.			8,000		8,000
(3) Miscellaneous furniture and equipment	L.S.			10,000		10,000
(4) Stream gages	L.S.			15,000		15,000
(5) Evaporation and rain gages	L.S.			1,000		1,000
(6) Sediment and degradation ranges	L.S.			68,000		68,000
Subtotal - operating equipment				106,000		106,000
Contingencies, 20% ±				21,000		21,000
Total - Operating equipment				127,000		127,000
(30.0) Engineering and Design				1,769,000		2,300,000
(31.0) Supervision and Administration				1,527,000		2,100,000
Subtotal - estimated first cost - dam and reservoir				51,740,000		55,877,000
B. ESTIMATES OF FIRST COST - CHANNEL RECTIFICATION						
(01.0) Lands and damages						
a. Land costs						
(1) Fee simple lands, improvements and severances	Acre	-	260	70,000	315	85,000
(2) Flood easement lands, improvements and severances	Acre	-	1,100	220,000	-	-
Subtotal - land costs				290,000		85,000
Contingencies, 25% ±				73,000		21,000
Total - Land costs				363,000		106,000
b. Land acquisition expense				190,000		48,000
Total - Lands and damages				553,000		154,000
(02.0) Relocations						
a. T. & N. O. Railway	L.S.			25,000		
b. State Highway 6	L.S.			43,200		
c. State Highway 21	L.S.					5,000
d. O.S.R. Highway	L.S.					40,000
e. County road	L.S.					20,000
f. Pipelines	L.S.			85,000		40,000
Subtotal - relocations				153,200		105,000
Contingencies, 25% ±				38,800		25,000
Total - Relocations				192,000		130,000
(09.0) Channel						
a. Clearing	Acre	250.00	260	65,000	280	70,000
b. Excavation, common	C.Y.	0.30	2,244,000	673,000	2,867,000	860,000
Subtotal - channel				738,000		930,000
Contingencies, 20% ±				148,000		186,000
Total - Channel				886,000		1,116,000
(30.0) Engineering and Design				100,000		150,000
(31.0) Supervision and Administration				89,000		110,000
Subtotal - estimated first cost - channel rectification				1,820,000		1,660,000
TOTAL ESTIMATED FIRST COST OF FLOOD CONTROL AND WATER SUPPLY				53,560,000		57,537,000
C. ESTIMATE OF FIRST COST - RECREATION AND FISH AND WILDLIFE						
(01.0) Lands and damages						
a. Land costs above general taking limits						
(1) Fee simple lands, improvements and severances	Acre	-	1,820	419,000	1,300	260,000
Contingencies, 25% ±				105,000		65,000
Total - Land costs				524,000		325,000
b. Acquisition expense	L.S.	-	-	18,000	-	13,000
Total - Lands and damages				542,000		338,000
(08.0) Access roads	Mile	35,000.00	6	210,000	4	140,000
Contingencies, 20% ±				42,000		28,000
Total - Access roads				252,000		168,000
(14.0) Facilities						
(1) Initial for first three years	L.S.	-	-	1,313,000	-	917,000
(2) Future development after three years	L.S.	-	-	1,750,000	-	1,271,000
Subtotal - Facilities				3,063,000		2,188,000
Contingencies, 20% ±				613,000		438,000
Total - Facilities				3,676,000		2,626,000
(30.0) Engineering and design				315,000		224,000
(31.0) Supervision and administration				275,000		194,000
Subtotal - estimated Federal first cost - recreation and fish and wildlife				5,060,000		3,550,000
Subtotal - estimated Federal first cost - recreation and fish and wildlife (with future facilities discounted)				(3,920,000)		(2,876,000)
D. TOTAL ESTIMATED PROJECT FIRST COST				$58,620,000		$61,087,000
TOTAL ESTIMATED PROJECT FIRST COST (with future recreation and fish and wildlife facilities discounted)				($57,480,000)		($60,413,000)

(1) Initial unit
(2) Future unit

TABLE 5

DETAILED ESTIMATE OF RELOCATION COSTS
MILLICAN RESERVOIR (1)
NAVASOTA RIVER WATERSHED

Item	Item Quantity	Unit Cost	Quantity	Cost
A. DETAILED ESTIMATE OF FIRST COST - DAM AND RESERVOIR RELOCATIONS				
a. Roads				
(1) State Highway 6				
(a) Embankment	C.Y.	$ 0.55	240,000	$ 132,000
(b) Foundation and surfacing	Mi.	30,000.00	1.0	30,000
(c) Riprap	C.Y.	8.00	21,000	168,000
(d) Bedding	C.Y.	6.00	8,000	48,000
(e) Guardrail	L.F.	2.50	8,800	22,000
(f) Bridge	L.F.	250.00	1,700	425,000
(g) Extend drainage structures	L.S.	-	-	2,500
(h) New road	Mi.	60,000.00	3.0	180,000
Total - State Highway 6				1,007,000
(2) State Highway 30				
(a) Embankment	C.Y.	0.55	315,000	173,250
(b) Foundation and surfacing	Mi.	30,000.00	1.2	36,000
(c) Bridge	L.F.	250.00	9,100	2,275,000
(d) Riprap	C.Y.	8.00	25,000	200,000
(e) Bedding	C.Y.	6.00	9,500	57,000
(f) Guardrail	L.F.	2.50	10,000	25,000
Total - State Highway 30				2,766,250
(3) F.M. Highway 244				
(a) Embankment	C.Y.	0.55	380,000	209,000
(b) Foundation and surfacing	Mi.	16,000.00	1.2	19,200
(c) Bridge	L.F.	200.00	1,000	200,000
(d) Riprap	C.Y.	8.00	30,000	240,000
(e) Bedding	C.Y.	6.00	10,000	60,000
(f) Guardrail	L.F.	2.50	10,000	250,000
(g) New road	Mi.	50,000.00	3.9	195,000
Total - F.M. Highway 244				948,200
(4) U.S. Highway 190 slope protection				
(a) Slope preparation		1.00	-	-
(b) Riprap	C.Y.	8.00	-	-
(c) Bedding	C.Y.	6.00	-	-
Total - U.S. Highway 190 slope protection				-
(5) County roads				
(a) Embankment	C.Y.	0.55	40,000	22,000
(b) Foundation and surfacing	Mi.	16,000.00	0.9	14,400
(c) Bridge	L.F.	175.00	50	8,750
(d) Riprap	C.Y.	8.00	3,000	24,000
(e) Bedding	C.Y.	6.00	1,000	6,000
(f) Guardrail	L.F.	2.50	3,000	7,500
(g) Minor drainage structures	L.S.	-	-	2,000
(h) New road	Mi.	48,000.00	8.5	408,000
Total - County roads				492,650
b. Cemeteries and Utilities				
(1) Electric lines				
(a) Brazos Electric Cooperative - 69 KV	Mi.	20,000.00	18	360,000
(b) Distribution lines	Mi.	1,800.00	15	27,000
Total - Electric lines				387,000
(2) Telephone lines	Mi	1,200.00	10	12,000
(3) Cemeteries	Graves	200.00	5	1,000
(4) Pipelines				
(a) Humble Company 7 - 8"	Mi.	125,000	15.2	1,900,000
(b) Magnolia 12"	Mi.	80,000	8.3	664,000
(c) Sinclair 10"	Mi.	70,000	0.2	14,000
(d) Atlantic 10"	Mi.	70,000	3.8	266,000
(e) Lone Star Gas 8"	Mi.	55,000	0.3	16,500
Total - Pipelines				2,860,500
Subtotal				8,474,600
Contingencies, 25% ±				2,118,400
TOTAL - RELOCATIONS				10,593,000

(1) Initial unit

TABLE 6

DETAILED ESTIMATE OF RELOCATION COSTS
NAVASOTA NO. 2 RESERVOIR (1)
NAVASOTA RIVER WATERSHED

Item	Item Quantity	Unit Cost	Quantity	Cost
A. DETAILED ESTIMATE OF FIRST COST - DAM AND RESERVOIR RELOCATIONS				
a. Roads				
(1) U.S. Highway 79				
(a) Embankment	C.Y.	$ 0.55	1,000,000	$ 550,000
(b) Foundation and surfacing	Mi.	30,000.00	2.7	81,000
(c) Bridge	L.F.	250.00	5,000	1,250,000
(d) Riprap	C.Y.	8.00	50,000	400,000
(e) Bedding	C.Y.	6.00	20,000	120,000
(f) Guardrail	L.F.	2.50	26,000	65,000
(g) New road	Mi.	70,000.00	4.0	280,000
Total - U.S. Highway 79				2,746,000
(2) State Highway 7				
(a) Embankment	C.Y.	0.55	1,000,000	605,000
(b) Foundation and surfacing	Mi.	30,000.00	3	90,000
(c) Bridge	L.F.	250.00	2,250	562,500
(d) Riprap	C.Y.	8.00	47,000	376,000
(e) Bedding	C.Y.	6.00	18,000	108,000
(f) Guardrail	L.F.	2.50	25,000	62,500
(g) Culverts	L.S.	-	-	-
Total - State Highway 7				1,804,000
(3) F.M. Highway 937				
(a) Embankment	C.Y.	0.55	27,000	14,850
(b) Foundation and surfacing	Mi.	22,000.00	1.33	29,260
(c) Riprap	C.Y.	8.00	1,200	9,600
(d) Bedding	C.Y.	6.00	400	2,400
(e) Guardrail	L.F.	2.50	700	1,750
(f) Culverts	L.S.	-		1,000
Total - F.M. Highway 937				58,860
(4) F.M. Highway 977				
(a) Embankment	C.Y.	0.55	416,000	228,800
(b) Foundation and surfacing	Mi.	22,000.00	1.3	28,600
(c) Bridge	L.F.	200.00	1,700	340,000
(d) Riprap	C.Y.	8.00	29,000	232,000
(e) Bedding	C.Y.	6.00	11,000	66,000
(f) Guardrail	L.F.	2.50	10,000	25,000
(g) Culverts	L.S.	-	-	31,000
(h) New road	Mi.	50,000.00	0.5	25,000
Total - F.M. Highway 977				976,400
(5) F.M. Highway 3				
(a) Embankment	C.Y.	0.55	270,000	148,500
(b) Foundation and surfacing	Mi.	22,000.00	0.8	17,600
(c) Bridge	L.F.	200.00	400	80,000
(d) Culverts	L.S.	-	-	30,000
(e) Riprap	C.Y.	8.00	17,000	136,000
(f) Bedding	C.Y.	6.00	7,000	42,000
(g) Guardrail	L.F.	2.50	8,000	20,000
(h) New road	Mi.	50,000.00	2.8	140,000
Total - F.M. Highway 3				614,100
(6) F.M. Highway 2096				
(a) Embankment	C.Y.	0.55	150,000	82,500
(b) Foundation and surfacing	Mi.	22,000.00	0.4	8,800
(c) Riprap	C.Y.	8.00	3,000	24,000
(d) Bedding	C.Y.	6.00	1,500	9,000
(e) Bridge	L.F.	200.00	300	60,000
(f) Guardrail	L.F.	2.50	4,000	10,000
(g) New road	Mi.	50,000.00	1.1	55,000
Total - F.M. Highway 2096				249,300
(7) F.M. Highway 1940				
(a) Embankment	C.Y.	0.55	275,000	151,250
(b) Foundation and surfacing	Mi.	22,000.00	0.6	13,200
(c) Riprap	C.Y.	8.00	15,000	120,000
(d) Bedding	C.Y.	6.00	5,000	30,000
(e) Bridge	L.F.	200.00	1,100	220,000
(f) Culverts	L.S.	-	-	-
(g) Guardrail	L.F.	2.50	9,000	22,500
(h) New road	Mi.	50,000.00	1.4	70,000
Total - F.M. Highway 1940				626,950
(8) County roads				
(a) Embankment	C.Y.	0.55	50,000	27,500
(b) Foundation and surfacing	Mi.	20,000.00	0.7	14,000
(c) Bridge	L.F.	175.00	100	17,500
(d) Riprap	C.Y.	8.00	2,000	16,000
(e) Bedding	C.Y.	6.00	1,000	6,000
(f) Guardrail	L.F.	2.50	4,000	10,000
(g) Culverts	L.S.	-	-	4,000
Total - County roads				95,000
(9) Missouri Pacific Railway				
(a) Embankment	C.Y.	0.55	1,640,000	902,000
(b) Ballast and trackwork	Mi.	90,000.00	2.9	261,000
(c) Bridge	L.F.	350.00	1,600	560,000
(d) Culverts	L.S.	-	-	11,000
(e) Riprap	C.Y.	8.00	101,000	808,000
(f) Bedding	C.Y.	6.00	35,000	210,000
(g) New railway	Mi.	130,000.00	4.6	598,000
Total - Missouri Pacific Railway				3,350,000
b. Utilities				
(1) Electric lines				
(a) T.P. & L. 138 KV (Waco to Jewett)	Mi.	22,000.00	2	44,000
(b) T.P. & L. 138 KV (Minerva to Jewett)	Mi.	22,000.00	18	396,000
(c) Gulf State Utilities 33 KV	Mi.	8,000.00	1.5	12,000
(d) R.E.A. Distribution Lines	Mi.	1,500.00	14	21,000
Total - Electric lines				473,000
(2) Telephone lines	Mi.	1,200.00	12	14,400
(3) Pipelines				
(a) Sun-Stanolind 8" and 10"	Mi.	105,000.00	3.3	346,500
(b) Bi-Stone Fuel Co. 8" gas	Mi.	50,000.00	0.8	40,000
Total - Pipelines				386,500
Subtotal				11,394,510
Contingencies, 25% ±				2,844,490
TOTAL - RELOCATIONS				14,239,000

(1) Future unit

TABLE 7

DETAILED ESTIMATES OF ANNUAL CHARGES
SELECTED PLAN OF IMPROVEMENT
NAVASOTA RIVER WATERSHED
(In thousand dollars)

	Millican Reservoir	Navasota No. 2 Reservoir
(Construction period - 8 years)(Amortization period 100 years)(Interest rate 3-1/8%)		
RESERVOIR		
A. INVESTMENT COST		
a. First cost	51,740.0	55,877.0
b. Interest during construction	6,468.0	6,984.0
Total investment - reservoir	58,208.0	62,861.0
B. ANNUAL CHARGES		
a. Interest on investment	1,819.0	1,964.6
b. Amortization on investment	87.9	94.9
c. Maintenance and operation (Includes replacement of parts)	100.0	107.0
Total annual charges - reservoir	2,006.9	2,166.3
CHANNEL		
A. INVESTMENT COST		
a. First cost	1,820.0	1,660.0
b. Interest during construction	228.0	208.0
Total investment - channel	2,048.0	1,868.0
B. ANNUAL CHARGES		
a. Interest on investment	64.0	58.4
b. Amortization on investment	3.1	2.8
c. Maintenance and operation	8.0	14.0
Total annual charges - channel	75.1	75.2
RECREATION		
A. INVESTMENT COST		
a. First cost	3,950.0	2,876.0
b. Interest during construction	490.0	360.0
Total investment - recreation	4,410.0	3,236.0
B. ANNUAL CHARGES		
a. Interest on investment	137.8	101.1
b. Amortization on investment	6.7	4.9
c. Maintenance and operation (Includes replacement of parts)	178.0	136.7
Total annual charges - recreation	322.5	242.7
TOTAL PROJECT ANNUAL CHARGES	2,404.5	2,484.2 (1)

(1) Based on year 2010

300 cfs. The reservoir would eliminate more than 40 percent of the residual average annual damages in the reaches below the dam site when considered as the last-constructed project of the Brazos River reservoir system. The authorized Ferguson Reservoir was considered an important element of the authorized reservoir system, designed to provide substantial flood protection to the lower Brazos River Basin. However, Millican Reservoir would adequately replace Ferguson Reservoir in this system, particularly since it would afford a higher degree of control of Navasota River floods than would Ferguson Reservoir. The dependable water supply yield would assist in providing the water supply needs of the study area until about 2010.

25. The selected plan of improvement provides for development of approximately the total water supply resources of the watershed by the addition of Navasota No. 2 Reservoir at the time additional water supply is needed, probably about year 2010. Navasota No. 2 Reservoir would provide an incremental dependable water supply yield of about 175 cfs. The projected needs and available resources indicate that the study area will become a water-deficient area about 2028 even with full development of the Navasota River watershed resources. The selected plan involves reallocation of the storage in Millican Reservoir at the time the Navasota No. 2 Reservoir project is constructed, as shown in table 3, in order to develop the total water supply resources. The transfer of flood storage upstream to the Navasota No. 2 site makes available additional water supply storage in the Millican site, thus allowing full development of the water supply resources from the incremental drainage area between the Millican and Navasota No. 2 Dams. With the Millican Reservoir project in operation, flood-control storage to afford protection to the incremental area between the Navasota No. 2 and Millican Dam sites could not be justified; however, through the reallocation of storage in the reservoir system it was possible to afford flood protection to this reach of the Navasota River. The flood protection provided to the flood-plain reaches below Millican Dam would not be changed.

26. The selected plan of improvement would greatly increase the water-oriented recreation and fish and wildlife opportunities in the lower Brazos River Basin. The reservoirs would inundate some wildlife habitat; however, comparison of the alternatives for providing for the overall water resource needs shows that the hunting losses are about the same for each of the plans. For example, the Bureau of Sport Fisheries and Wildlife report shows that the large Millican Reservoir, stage-development Plan II, and stage-development Plan VIII would result in hunting losses in man-days annually of 26,400; 26,100; and 28,400, respectively.

27. Although the selected plan has been justified entirely by monetary benefits, the projects would also provide important intangible benefits to the area and to the State. The flood control effects of the reservoirs would reduce the threat to lives and further stabilize the economy of the area subject to flooding downstream from the projects. The recreation and fish and wildlife enhancement aspects of the projects would improve the social well being of a large segment of the population within the study area. The water supply features would stimulate the general economy of the area. The intangible benefits of the selected plan are considered significant and would add materially to the justification of the plan.

28. The flexibility and adaptability of the selected plan of improvement is indicated by the fact that the initial unit of the plan (Millican Reservoir) would still be the optimum economical development of the resources of the watershed in case the need for the additional water supply to be provided by the future unit (Navasota No. 2 Reservoir) does not develop because of technological advances or other developments. The Millican Reservoir project included in the selected plan is the size project found to be the optimum economical development of a single reservoir in the analyses presented in table 1 and on figure 2. The selected plan of improvement was found to be fully responsive to the objectives, formulation concepts, and basic consideration outlined at the beginning of this appendix, including the request of the State of Texas.

29. After the plan of improvement had been formulated and scaled, consideration was given to the area redevelopment effects of the investigated plans. The evaluation of area redevelopment benefits is discussed in appendix III. The average annual equivalent area redevelopment benefits for using unemployed persons from the ARA counties in the area as part of the on-site construction and operation and maintenance were estimated at $85,800 if Millican Reservoir were the first project constructed and $104,300 if Navasota No. 2 Reservoir were the first project constructed. The additional benefits to be gained by starting with Navasota No. 2 Reservoir as the initial unit are very minor when compared to the excess benefit-advantage of the selected plan over the best plan with Navasota No. 2 Reservoir as the first unit and would not justify modifying the selected plan of improvement.

30. FOUNDATION CONDITIONS - MILLICAN DAM.- The Millican Dam site is situated within the outcrop of the Catahoula formation of Oligocene age. Catahoula strata consist of clays, uncemented sands, variably cemented sandstones, and silts and siltstones. The Catahoula clays are tuffaceous and sandy and the sands, which range from fine to medium grained, are also tuffaceous and contain tuff beds. The sandstone layers are frequently quartizitic and

conglomeritic. Eight core borings were drilled at the dam site, all of which penetrated Catahoula strata. These borings revealed that the Catahoula is covered by a relatively thin residual mantel on the abutments about 5 to 10 feet in thickness, and that alluvium in the river valley ranges from 15 to 30 feet in thickness. The regional dip of Catahoula strata is to the southeast, and its thickness in the site area is about 350 feet.

31. Faulting exists in the general area of the dam site. This structure has a northeast-southwest strike and displacement of about 200 feet with downthrow to the northwest. The fault zone, where observed in limited surface outcrops, appears to be tight and free of a gouge or brecciated zone. The faulting, which is described in Research Report No. 14, May 1950, "Geology of Brazos County, Texas," Texas Engineering Experiment Station, has been considered with respect to its influence on the proposed project. It is believed that the faults will have no adverse effect on the project.

32. It can be anticipated that some seepage will take place through alluvial strata in the flood plain and on the abutment slopes and through sandy primary strata in the abutments. The seepage can be minimized or relieved by blanketing, cutoff trench, or relief wells to the extent that there would be no material reduction in the estimated dependable water supply yield in the proposed project. The total estimated cost of the proposed project is sufficient to cover the cost of any remedial work for seepage control at the proposed dam site.

33. FOUNDATION CONDITIONS - NAVASOTA NO. 2 DAM.- The dam site and reservoir will be located on beds of Eocene Age, ranging from middle Claiborne Group at the dam site to middle Wilcox Group in the upper reaches of the reservoir. These beds are generally terrestial or near shore marine deposits, are poorly consolidated, and are basically sands, sandy clays and clay-shales. Some of the sands are well indurated locally, and subsequently cause the cuesta-like outcrops. Four core borings were made at the dam site, all of which penetrated bedrock to varying depths. The entire site is covered with alluvial and residual overburden. The alluvium on the valley floor ranges from 20 to 30 feet in depth and the terrace alluvium and residium on the abutments range from 5 to 15 feet in depth. Pervious sands and gravels are included in the valley alluviums. The bedrock at the dam site is a series of sands, sandy clays, clay shales, and carbonaceous clays of the Claiborne Group, probably Stone City and/or Sparta formations. The highest points on the abutments may represent near outcrop of the Crockett formation.

34. The dam site and reservoir are located about twenty miles east of the Luling-Mexia-Talco Fault System, but as of this date faulting has not been encountered at the site. However, more detailed investigation may encounter minor structural disturbances inasmuch as the material types comprising the local bedrock are conducive to differential compaction and surface shifting. The only known structural anomaly in the area is the Marquez Salt Dome, located in the upper end of the reservoir. Faulting and increased bedding dips are likely to be present in that area, but will not affect the foundation at the dam site.

35. No data are available as to the permeability of the overburden. It is assumed, however, that an impervious cutoff will be required to preclude seepage through the valley sands and gravels. Core boring logs indicate that the bedrock is relatively impervious.

36. AVAILABILITY OF MATERIALS.- Borrow materials for Millican and Navasota No. 2 Dams should be readily available both up and downstream from the dam sites. Swampy conditions on the valley floor may necessitate borrowing from the abutments. Embankment sections including a compacted impervious core and compacted random sandy shells has been developed to conform with the anticipated distribution of borrow soil.

37. Other construction materials of acceptable quality and in ample quantities for the Millican and Navasota No. 2 Dams are available within an economical haul distance of the project site. Stone quarries which can produce coarse aggregate for concrete and riprap are located near Palestine and Georgetown, Texas. Acceptable stone deposits occur in the Mexia area; however, there are no commercial quarries producing from these deposits at present. Sources which are producing natural sand and gravel that would be acceptable for use as concrete aggregates, bedding and drainage blanket materials are located in Texas near Belton, Columbus, Eagle Lake, Hearne, LaGrange, Romayor, Urbana, and Waco. Materials for the drainage blankets can be obtained at the dam sites. Local sources probably could not economically produce concrete aggregate.

38. COST ALLOCATION AND APPORTIONMENT.- Cost allocation studies were made to determine the equitable distribution of the costs to the various purposes of the selected plan of improvement (Plan II), as well as various other alternate plans (Plans V and VI) for comparison purposes. The cost allocation studies were made on the basis of the Separable Costs-Remaining Benefits method. This method involves studies of single-purpose and multiple-purpose reservoirs as instruments in the allocation procedures. The detailed cost allocation of construction, investment, and annual operation and maintenance

costs of the selected plan of improvement to the purposes of flood control, water supply, and recreation and fish and wildlife enhancement are presented in table 8.

39. Alternatives were considered for furnishing the dependable water supply yield included in the selected plan of improvement. After evaluating these alternatives in view of the quantity and location of the water requirements, the most efficient method among the feasible alternatives was determined to be a stage-development plan of water supply reservoirs on the Navasota River. The cost of the cheapest plan to develop the yield was used as the alternative cost for water supply. A single-purpose flood control reservoir at the project site was used as the flood control alternative for the Millican Reservoir. The flood control benefits creditable to Navasota No. 2 Reservoir are an incidental effect of the reallocation of storages for total development of the water supply resources as explained in paragraph 25. A flood-control channel within the reach between Millican Reservoir and Navasota No. 2 Dam was used as the cheapest alternative for the incremental flood-control benefits provided by the future Navasota No. 2 Reservoir. The cheapest alternative for recreation and fish and wildlife enhancement purposes was determined to be a single reservoir for recreation only that would develop the total potential of the stage-development plan. The cost of this project was prorated to Millican and Navasota No. 2 Reservoirs on the basis of their respective estimated visitation or annual benefits.

40. The construction cost and the annual maintenance and operation cost of the selected plan of improvement (Plan II) was apportioned to Federal and non-Federal interests in accordance with existing laws, policies, and procedures. A cost allocation and apportionment summary for Plans II, V, and VI is presented in table 9.

41. The costs allocated to flood control are apportioned to the Federal Government in accordance with the general policy established in the Flood Control Act of 1936, Public Law 738, 74th Congress, as amended. The apportionments are made to the Federal Government because of the widespread and general nature of the benefits associated with the flood control effects of the reservoir project.

42. The costs allocated to water supply are apportioned to non-Federal interests in accordance with the provisions of the Water Supply Act of 1958, Public Law 580, 85th Congress, as amended.

43. The costs allocated to recreation and fish and wildlife enhancement are apportioned to Federal and non-Federal interests in accordance with Public Law 89-72 (S. 1229; HR 5269), approved July 9, 1965, cited as the Federal Water Project Recreation Act.

TABLE 8

ALLOCATION OF COSTS
(SEPARABLE COSTS-REMAINING BENEFITS METHOD)
SELECTED PLAN OF STAGE DEVELOPMENT (PLAN II)
OPTIMUM DEVELOPMENT OF RECREATION AND FISH AND WILDLIFE ENHANCEMENT

Item	MILLICAN RESERVOIR AS THE INITIAL UNIT						
	Single-purpose			Multiple-purpose	Dual-purpose		
	FC	WS	R		FC-WS	FC-R	WS-R
PERTINENT INFORMATION							
First cost, dollars	34,600,000	80,650,000	29,236,000	57,480,000	53,560,000	51,790,000	40,400,000
Investment costs, dollars	37,844,000	92,330,000	31,590,000	64,666,000	60,256,000	57,455,000	44,819,000
Annual charges, dollars	1,327,700(1)	3,179,700(2)	1,410,900(3)	2,404,500	2,082,000	2,163,200	1,716,300
Annual maintenance and operation, dollars	88,000	155,000	376,000	286,000	108,000	281,000	248,000
Dependable yield, second-feet	-	470.0	-	300.0	300.0	-	300.0
Dependable yield, million gallons daily	-	303.8	-	193.9	193.9	-	193.9
Dependable yield, thousand gallons annually	-	110,875,681	-	70,771,700	70,771,700	-	70,771,700
Total annual benefits, dollars	3,111,500	3,565,800	3,799,800	6,648,400	4,431,500	5,328,400	3,536,900
Flood control storage, acre-feet	795,500	-	-	784,800	784,800	784,800	-
Water supply storage, acre-feet	-	2,682,100	496,000	680,200	680,200	430,600	705,100
Sediment storage, acre-feet	92,400	111,500	69,500	92,400	92,400	92,400	92,400
Total storage, acre-feet	887,900	2,793,600	565,500	1,557,400	1,557,400	1,307,800	797,500
COST ALLOCATIONS							
Allocation of annual charges, dollars							
1. Benefits	3,111,500	1,320,000	2,216,900	6,648,400			
2. Alternate cost	1,327,100(1)	1,114,600(2)	823,000(3)	-			
3. Benefits limited by alternate cost	1,327,100	1,114,600	823,000	-			
4. Separable costs	688,200	241,300	322,500	1,252,000			
5. Remaining benefits	638,900	873,300	500,500	2,012,700			
6. Percent distribution of item 5	31.74	43.39	24.87	100.00			
7. Allocated joint cost	365,800	500,100	286,600	1,152,500			
8. Total allocation	1,054,000	741,400	609,100	2,404,500			
9. Percent distribution of item 8	43.84	30.83	25.33	100.00			
Allocation of operation and maintenance costs, dollars							
10. Separable costs	38,000	5,000	178,000	221,000			
11. Percent joint costs of item 6	31.74	43.39	24.87	100.00			
12. Allocated joint costs	20,600	28,200	16,200	65,000			
13. Total allocation	58,600	33,200	194,200	286,000			
14. Percent distribution of item 13	20.49	11.61	67.90	100.00			
Allocation of initial investment, dollars							
15. Allocated annual charges	1,054,000	741,400	609,100	2,404,500			
16. Allocated operation and maintenance costs	58,600	33,200	194,200	286,000			
17. Remainder	995,400	708,200	414,900	2,118,500			
18. Percent distribution of item 17	46.99	33.43	19.58	100.00			
19. Allocated investment	30,386,600	21,617,800	12,661,600	64,666,000			
20. Allocated first costs	27,009,900	19,215,500	11,254,600	57,480,000			
21. Discounted first cost increment of future recreation facilities	-	-	1,140,000	1,140,000			
22. Total allocated first cost	27,009,900	19,215,500	12,394,600	58,620,000			
Ratio of annual benefits to allocated annual charges	2.95	1.78	3.64	2.76			
Allocated unit construction cost (cost/acre-feet exclusive of operation and maintenance), dollars							
Flood control storage				34.53			
Water supply storage				28.25			
Allocated water supply cost per 1000 gallons, dollars							
(100-year basis)				0.0105			
(50-year basis)				0.0126			

SPECIFIC COSTS

Purpose	Amount (dollars)
Flood control	
First cost	1,820,000
Annual charges	75,100
Annual operation and maintenance	8,000
Recreation	
First cost	5,060,000
First cost (present-value)	3,920,000
Annual charges	322,500
Annual operation and maintenance	178,000

NOTES:

(1) Fixes alternative for total plan is reservoir at Millican site and upstream channel--use reservoir-cost portion.

(2) Fixed alternative for total plan is two reservoirs--apportion total cost to each unit according to water supply benefits--initial-unit portion discounted 5 years.

(3) Fixed alternative for total plan is one recreation reservoir--cost apportioned to each unit according to recreation benefits.

Item	NAVASOTA NO. 2 RESERVOIR AS THE FUTURE UNIT						
	Single-purpose			Multiple-purpose	Dual-purpose		
	FC*	WS	R		FC*-WS	FC-R	WS-R
PERTINENT INFORMATION							
First cost, dollars	4,400,000	80,650,000	29,236,000	60,413,000	57,537,000	28,032,700	58,550,000
Investment costs, dollars	4,812,500	92,330,000	31,590,000	67,964,500	64,730,000	30,222,800	65,869,000
Annual charges, dollars	174,700(1)	3,179,700(2)	1,410,900(3)	2,484,200	2,241,500	1,202,800(4)	2,383,900
Annual maintenance and operation, dollars	17,000	155,000	376,000	257,700	121,000	212,700	226,700
Dependable yield, second-feet	-	470.0	-	175.0	175.0	-	175.0
Dependable yield, million gallons daily	-	303.8	-	113.1	113.1	-	113.1
Dependable yield, thousand gallons annually	-	110,875,681	-	41,283,498	41,283,498	-	41,283,498
Total annual benefits, dollars	156,700	3,565,800	3,799,800	3,648,000	2,065,100	1,739,600	3,491,300
Flood control storage, acre-feet	-	-	-	550,700	550,700	-	-
Water supply storage, acre-feet	-	2,682,100	496,000	1,315,400	1,315,400	367,300	1,866,100
Sediment storage, acre-feet	-	111,500	69,500	69,500	69,500	69,500	69,500
Total storage, acre-feet	-	2,793,600	565,500	1,935,600	1,935,600	436,800	1,935,600
COST ALLOCATIONS							
1. Benefits	156,700	1,908,400	1,582,900	3,648,000			
2. Alternate cost	174,700(1)	1,879,200(2)	587,900(3)	-			
3. Benefits limited by alternate cost	156,700	1,879,200	587,900	-			
4. Separable costs	100,300	1,281,400	242,700	1,624,400			
5. Remaining benefits	56,400	597,800	345,200	999,400			
6. Percent distribution of item 5	5.64	59.82	34.54	100.00			
7. Allocated joint cost	48,500	514,300	297,000	859,800			
8. Total allocation	148,800	1,795,700	539,700	2,484,200			
9. Percent distribution of item 8	5.99	72.28	21.73	100.00			
10. Separable costs	31,000	45,000	136,700	212,700			
11. Percent joint costs of item 6	5.64	59.82	34.54	100.00			
12. Allocated joint costs	2,500	26,900	15,600	45,000			
13. Total allocation	33,500	71,900	152,300	257,700			
14. Percent distribution of item 13	13.00	27.90	59.10	100.00			
15. Allocated annual charges	148,800	1,795,700	539,700	2,484,200			
16. Allocated operation and maintenance costs	33,500	71,900	152,300	257,700			
17. Remainder	115,300	1,723,800	387,400	2,226,500			
18. Percent distribution of item 17	5.18	77.42	17.40	100.00			
19. Allocated investment	3,520,600	52,618,100	11,825,800	67,964,500			
20. Allocated first costs	3,129,400	46,771,700	10,511,900	60,413,000			
21. Discounted first cost increment of future recreation facilities	-	-	674,000	674,000			
22. Total allocated first cost	3,129,400	46,771,700	11,185,900	61,087,000			
Ratio of annual benefits to allocated annual charges	1.05	1.06	2.93	1.47			
Flood control storage				56.83			
Water supply storage				35.56			
(100-year basis)				0.0435			
(50-year basis)				0.0525			

SPECIFIC COSTS

Purpose	Amount (dollars)
Flood control	
First cost	1,660,000
Annual charges	75,200
Annual operation and maintenance	14,000
Recreation	
First cost	3,550,000
First cost (present-value)	2,876,000
Annual charges	242,700
Annual operation and maintenance	136,700

NOTES:

*FC incidental to reallocation of storages to develop total water supply resources.

(1) Fixed alternative for total plan is reservoir at Millican site and upstream channel--channel-cost portion.

(2) Fixed alternative for total plan is two reservoirs--apportion total cost to each unit according to water supply benefits.

(3) Fixed alternative for total plan is one recreation reservoir--cost apportioned to each unit according to recreation benefits.

(4) Recreation reservoir and flood control channel to provide $156,700 annual benefits.

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TABLE 9

SUMMARY OF ALLOCATION AND APPORTIONMENT OF COSTS
SELECTED AND ALTERNATE PLANS OF IMPROVEMENT
NAVASOTA RIVER WATERSHED

	OPTIMUM DEVELOPMENT OF RECREATION AND FISH AND WILDLIFE ENHANCEMENT									
	PLAN I	PLAN II			PLAN V			PLAN VI		
Item	Millican Reservoir Only	Millican Reservoir	Navasota No. 2: Reservoir	Total Plan	Millican Reservoir	Navasota No. 2: Reservoir	Total Plan	Navasota No. 2: Reservoir	Millican Reservoir	Total Plan
Assumed year of completion	1975	1975	2010		1975	2005		1975	2005	
1. ALLOCATED FIRST COST (Costs in $1,000)										
Non-Federal:										
Water supply	41,753.0	19,215.5	46,771.7	65,987.2	12,165.0	54,773.0	66,938.0	15,388.0	49,125.0	64,513.0
Recreation	4,325.0	2,530.0	1,775.0	4,305.0	2,530.0	1,775.0	4,305.0	2,445.0	1,850.0	42,950.0
Subtotal	46,060.0	21,745.5	48,546.7	70,292.2	14,695.0	56,548.0	71,243.0	17,833.0	50,975.0	68,808.0
Federal:										
Flood control	27,312.0	27,009.9	3,129.4	30,139.3	29,265.0	2,837.0	32,102.0	25,617.0	10,020.2	35,637.2
Recreation	17,888.0	9,864.6	9,410.9	19,275.5	10,770.0	7,890.0	18,660.0	11,587.0	7,474.8	19,061.8
Subtotal	45,200.0	36,874.5	12,540.3	49,414.8	40,035.0	10,727.0	50,762.0	37,204.0	17,495.0	54,699.0
Total	91,260.0	58,620.0	61,087.0	119,707.0	54,730.0	67,275.0	122,005.0	55,037.0	68,470.0	123,507.0
2. ALLOCATED AVERAGE ANNUAL OPERATION AND MAINTENANCE (Costs in $1,000)										
Non-Federal:										
Water supply	48.0	33.2	71.9	105.1	23.5	82.0	105.5	31.3	78.6	109.9
Recreation	220.0	178.0	136.7	314.7	178.0	136.7	314.7	178.0	136.7	314.7
Subtotal	268.0	211.2	208.6	419.8	201.5	218.7	420.2	209.3	215.3	424.6
Federal:										
Flood control	57.0	58.6	33.5	92.1	60.7	31.0	91.7	97.3	24.2	121.5
Recreation	33.0	16.2	15.6	31.8	18.8	11.3	30.1	25.4	10.2	35.6
Subtotal	90.0	74.8	49.1	123.9	79.5	42.3	121.8	122.7	34.4	157.1
Total	358.0	286.0	257.7	543.7	281.0	261.0	542.0	332.0	249.7	581.7
3. ALLOCATED AVERAGE ANNUAL CHARGES (WITH FUTURE RECREATIONAL FACILITIES DISCOUNTED)(Costs in $1,000)										
Non-Federal:										
Water supply	1,607.2	741.4	1,795.7	2,537.1	466.2	2,100.7	2,566.9	590.5	1,889.1	2,479.6
Recreation	323.7	250.3	189.7	440.0	248.3	189.7	438.0	246.2	192.5	438.7
Subtotal	1,930.9	991.7	1,985.4	2,977.1	714.5	2,290.4	3,004.9	836.7	2,081.6	2,918.3
Federal:										
Flood control	1,077.1	1,054.0	148.8	1,202.8	1,126.0	135.5	1,261.5	1,028.3	393.5	1,421.8
Recreation	643.4	358.8	350.0	708.8	391.1	289.7	680.8	425.8	273.1	698.9
Subtotal	1,720.5	1,412.8	498.8	1,911.6	1,517.1	425.2	1,942.3	1,454.1	666.6	2,120.7
Total	3,651.4	2,404.5	2,484.2	4,888.7	2,231.6	2,715.6	4,947.2	2,290.8	2,748.2	5,039.0
4. UNIT COST OF WATER SUPPLY PER 1,000 GALLONS (Costs in $)										
Dependable yield, cfs	480	300	175	475	240	235	475	232	238	470
Unit cost water supply only										
(100-year)	0.0142	0.0105	0.0435	0.0226	0.0082	0.0379	0.0229	0.0108	0.0336	0.0224
(50-year)	0.0167	0.0126	0.0525	0.0273	0.0099	0.0457	0.0276	0.0130	0.0407	0.0270
Unit cost water supply and recreation										
(100-year)	0.0171	0.0140	0.0481	0.0266	0.0126	0.0413	0.0268	0.0153	0.0371	0.0263
(50-year)	0.0204	0.0164	0.0573	0.0315	0.0146	0.0493	0.0318	0.0177	0.0442	0.0312
5. PRESENT VALUE (1975) OF ALLOCATED WATER-SUPPLY-ONLY COST										
First cost (Costs in $1,000)	41,735.0	19,215.5	15,930.4	35,145.9	12,165.0	21,761.3	33,926.3	15,388.0	19,517.4	34,905.4
Annual charges (Costs in $1,000)										
100-year basis	1,607.2	741.4	611.6	1,353.0	466.2	834.6	1,300.8	590.5	750.5	1,341.0
50-year basis	1,892.1	893.4	737.6	1,631.0	561.3	1,006.7	1,568.0	710.6	904.9	1,615.5
Unit cost per 1,000 gallons (Costs in $)										
100-year basis	0.0142	0.0105	0.0148	0.0121	0.0082	0.0151	0.0116	0.0108	0.0134	0.0121
50-year basis	0.0167	0.0126	0.0179	0.0146	0.0099	0.0182	0.0140	0.0130	0.0161	0.0146
6. INITIAL WATER SUPPLY CONTRACT REQUIREMENT WITH 30 PERCENT OF TOTAL PROJECT FIRST COST DEFERRED (Costs in $1,000)	14,337.0	1,629.5	28,445.6	-	0	34,590.5	-	0	28,584.0	-

APPENDIX V

REPORTS BY OTHER FEDERAL AGENCIES

REVIEW OF REPORTS
ON
BRAZOS RIVER AND TRIBUTARIES, TEXAS
COVERING
NAVASOTA RIVER WATERSHED

CONTENTS

96-129 O-68-9

RECONNAISSANCE REPORT
RECREATIONAL USE AND DEVELOPMENT
NAVASOTA RIVER WATERSHED
BRAZOS RIVER BASIN
TEXAS

Prepared by
Region Three Office, National Park Service
Department of the Interior

for
Fort Worth District
U. S. Corps of Engineers
Department of the Army

April 1960

William L. Bowen, Regional Chief
Division of Recreation Resource Planning

Milton J. McColm, Regional Chief
Branch of State Cooperation and
Reservoir Recreation Planning

Field Study and Report by:
Urban E. Rogers
Park Landscape Architect

River Basin Code No. XXXVI/96

INTRODUCTION

Authority

This reconnaissance report has been prepared pursuant to the Park, Parkway and Recreational Area Study Act of June 1936 and the Corps of Engineers', Fort Worth District Office, letter request of February 17, 1960.

A field investigation of the reservoir sites was made on March 2 and 3 by Messrs. F. K. Mixon and F. E. Clary of the Corps of Engineers Fort Worth District Office and Park Landscape Architect Urban E. Rogers of the Region Three Office, National Park Service.

Purpose

This report presents an appraisal of the recreational potentials of the proposed reservoir projects on the Navasota River Watershed. The report also indicates the type of recreation development believed justified and includes an estimated monetary evaluation of recreation benefits.

GENERAL DESCRIPTION

Location

Three reservoir sites, Millican, Ferguson No. 3 and Navasota No. 2, on the Navasota River, Brazos River Basin, are being investigated. Millican, the downstream site, is 7 miles northwest of Navasota in Grimes and Brazos Counties. Ferguson Site No. 3 in Grimes, Brazos and Madison Counties is 9 miles east of Bryan and approximately 18 miles upstream from the Millican site. The upstream site, Navasota No. 2, is 20 miles northeast of Bryan in Robertson and Leon Counties. A network of Federal and State highways and farm roads affords direct access to and through the reservoir basins.

Purpose

Ferguson was authorized earlier as a multiple-purpose project, but is currently being investigated for possible relocation of the dam site. The restudy is considering three reservoir sites for flood control and conservation storage purposes.

The following preliminary data were supplied by the Corps of Engineers:

	RESERVOIR SITES		
	Millican	Ferguson No. 3	Navasota No. 2
Max. Design W. S.			
Elevation (ft. M.S.L.)	236.7	262.0	326.6
Surface Area (acres)	59,400	57,800	39,200
Capacity (acre-feet)1/	1,489,300.	1,390,500	1,215,000
Conservation Storage			
Elevation (ft. M.S.L.)	218.0	244.0	307.5
Surface Area (acres)	36,780	32,350	25,800
Capacity (acre-feet)1/	599,200	600,400	585,000
Five-Year Pool			
Elevation (ft. M.S.L.)	227.0	253.0	317.0
Surface Area (acres)	47,210	42,850	33,000

1/ Does not include 50-year sedimentation

The impounded water behind any one of the proposed earth fill dams would extend a considerable distance up the Navasota River. The length of river inundated is dependent on which dam is constructed.

Physical Characteristics

The proposed reservoir projects are situated in the Navasota River Valley of East Central Texas. This valley although impressive is not spectacular. Navasota Site No. 2 is located in the Post Oak Belt and Ferguson No. 3 and Millican sites are located in the upper Coastal Plains section. Both sections are characterized by rolling to hilly terrain timbered with several species of oak, elm, mesquite, ash, mulberry, walnut, pecan, gum, hickory, sycamore, cottonwood and some pine trees. The wooded areas are also characterized by thick undergrowth which has been intermittently cleared for pasture improvements. The upland sandy and clay soils have been deposited on the wide river bottom lands indicating the Navasota River carries some silt. The valley has primarily an agricultural economy; however, the surrounding area also has a diversified income from industry and military and educational institutions.

Climate

Data collected by the U. S. Weather Bureau at College Station, seven miles west of the project, should be typical for the area. Annual precipitation is 38.94 inches occurring as rain. The rainfall is heaviest in the spring and evenly distributed the remainder of the year. The temperature averages 51 degrees in January and 84 degrees in July with a mean annual temperature of 68 degrees. The maximum recorded temperature is 110 degrees. Prevailing winds are from the south. The 259 frost free days provide a lengthy growing season.

Historical and Archaeological Investigations

Upon authorization of the project and prior to construction, a historical and archaeological survey should be made of the reservoir area and at the dam construction site.

Present Recreation Use

The Navasota Valley area receives considerable recreation use by hunters and fishermen and limited use by picnickers and boaters. Several small cabins located on the shore of Normangee Park Lake provide over night accommodations.

FACTORS INFLUENCING RECREATION DEVELOPMENT

Of significance to the development of recreational facilities at any one of these reservoirs is the close proximity of existing paved roads; the attractive park like atmosphere of the rolling timbered terrain; the magnitude of the proposed impoundments; and the fact that the conservation pool should not fluctuate more than a few feet.

Navasota Valley has primarily an agricultural economy with a large rural population. The total population within 50 miles of the proposed project reservoirs is estimated to be over 300,000. The population within 50 miles of any one of the three reservoir sites is near 200,000.

Three major Texas cities, Houston, Austin and Waco, are within 100 miles distance. The estimated combined population of these metropolitan areas was near one and one-half million people in 1957.

One national forest, two State parks, two State historical parks and one small city park are the only known existing areas within one hour's drive of the project. The latter, Normangee Park Lake, is located about eight miles west of Normangee and consists of a small impoundment on Running Creek. This impoundment provides the setting for several picnic sites, limited boating facilities and a few small cabins.

Fort Parker State Park and Old Fort Parker Historical Park are located near Mexia. Public use facilities are available at the State park and include camping, picknicking, fishing, boating and swimming as well as a group camp. Washington Historical Park near Navasota provides picnicking, fishing and camping facilities for the visiting public.

Huntsville State Park near Huntsville is situated in Sam Houston National Forest. Both the State park and other established recreation areas within the national forest are popular recreation outlets for picnickers, campers, swimmers, boaters and fishermen.

One proposed Corps of Engineers reservoir project, Somerville, is located nearby. This project, authorized but not under construction, is on Yegua Creek near Somerville. Recreation sites for the future 6,890-acre conservation pool are being selected by the Corps of Engineers.

ESTIMATE OF RECREATION NEED AND USE

Visitation at existing recreation areas in East Central Texas is high and has shown a definite increase in recent years which points out the importance and use of public recreational facilities.

This project with pleasant scenery and a large visitation potential is easily accessible and should receive, with adequate facilities, a great deal of recreational use.

It appears that this project will more than meet the recreational needs of the local people. The reservoir should appeal to residents of the surrounding counties and nearby metropolitan areas, especially Houston.

Day-use would comprise an appreciable portion of the total visitation with some camping and other overnight accommodations desirable.

RECREATION ANALYSIS

The recreation potentialities of the three reservoir sites appear equal. Each site possesses many natural features considered desirable for recreational development purposes. The size of each reservoir, approximately 30,000 surface acres, lends the impoundments to water types of recreation. The proximity of existing roads makes any future developments easily accessible. The population within a 50-mile radius of each reservoir site is approximately the same.

It is believed that any recreation development on the future reservoir shoreline would enhance the existing developments in nearby recreation areas.

Due to the relatively mild winters in East Central Texas, any recreational development would receive limited use during the winter months. The major use would occur in the spring, summer and fall.

Initial development should adequately provide for the local and surrounding county residents. The ultimate recreation development should consider some visitor use from nearby metropolitan areas, particularly Houston.

Due to the recreational significance of the project, The Texas State Parks Board may be interested in adding an attractive State park to their present system.

RECOMMENDED RECREATION DEVELOPMENT

Public use, concession and administration facilities are recommended for development on the future shore lines of the reservoir authorized for construction. The former are considered essential for the visitors' enjoyment of the reservoir and should include: roads; parking areas; trails; signs; utility installations; site preparation as required; boat docks and launching ramps for boating, fishing and water skiing; picnic areas; swimming beaches; campgrounds; and the installation of basic safety features.

Concession facilities are very desirable to complete the recreation development. These facilities are generally revenue producing and furnished by the administering agency or its authorized concessioner. Such facilities could include a marina and fishing supply center, snack bar, additional boat docks and mooring facilities and overnight accommodations.

Due to the extensive recreational development envisioned, administration facilities should be provided to assure the safe and full public use of all facilities. Utility buildings, service areas, employee housing and additional facilities desirable to realize more fully the recreation potentials of the reservoir are recommended.

ESTIMATED MONETARY EVALUATION OF RECREATION BENEFITS

Many economic benefits are generated from the availability of adequate recreation facilities at water control projects. However, a long study of the subject has convinced economists of the National Park Service that such benefits cannot be measured scientifically in monetary terms. The Service, however, believes that its experience warrants a "judgment value" approach to assigning certain monetary values to potential recreation benefits of such projects.

An estimate in monetary terms of the recreation values of reservoirs with developments proposed is based on the estimated number of visitor-days of use expected, multiplied by a visitor-day factor. The annual use, in addition to estimated use of the area without the projects, is conservatively estimated at 500,000 visitor-days. Research by statisticians of the National Park Service has produced a factor or derived monetary value of $1.60 per visitor-day for all types of recreation.

Using this value, the estimated monetary recreational benefit of this project would equal $800,000 annually.

No known existing recreation values of significance will be destroyed by construction of the project reservoir. If Navasota Site No. 2 is authorized, it would be possible to adjust the Normangee Lake Park development to the new reservoir.

LANDS NEEDED

It is apparent that more land than is required for project purposes is needed for recreation access roads and development sites. Sufficient land should be purchased to protect each development site and provide for foreseeable future expansion.

If The Texas State Parks Board is interested in the establishment of a State park, it would be desirable to purchase and reserve land for this purpose.

ADMINISTRATION, OPERATION, MAINTENANCE

Nearby communities and The Texas State Parks Board should be approached regarding the administration of the recreational resources of the authorized reservoir.

FURTHER STUDY AND PLANNING

Upon authorization of the project, it will be necessary to select recreation sites and to determine the extent of development and land requirements necessary to realize the recreational resources inherent in the project.

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
POST OFFICE BOX 1306
ALBUQUERQUE, NEW MEXICO 87103

April 2, 1965

District Engineer
Corps of Engineers, U. S. Army
P.O. Box 1600
Fort Worth, Texas

Dear Sir:

This letter constitutes a revision of the Bureau of Sport Fisheries and Wildlife revised report dated August 16, 1961, on the fish and wildlife resources affected by Millican, Ferguson, and Navasota Site No. 2 Reservoir projects, Brazos River and Tributaries, Navasota River Basin, Texas. The project is located in Brazos, Grimes, Madison, Leon, Robertson, and Limestone Counties. This report has been prepared under the authority of and in accordance with the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). It has received concurrence from the Texas Parks and Wildlife Department by letter dated March 11, 1965, signed by Executive Director J. Weldon Watson. A copy of that letter is enclosed. The report has been coordinated with the Bureau of Commercial Fisheries.

This report considers 12 plans of development under investigation by the Corps of Engineers. These plans differ substantially from the 12 plans evaluated in our August 16, 1961, report. Evaluations for fishing and hunting have been revised to reflect a 100-year period of analysis (1975-2075) and current Federal policies pertaining to acquisition of reservoir lands. The evaluations of fishing and hunting are based upon the Evaluation Standards for Primary Outdoor Recreation Benefits as set forth in Senate Document No. 97, Supplement No. 1, approved by the Ad Hoc Water Resources Council, Washington, D. C., on June 4, 1964.

Preparation of the revised report was undertaken in response to the request contained in your letter dated June 1, 1964. Additional and revised data were provided us on December 24, 1964, by your office.

DESCRIPTION OF THE AREA

The greater part of the project area lies in the East Texas Timber Country region. Soils of the region are predominantly light, well-drained, sandy loams with alluvial soils along the river bottoms. Vegetative cover is primarily post oak and blackjack oak on the uplands with elm, hackberry, and mast-producing species on the bottomlands. These species predominate above an understory of French mulberry, yaupon, holly, coralberry, pigweed, croton, broomweed, ragweed, partridge pea, bluestem, three-awn, buffalo grass, and grama grasses. An isolated band of the Blackland Prairie extends across the Navasota Reservoir Site No. 2. Dark clay loams of the Crockett Group predominate here, and the region is largely in pasture. About 86 percent of the project area is timbered, and 14 percent is in crop and pasture. The trend toward increasing grazing lands can be expected to reduce the timber acreage by 25 percent.

The project area lies in a region where rainfall is well distributed throughout the year. Mean annual precipitation is about 36 inches, and mean annual evaporation is 53 inches. Extremes in precipitation have ranged from 60.75 inches in 1900 to 21.17 inches in 1940.

Temperatures average 51° F. in January and 83° F. in July; the mean annual temperature is about 66° F. The frost free season is 243 days.

Project reservoir sites are in a moderately populated rural area. Farming, ranching, lumbering, and small retail businesses are the principal sources of income. The populous Bryan-College Station area lies only 25 miles to the south. It is an agricultural, educational, light industrial, and military center. About 270,000 people reside within 60 miles of the project area. By the year 1975, the population is expected to be 350,000; by the year 2070, the population will be about one million persons. Federal and State highways, pipelines, buslines, and airline transportation facilities serve the project area.

The Navasota River is a turbid, sluggish-flowing stream with headwaters in the Blackland Prairies of north-central Texas. It flows in a southerly direction for 197 miles through the western extension of the East Texas Timber Country and joins the Brazos River near the community of Navasota, Texas. Streamflows at the Easterly Gaging Station for 38 years of record (1924-1962) have averaged 415 second-feet; instantaneous daily flows have ranged from a maximum of 60,300 second-feet to a minimum of zero.

Within the project area, the Navasota River is a small, intermittent stream. Small deep pools, separated by silt islands, are common. The stream bottom is predominantly silt and clay. Throughout its course, the stream is moderately entrenched and extremely crooked. There are numerous old cutoff channels and oxbow lakes and several man-made impoundments on either side of the main channel. A dense canopy of pecan, ash, elm, pin oak, hickory, locusts, gum, and willow shades the water surface in most places. Sparse amounts of water lilies and water hyacinth have invaded the stream. There are three distinct flood terraces, each with a dense, complex bottomland flora, dominated by mast-producing hardwood timber. These flood terraces provide food and cover for white-tailed deer, squirrels, and surface-feeding waterfowl. This is typical of the floodplain in the entire project area except that portion lying downstream from the site of the proposed Millican Reservoir. Much of the floodplain below the Millican Reservoir site has been cleared and is devoted to cropland and improved pasture.

DESCRIPTION OF THE PROJECT

It is our understanding that the three reservoir sites on the Navasota River are being restudied to determine the most feasible plan for controlling floods and providing water storage for municipal, industrial, and possibly agricultural uses. The restudy also provides for certain additional investigations requested by the Governor of Texas and those appropriate to reflect current Federal laws and policies. The project will be operated for flood control in the Brazos River basin as a unit in the system which will include Waco, Somerville, Whitney, Proctor, Belton, Stillhouse Hollow, Laneport, South Fork of the San Gabriel, and the North Fork of the San Gabriel Reservoirs.

The three damsites are:

1. Millican, at river mile 24.05, with a drainage area of 2,120 square miles.

2. Ferguson, at river mile 41.46, with a drainage area of 1,778 square miles.

3. Navasota Site No. 2, at river mile 83.36, with a drainage area of 1,340 square miles.

The 12 plans under investigation include flood control, conservation, and sediment storages. Flood control storage ranges from 539,500 acre-feet to 911,500 acre-feet, while conservation storage ranges from 566,200 acre-feet to 2,462,200 acre-feet. Plans 11 and 12 provide for stage development of Millican and Navasota Site No. 2 Reservoirs. These plans contemplate initial development of either Millican or Navasota Site No. 2 Reservoir followed by construction of the remaining reservoir when water supply requirements dictate a need (estimated to be 20 to 40 years after initial development). Various schemes of reallocation and increment of storages for conservation and flood control are advanced in Plans 11 and 12.

Table 1 presents pertinent data for each plan of investigation.

Table 1. Pertinent Data for Investigated Plans

Plan	Reservoir Site	Flood-Control Storage (acre-feet)	Conservation Pool Storage (acre-feet)	Conservation Pool Area (acres)
1	Millican	784,800	680,200	42,400
2	Millican	815,000	1,410,400	64,200
3	Millican	786,400	2,408,300	90,200
4	Ferguson	695,300	566,200	31,590
5	Ferguson	687,800	1,243,400	52,530
6	Ferguson	696,900	1,835,700	66,580
7	Navasota Site No. 2	543,200	678,700	29,000
8	Navasota Site No. 2	541,100	954,100	36,340
9	Navasota Site No. 2	546,300	1,206,800	42,180
10	Navasota Site No. 2	539,500	1,574,100	49,160
Stage Development				
11	First Stage Navasota Site No. 2	541,100	954,100	36,340
	Second Stage Navasota Site No. 2	541,100	954,100	36,340
	Second Stage Millican	352,300	1,508,100	66,000
Stage Development				
12	First Stage Millican	784,800	680,200	42,400
	Second Stage Millican	360,800	1,144,600	55,500
	Second Stage Navasota Site No. 2	550,700	1,315,400	44,540

It is important to note that the initial stages of Plan 11 (Navasota Site No. 2 Reservoir) and Plan 12 (Millican Reservoir) are identical to Plans 8 and 1, respectively. Therefore, the fish and wildlife values for these stages are identical to those given for Plans 8 and 1, but must be adjusted accordingly to the period of time that they will exist. It is equally important to note that the initial evaluations must be discarded when the second stages are developed at which time the fish and wildlife evaluation given for Plans 11 and 12 must be applied.

Engineering features pertinent to each plan of investigation include an earthen dam and concrete, ogee-type gated spillway. Outlet works will be controlled by two 2-foot by 4-foot, gate-controlled sluices. The spillway will be located on the left bank at the Ferguson damsite and on the right bank at the other sites. Fee title will be acquired on lands below a line three feet above the top of flood control elevation, in addition to lands required for structures, maintenance and operation, safety, and public use.

FISH

Without the Project

The area evaluated for effects of the different plans on fish includes varying stretches of the Navasota River ranging up to 128 miles in length depending upon the plan investigated. Also included in the area are 13 oxbow lakes and three man-made lakes within or adjacent to the flood plain of the Navasota River.

Stream and lake fishing of minor importance occurs in the project area. The lower 83 miles of the Navasota River, and the 13 oxbow and three man-made lakes totaling 1,250 acres, support light to moderate sport fishing. Fisherman access to the Navasota River and to all but one lake is limited by landowner or private club restrictions. There are a few roads crossing the stream. Normangee City Park Lake is open to public use, but a fee is charged.

Principal fishes taken from the river for sport are catfishes, carp, freshwater drums, and bluegills. In addition to these fishes, white crappies and largemouth bass are taken from the oxbow and man-made lakes. Trotline, throwline, pole and line, and bait casting are the principal methods of fishing. This fishery would prevail throughout the 100-year period of project analysis without the project.

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Twelve part-time and two full-time commercial fishermen work the lower 70 miles of the Navasota River with trotlines, gill nets, and trammel nets. Catfishes, smallmouth buffalo, carp, and freshwater drums are the principal fishes taken. All fishes are marketed locally by fishermen. About 19,000 pounds of fishes, valued at about $6,000, are taken annually. The annual take of commercial fishes is expected to increase to about 30,000 pounds of fishes worth about $10,000 during the 100-year period of project analysis.

With the Project

Establishment of the reservoirs investigated will inundate or cause dewatering of fish habitat in the Navasota River varying from 62 to 83 miles and in 1 to 16 lakes varying from 40 to 1,250 surface acres depending upon the plan selected. The habitat will be lost, with a resultant loss of fishing.

Under any of the plans, the project will provide highly productive game-fish habitat, especially in the early years of impoundment. The reservoir or reservoirs will have abundant shoreline spawning and forage areas and will be deep enough to maintain a clear-water fishery. Principal species of game fishes will be largemouth bass, bluegill, white crappie, and channel catfish.

Interest in sport fishing is high within 60 miles of the project area; many people travel as far as 100 miles to fish. Based upon human population trends, demands for fishing will increase in the future. Much of the demand will be satisfied by Belton, Springfield, and Waco Reservoirs, and by farm ponds, private lakes, and streams, all within 100 miles of the project area. In addition, Somerville Reservoir on Yegua Creek, about 40 miles from the project area and now under construction, will assist in meeting the fishing needs.

One reservoir on the Navasota River, as proposed in Plans 1 through 10, will receive approximately 200,000 man-days of sport fishing annually. Two reservoirs as proposed in Plans 11 and 12 will receive a combined total of about 240,000 man-days of fishing annually.

The average number of man-days of fishing which could be expected to occur over the period of analysis both with and without the project, for each plan under investigation, are presented in Table 2. Table 3 presents sport fishing benefits for each project plan.

Table 2. Summary of Sport Fishing in Man-Days Annually

Plan	Without the Project	With the Project	Gain
1	6,000	200,000	194,000
2	8,000	200,000	192,000
3	10,000	200,000	190,000
4	9,000	200,000	191,000
5	10,500	200,000	189,500
6	11,000	200,000	189,000
7	13,000	200,000	187,000
8	17,000	200,000	183,000
9	17,000	200,000	183,000
10	17,000	200,000	183,000
11	17,000	240,000	223,000
12	17,000	240,000	223,000

Table 3. Average Annual Sport Fishing Benefits

Plan	Value
1	$194,000
2	192,000
3	190,000
4	191,000
5	189,500
6	189,000
7	187,000
8	183,000
9	183,000
10	183,000
11	223,000
12	223,000

Carp, buffalofishes, river carpsuckers, and freshwater drums will flourish in the impounded waters. The catch, however, is expected to parallel local market demands which will be about 60,000 pounds of fish annually. The annual value of commercial fish taken with the project will be about $20,000 for any of the project plans. The benefit to commercial fishing will be $10,000 annually for any of the project plans.

WILDLIFE

Without the Project

The areas evaluated for effects of the different plans on wildlife include the investigated reservoir sites varying in size from 44,540 acres to 116,400 acres and the floodplain of the Navasota River downstream from the reservoir sites varying in size from 20,000 acres to 53,000 acres.

Wildlife species of importance in the project area are white-tailed deer, fox squirrel, mourning dove, bobwhite, raccoon, red fox, and gray fox. A small population of resident wood ducks remains in the area, while mallards, pintails, redheads, and gadwalls occasionally use the river and lakes for brief resting periods during migration.

Approximately 65 percent of the project area is excellent habitat for white-tailed deer, foxes, raccoons, and squirrels. Bobwhites and mourning doves occur throughout the project area, but are more abundant in cleared areas which have developed a cover of forbs.

The white-tailed deer is the most sought-after wildlife species in the project area, and its abundance has created a great demand for leasing privileges. Deer-hunting rights are sold by private landowners for $100 per hunter season. These same hunters do most of the hunting for squirrels and bobwhites. Generally, hunters who cannot afford the price for deer leases hunt mourning doves and cottontails. Sport hunting of raccoons and foxes also occurs. Waterfowl hunting in the project area is insignificant. The present amount of hunting in the project area could be expected to prevail over the 100-year period of analysis.

With the Project

Whichever plan is proposed, project construction will result in considerable loss of wildlife habitat in the reservoir basin as a result of permanent inundation. Additional habitat will be impaired by periodic flooding. The extent of habitat losses will vary with the wildlife species involved, the site, and the proposed plan of development.

Permanent inundation, periodic fluctuations of the reservoirs, and human disturbance will affect seriously all wildlife populations in adjacent areas. Moreover, the excellent habitat of the floodplain downstream from each of the reservoirs, except that below Millican Reservoir, will be adversely affected. Lack of periodic natural flooding in the floodplain will result in the eventual loss of some of the most valuable mast-producing timber and semi-aquatic food-producing vegetation. Reduction in frequency of flooding also will result in accelerated clearing of bottomlands. Populations of white-tailed deer, squirrels, mourning doves, bobwhites, and foxes will be drastically reduced by the project. Loss of these animals will greatly reduce the hunting opportunities. Demands for hunting will continue to be great, and many people will have to go outside the project area to hunt.

The reservoir or reservoirs will result in habitat for waterfowl, primarily for resting during periods of migration. Lack of food will preclude waterfowl use of the reservoirs except for short periods of time. Waterfowl hunting will be difficult on the large reservoir areas.

Man-days of hunting for white-tailed deer and upland game without and with the project are presented in Table 4.

Waterfowl hunting which is insignificant without the project will total 1,600 man-days annually with plans 1 through 10 and 2,000 man-days with plans 11 and 12. Waterfowl hunting benefits will be $7,200 annually for plans 1 through 10 and $9,000 annually for plans 11 and 12.

Table 4. Summary of Hunting in Man-Days Annually

Plan	Kind	Without the Project	With the Project	Loss
1	Deer	11,700	2,100	9,600
	Upland game	7,200	2,900	5,300
2	Deer	15,000	2,300	12,700
	Upland game	10,300	3,200	7,100
3	Deer	18,900	2,100	16,800
	Upland game	12,200	2,600	9,600
4	Deer	13,200	3,600	9,600
	Upland game	8,200	4,700	3,500
5	Deer	15,900	3,200	12,700
	Upland game	10,300	4,300	6,000
6	Deer	18,000	3,200	14,800
	Upland game	11,300	4,200	7,100
7	Deer	12,200	4,150	8,050
	Upland game	9,600	6,200	3,400
8	Deer	13,200	4,150	9,050
	Upland game	10,900	6,200	4,700
9	Deer	13,500	4,250	9,250
	Upland game	11,200	6,500	4,700
10	Deer	14,600	4,600	10,000
	Upland game	12,600	7,200	5,400
11	Deer	19,600	2,800	16,800
	Upland game	15,800	4,200	11,600
12	Deer	19,300	3,800	15,500
	Upland game	15,600	5,000	10,600

DISCUSSION

Use assigned to fishing and hunting is based upon the assumption that adequate access roads to the reservoir and parking areas will be provided and boat-launching ramps will be constructed. A minimum of 4 access-parking sites will be required at each reservoir to meet sportsmen's requirements. Parking areas should be at least 2 acres in area and should be cleared of all vegetation to ground level.

Since the project will provide a reservoir or reservoirs having clear water, extensive timber clearing within the reservoir basin would make fishing less successful. Timber clearing operations within areas above conservation-pool elevations would destroy much needed wildlife habitat and reduce further hunting opportunities. If clearing operations were held to a minimum, the loss of wildlife habitat caused by the project would be reduced and fishing opportunities would be benefited.

RECOMMENDATIONS

It is recommended:

1. That the report of the District Engineer, Corps of Engineers, include conservation and development of fish and wildlife among the purposes for which the project is authorized.

2. That clearing operations within the fee-title area be held to the absolute minimum compatible with necessary construction and reservoir operation purposes.

In summary, the most favorable plan for fish and wildlife will occur by construction of Navasota Site No. 2 Reservoir with conservation storage as proposed under Plan 7. All plans under investigation will provide a fishery of importance but will result in loss of wildlife habitat. Hunting opportunities generally will be fewer with the project, even though there will be an increase in waterfowl hunting.

The investigations preparatory to this report were made in cooperation with the Texas Parks and Wildlife Department. The report is based on data available from the Corps of Engineers, Fort Worth District, as of

June 1, 1964, and supplemented by additional and revised data presented on December 24, 1964. Our report is subject to revision upon receipt of additional project information. Any modification to the plans investigated should be brought to the attention of the Bureau of Sport Fisheries and Wildlife and the Texas Parks and Wildlife Department. The cooperation of the Fort Worth District, Corps of Engineers, in furnishing engineering data and planning information is appreciated.

Sincerely yours,

John C. Gatlin

John C. Gatlin
Regional Director

Enclosure

Copies (10)

Distribution:

(4) Executive Director, Texas Parks and Wildlife Department, Austin, Texas
(2) Regional Director, Bureau of Commercial Fisheries, Region 2, St. Petersburg Beach, Florida
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(1) Regional Engineer, Public Health Service, Region 7, Dallas, Texas
(1) Regional Director, National Park Service, Southwest Region, Santa Fe, New Mexico
(2) Field Supervisor, Branch of River Basin Studies, Bureau of Sport Fisheries and Wildlife, Fort Worth, Texas

WATER SUPPLY

AND

WATER QUALITY CONTROL STUDY

NAVASOTA RIVER WATERSHED

LOWER BRAZOS RIVER SYSTEM

TEXAS

Abstract

An investigation has been carried out which discloses the need for and value of storage for municipal and industrial purposes in the proposed Millican and Navasota II Reservoirs on the Navasota River. A portion of the future needs for water in the study area can be satisfied from storage in these projects. The investigation further found that there is no need for storage for water quality control in the proposed reservoirs. Economic and demographic studies revealed a potential for increased industrial development and population growth, and serve as the foundation for the projected needs.

Prepared for

DEPARTMENT OF THE ARMY

U.S. Army Engineer District

Fort Worth, Texas

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service, Region VII
Dallas, Texas

JUNE 1965

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APPENDIX

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I. INTRODUCTION

Request and Authority

In a letter dated June 8, 1959, the Corps of Engineers, Fort Worth District, requested ". . .Views and recommendations of Health, Education, and Welfare on present and prospective needs for municipal and industrial water supply for Bryan, Navasota, and College Station, also industrial and irrigation water for consumers in the lower Brazos valley and desirability of meeting these needs from a reservoir project on the Navasota River. . . ." In compliance with this request, a report entitled "Municipal and Industrial Water Requirements, Millican Reservoir, Navasota River, Lower Brazos River System, Texas" was prepared and submitted in July 1960. Since the preparation of this report, there have been several changes in (1) the laws governing water resources planning; (2) the planning policies of Federal agencies; and (3) the plans for the reservoir projects included in the original request.

The U.S. Army Engineer District, Fort Worth, in a letter dated February 17, 1964, requested a restudy of the Navasota River ". . .to determine for a 100-year period the municipal and industrial water requirements, the quality of water, the extent of existing and potential pollution, as well as the need for and the benefits from conservation storage for purposes of municipal and industrial water supply and water quality control. . . ."

This study has been made in accordance with: (1) A Memorandum of Agreement between the Department of the Army and the Department of Health, Education, and Welfare, dated November 4, 1958; and (2) The Federal Water Pollution Control Act, as amended (33 USC 466 et seq.).

Purpose and Scope

The purpose of this study is to estimate the water requirements for municipal, industrial, and water quality control purposes to the year 2075 in the lower Brazos River basin, which includes the Navasota River watershed. Estimates are made of the value of benefits attributable to the storage of water for these purposes in the Federally proposed Navasota River reservoir projects.

Acknowledgments

The cooperation of many persons and agencies is gratefully acknowledged. Special appreciation is expressed to the following:

U.S. Army Engineer District, Fort Worth, Texas
U.S. Geological Survey, Austin, Texas

Texas State Department of Health, Austin, Texas
Texas Water Commission, Austin, Texas
Brazos River Authority, Waco, Texas
Bryan-College Station Chamber of Commerce, Bryan, Texas
Officials of cities in the study area

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II. SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of Findings

1. The U.S. Army Engineer District, Fort Worth, is considering the development of the Navasota River watershed through the construction of multiple-purpose reservoirs. Generally these plans utilize three main stem reservoir sites: Millican at river mile 24.05; Ferguson at mile 41.46; and Navasota Site II at mile 83.36.

2. The study area comprises 21 counties in south-central Texas, enclosing an area with boundaries generally coincident with the lower Brazos River basin, as shown on figure III-1.

3. These 21 counties had a total population of about 789,000 in 1960. Of this total, 474,000 were classified as urban, and 315,000 as rural.

4. Except for the Standard Metropolitan Statistical Areas (SMSA's) of Waco and Galveston-Texas City, the area is generally rural in character. Rapid urbanization is taking place, however, in such cities as Mexia, Temple, Bryan-College Station, Richmond, and Freeport whose present population exceeds 10,000.

5. The study area is in a period of rapid economic expansion. Waco has a highly diversified manufacturing complex, and growth of the petrochemical industry in the Freeport and Galveston-Texas City areas is extremely dynamic.

6. Present municipal and industrial water use in the study area is about 340 million gallons per day (mgd), with surface water sources supplying almost 255 mgd and ground water contributing about 85 mgd. Eighty-three percent (280 mgd) of this use is centered in the gulf coast counties. In addition, the chemical industry along the gulf coast uses about 2,500 mgd of brackish water for cooling.

7. The major water-using industries in the study area are chemicals and allied products, and food and kindred products. Other major uses are irrigation and recreation.

8. The aggregate storage of the existing and under construction major reservoirs is 1,657,370 acre-feet. Reported ground water pumpage in 1958 amounted to more than 250,000 acre-feet.

9. Current inventories show that there are 83 municipal and industrial waste treatment plants in operation in the study area. In general, these plants provide secondary treatment and are operating efficiently.

10. The organic quality of the waters of the lower Brazos River basin as measured by dissolved oxygen can be described as good. (The dissolved oxygen concentration does not drop below 4.0 milligrams per liter (mg/1).)

11. The mineral quality of the Brazos River main stem, downstream from Whitney Reservoir, is poor. The weighted average total dissolved solids concentrations vary from 415 mg/1 near the mouth to 1,240 mg/1 at Waco, Texas. This condition is due primarily to extensive natural brine pollution in the upper Brazos River basin.

12. The water quality of the proposed project reservoirs is acceptable for municipal, industrial, recreational, fish and wildlife, and agricultural uses.

13. This study, comprising the lower Brazos River basin, and its findings will be included in the pending investigation of the entire Brazos River basin by the Public Health Service.

Conclusions

1. To insure continued growth, careful planning for efficient development of all of the study area's water resources is essential.

2. The study area's population is expected to reach 2,040,000 by the year 2025, and 3,401,000 by the year 2075. The urban segment of these totals is 1,878,000 and 3,267,000 in 2025 and 2075, respectively. Similarly, the rural portion of the population is expected to be 162,000 in 2025, and 134,000 in 2075.

3. Estimated future municipal, industrial, and rural water supply needs for the lower Brazos River basin, including the assigned intervening coastal area, are 1,326 million gallons per day (mgd) in the year 2025 and 2,088 mgd in the year 2075.

4. With the water supply plan as presented herein, the potential water resources of the lower Brazos River basin are sufficient to satisfy municipal, industrial, and rural water requirements until about the year 2028. It is assumed that the projected irrigation needs to this time will also be satisfied.

5. The future organic quality of lower Brazos River basin waters is expected to remain satisfactory for municipal, industrial, recreational, fish and wildlife, and agricultural uses.

6. Present undesirable concentrations of total dissolved solids in the main stem of the Brazos River downstream from Whitney Reservoir can be expected until natural brine pollution of the upper basin is controlled. Current studies being made by the Corps of Engineers and the Public Health Service indicate that adequate control of the brine emission areas may be possible.

7. Municipal and industrial water supply releases from the project reservoirs (Millican and Navasota II) will reduce concentrations of total dissolved solids under stated drought conditions to some extent in the Brazos River below the mouth of the Navasota River even if none of the natural brine pollution of the upper basin is controlled. This incidental reduction, however, is not considered sufficient to create significant benefits to water users in the lower Brazos basin.

8. Storage in Millican and Navasota II Reservoirs will satisfy a portion of the future municipal and industrial water requirements in the study area. The need for storage for water quality control purposes is not foreseen at this time.

9. Minimum annual values of benefits of storage for water supply based on the cost of the most likely alternative (single-purpose impoundments at the project site) are as follows:

Reservoir	Annual Water Supply Benefits
Millican	$1,418,000
Navasota II	914,000

III. PROJECT DESCRIPTION

General

The Navasota River is a principal tributary of the lower Brazos River in east-central Texas. Originating in the southeast corner of Hill County, the river flows southeastwardly across Limestone County, where it begins a southerly course forming the eastern boundaries of Robertson and Brazos Counties to its confluence with the Brazos River at mile 233, near Navasota, Texas. The Navasota River drainage area comprises 2,211 square miles, having a length of 122 miles and a maximum width of 35 miles.

The watershed includes portions of Hill, Limestone, Robertson, Leon, Brazos, Madison, and Grimes Counties, and lies within the West Gulf Coastal Plain section of the Coastal Plain physiographic province. The watershed changes gradually from typical prairie topography and vegetation in the north portion to the relatively hilly and forested characteristics of the East Texas Timber Belt in the south portion. Elevations in the watershed vary from about 650 feet near the headwater divide, to about 185 feet near its mouth. The boundaries of the watershed are shown in figure III-1 at the back of this report.

Pertinent Project Data

There are several development plans for the Navasota River under consideration by the Corps of Engineers. These plans generally include some combination of the Millican and Navasota Site II or Ferguson Reservoir sites. The conservation storage for municipal and industrial water supply of these plans varies from 566,200 acre-feet to 2,462,200 acre-feet. Similarly, the dependable yields vary from 150 mgd to 310 mgd.

The locations of the reservoir sites are shown in figure III-1, and more specific pertinent data for a number of the plans being considered are shown in table III-1.

Table III-1

Pertinent Data
Navasota River Reservoir Projects

Reservoir and Plan	River Mile	Conservation Storage (acre-feet)	Dependable Yield (mgd)
Millican	24.05		
Plan A		680,200	194
Plan B		1,410,400	246
Plan C		2,408,300	310
Ferguson	41.46		
Plan A		566,200	162
Plan B		1,243,400	210
Plan C		1,835,700	248
Navasota Site II	83.36		
Plan A		678,700	150
Plan B		1,206,800	187
Plan C		1,574,100	210
Millican & Navasota Site II System			
Plan A (Navasota No. II as first project)	(See above)	2,462,200	304
Plan B (Millican as the first project)		2,460,000	307

Source: Corps of Engineers 1/

IV. STUDY AREA DESCRIPTION

Location and Boundaries

The study area comprises 21 counties enclosing an area with boundaries generally coincident with the lower Brazos River basin. (See figure III-1 at the back of this report.) This study and its findings will be included in the pending investigation of the entire Brazos River basin by the Public Health Service.

Although this study is primarily concerned with water resource development in the Navasota River watershed (see preceding section on PROJECT DESCRIPTION), this study area was chosen so as to include the entire area which might be served by the water resources of the lower Brazos River basin utilizing a single integrated plan of development. This plan utilizes ground water resources in the entire area, as well as surface water resources of the entire lower Brazos River basin.

Geography and Topography

The Brazos River flows in a general southeasterly direction through the study area to the Gulf of Mexico. The slope of the riverbed varies from approximately 1.2 feet per mile near Waco to less than 0.5 feet per mile near the gulf. [2/]

The terrain changes from rolling hills in the northern portion of the study area to a flat coastal plain in the southern section. The table-like topography of the alluvial plain along the main channel of the Brazos River does not afford economical reservoir sites.

Climate

The lower Brazos area is characterized by a mild and fairly uniform climate. The mean annual temperature varies from about 70° in the coastal area to 66° in the vicinity of Waco. From Waco to the gulf coast, the normal annual rainfall varies from 33 inches to 47 inches. The average length of the growing season ranges from 260 days in the northern portion to 320 days near the coast.

Principal Communities and Industries

The study area was divided into four subareas for the purpose of providing suitable size base areas for study and at the same time maintaining a reasonable degree of homogeneity of economic, water resource, and geographic factors. The principal characteristics of each of the subareas are shown in table IV-1. The boundaries of the subareas are shown on figure III-1.

Table IV-1

Characteristics of the Subareas

Sub-area	Counties	Principal Cities	1960 Population (1,000's)	Population Class	Economy	Topography	Altitude (feet)	Mean Annual Temp. (°F)	Growing Season (days)	Average Rainfall (inches)
1	Falls, Hill McLennan	Marlin, Hillsboro, Waco	195	Metropolitan	Industrial, Commercial, Agriculture, Livestock	Level to Rolling	300-900	66	241	35.7
2	Brazos, Grimes, Leon, Limestone, Madison, Robertson	Bryan, College Station, Navasota, Centerville Mexia, Madisonville, Hearne	111	Non-Metropolitan	Agriculture, Livestock, Industrial, Commercial	Level to Rolling	150-600	66	248	38.8
3	Bell, Burleson, Burnet, Lee, Milam, Williamson	Temple, Caldwell, Burnet, Giddings, Cameron, Rockdale, Taylor, Georgetown	181	Non-Metropolitan	Agriculture, Livestock, Industrial, Mining	Hilly to rolling	225-1600	67	257	34.1
4	Austin, Brazoria, Fort Bend, Galveston, Waller, Washington	Bellville, Freeport, Angleton, Richmond, Sugarland, Galveston, Texas City, Hempstead, Brenham	302	Metropolitan	Industrial, Agriculture, Mining, Shipping	Coastal plain to rolling	0-500	69	285	43.1

Source: A. H. Belo Corporation 4/

V. WATER RESOURCES OF THE STUDY AREA

Ground Water

Principal aquifers in the basin are the Trinity group; the Carrizo sand and Wilcox formation, undifferentiated; the Miocene sands (Catahoula sandstone, Oakville sandstone, and Lagarto clay, undifferentiated); the Coastal sands (Goliad sand, Willis sand, and Lissie formation and Beaumont clay); and the Quaternary alluvium in the West Gulf Coastal Plain. Figure V-1 shows the general location of these aquifers in the basin.

Secondary aquifers include the Trinity group in the Central Texas section and the Mount Selman formation, Sparta sand, and Yegua formation in the West Gulf Coastal Plain. Several additional aquifers yield small quantities of water to individual areas in the basin.

Quantity of Water Available

Present ground water withdrawal in the lower Brazos River basin and the intervening coastal area* is 223.7 mgd, with over one-half of this total used in Subarea 4. Table V-1 presents 1958 ground water usage by subareas.

Table V-1

Base Year Ground Water Withdrawal
Lower Brazos River Basin and Intervening Coastal Area

Subarea	1958 Ground Water Withdrawal (mgd)
1	16.0
2	42.5
3	27.6
4	137.6
TOTAL	223.7

Source: University of Texas 3/
Texas Board of Water Engineers 4/

*This is a coastal drainage area which has been assigned to the Brazos River basin for water supply planning purposes in previous statewide planning reports. See figure III-1.

The ground water that is potentially available for municipal and industrial, thermal power generation, irrigation, and rural use throughout the lower Brazos River basin and intervening coastal area was evaluated as 450.9 mgd. Approximately 65 percent of this total is located in Waller, Fort Bend, Brazoria, and Galveston Counties in Subarea 4. Table V-2 shows the distribution of the available ground water by subareas.

Table V-2

Ground Water Availability
Lower Brazos River Basin and Intervening Coastal Area

Subarea	Ground Water Availability (mgd)
1	25.1
2	86.2
3	25.7
4	313.9
TOTAL	450.9

Source: Texas Water Commission 5 6/

Quality of Water Available

The chemical quality of ground water differs throughout each aquifer as well as in different aquifers. Analysis of the water from selected wells in the principal aquifers in the basin is given in table V-3. The extreme and the mean were evaluated from only a portion of the total number of analyses on record, but they were considered as representative of the quality of the water in the aquifer. Because of the difficulty in differentiating the Miocene sands and the Coastal sands, these aquifers were studied as a unit. In general, the chemical quality of ground water in the principal aquifers is such that with proper treatment the water is acceptable for municipal and industrial water supply purposes.

The public water supplies of many communities are obtained from the Trinity sands, although the concentrations of dissolved solids, iron, and fluoride in many of the wells exceed the recommended upper limits of the U.S. Public Health Service. The water is suitable for most types of industries, but high concentrations of sodium bicarbonate may be undesirable in boiler and laundry operations. Generally, the Trinity sands yield water that is suitable for irrigation.

The quality of water in the northwestern part of the Carrizo and Wilcox sands formation 6/ is acceptable for municipal use.

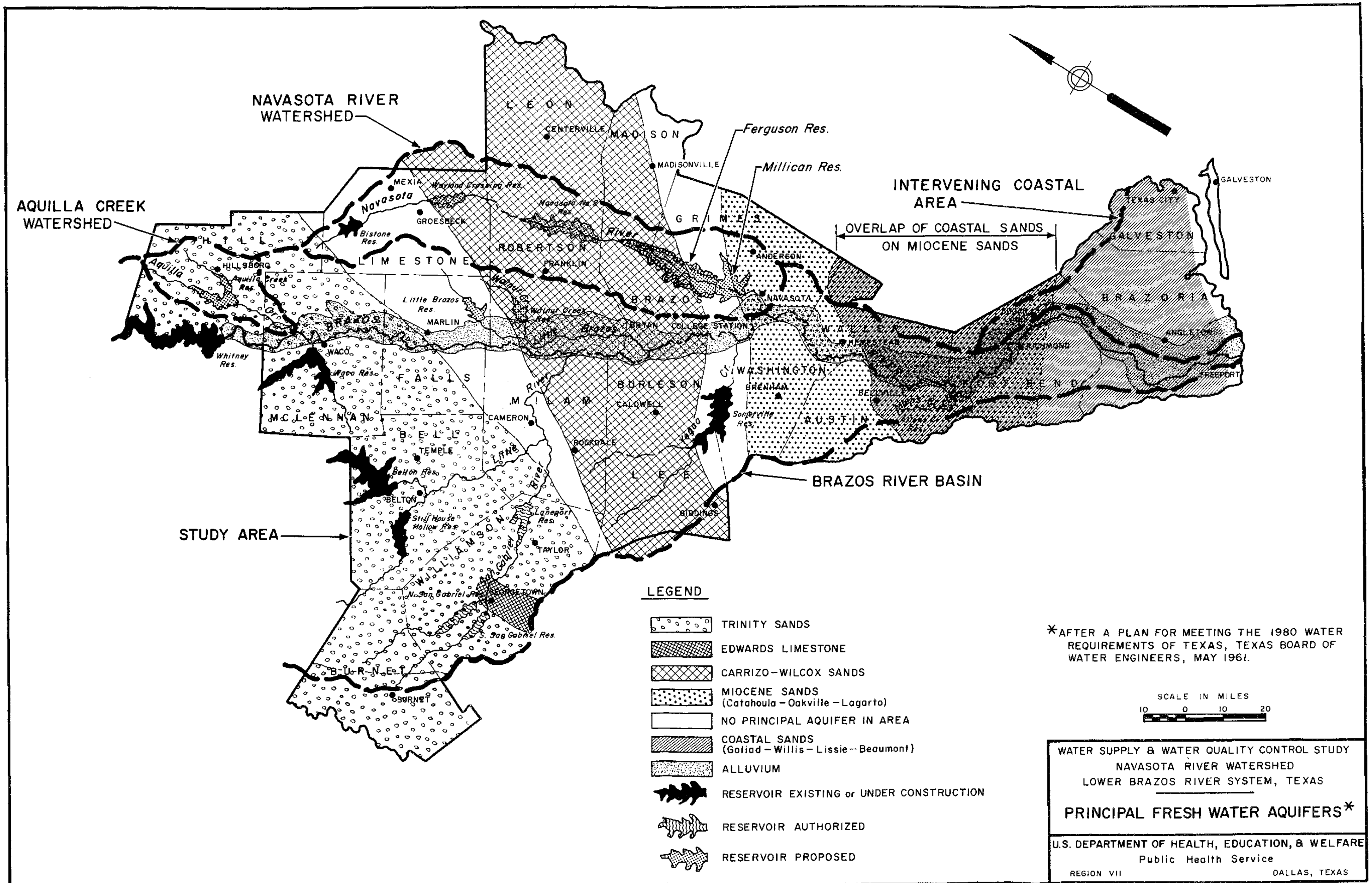

FIGURE V-1

96-129 O-68 (Face p. 144)

Table V-3

Characteristic Analysis of Ground Water from the Principal Aquifers in the Lower Brazos River Basin and Intervening Coastal Area

Characteristic	Trinity Sands a/ Concentration (mg/l)			Carrizo-Wilcox Sands b/ Concentration (mg/l)			Miocene and Coastal Sands c/ Concentration (mg/l)			Alluvium d/ Concentration (mg/l)		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
Silica (SiO_2)	24	13	20	25	16	20	29	15	21	23	16	18
Iron (Fe)	0.94	0.01	0.23	11	0.02	2	0.37	0.08	0.19	*	*	*
Calcium (Ca)	270	2.8	48	121	2.4	26	74	22	44	440	56	171
Magnesium (Mg)	42	0.8	9	37	0.5	7	18	6.1	11	136	5	50
Sodium & Potassium (Na & K)	1420	213	540	656	45	217	188	89	129	384	15	164
Bicarbonate (HCO_3)	492	209	384	714	78	417	367	253	308	828	276	509
Sulfate (SO_4)	3320	75	690	186	0	37	118	0.2	31	570	17	182
Chloride (Cl)	628	50	206	620	19	128	305	43	106	890	16	290
Fluoride (F)	3.6	0.8	2.1	0.7	0.1	0.4	0.6	0.2	0.4	0.5	0.1	0.3
Nitrate (NO_3)	1.2	0	0.4	2.0	0	0.6	2.5	0	0.5	76	0	21
Dissolved Solids	5370	594	1731	1650	247	649	792	300	499	2790	407	1234
Hardness (as $CaCO_3$)	846	10	158	454	8	93	258	80	155	1630	227	637
Percent Sodium	98	78	86	99	19	72	*	*	*	40	22	31
Specific Conductance (micromhos @ 25°C)	3300	988	2018	2880	441	1340	1430	516	858	4300	825	1935
pH (pH units)	8.2	7.3	8.0	8.5	6.2	7.7	8.2	7.0	7.5	7.7	6.7	7.1

a/ Data from 8 wells
b/ Data from 9 wells
c/ Data from 6 wells
d/ Data from 13 wells

* Data not available

Source: Texas Water Commission 6/

Concentrations of iron in excess of 0.3 milligrams per liter (mg/l), the upper limit established for drinking water by the U.S. Public Health Service, exist in some locations and treatment is desirable. The water is suitable for many industrial needs or can be made suitable with nominal treatment. Water from the northwestern half of the aquifer is suitable for at least supplemental irrigation. 6/

Most of the water in the Catahoula sandstone, Oakville sandstone, and Lagarto clay, undifferentiated, and the Goliad sand, Willis sand, and Lissie formation, undifferentiated, is moderately hard to very hard, although soft water can be obtained in the central part of the region by selectively screening wells in the 1,000 to 2,500 foot depth zone. 6/ The water is generally suitable for public supplies and most industrial purposes. Water from these formations that is being used for irrigation would be classified as low to medium for the alkali hazard and medium to high for the salinity hazard.

The quality of the water from wells in the alluvium along the Brazos River varies greatly, as shown by the following range of concentrations; dissolved solids, 407 to 2,790 mg/l, hardness, 227 to 1,630 mg/l, chloride, 16 to 890 mg/l, specific conductance, 825 to 4,300 micromhos per centimeter. No public water supplies are obtained from the alluvium below the Navasota River.

Table V-4 shows the range and mean values of chemical constituents of the ground water from municipal wells in the Navasota River watershed. These concentrations are within the limits set by the U.S. Public Health Service with the exception of total dissolved solids (TDS). The maximum value of 637 mg/l TDS was in the supply of the city of Navasota, the only community to exceed 500 mg/l.

Table V-4

Characteristic Analysis of Water from Municipal Wells in the Navasota River Watershed

Item	Concentration (mg/l) Max.	Min.	Avg.
Iron (Fe)	0.25	0.04	0.12
Calcium (Ca)	35	2	14
Magnesium (Mg)	10	1	3
Sodium (Na)	220	23	111
Sulfate (SO_4)	29	1	15
Chloride (Cl)	83	13	43
Fluoride (F)	0.5	0.2	0.3
Nitrate (NO_3)	1.3	0.4	0.6
Total Hardness (as $CaCO_3$)	128	5	52
Total Dissolved Solids (Residue at 105°C)	637	125	335
pH (in pH units)	8.3	6.3	7.6

Source: Texas State Department of Health [78]

Surface Water

Quantity of Water Available

In the lower Brazos River basin, there are 6 reservoirs either existing or under construction which have a total dependable yield of 566.6 mgd or 634,650 acre-feet per year. [1] These are Whitney, Belton, Waco, Stillhouse Hollow, Somerville, and Bistone. In addition, North San Gabriel, South San Gabriel, and Laneport are authorized projects which will yield 52.4 mgd. Construction of proposed reservoirs will increase the total yield of the studied basin to 1,140.8 mgd in 2025 and 1,163.1 mgd in 2075. Table V-5 lists the individual reservoir yields.

Table V-5

Reservoir Yields
Lower Brazos River Basin

Reservoir		Dependable Yield (mgd)
Existing or under construction		
Whitney		304.0
Belton		104.7
Waco		54.9
Stillhouse Hollow		63.3
Somerville		36.2
Bistone		3.5
	SUBTOTAL	566.6
Authorized		
North San Gabriel		19.4
Laneport		22.0
South San Gabriel		11.0
	SUBTOTAL	52.4
Proposed		
Millican		193.9
Aquilla Creek		9.7
Long Range		
Navasota II (incremental yield)		113.1
Walnut Creek		19.4
Allens Creek		185.7
Wayland Crossing (to be constructed after 2025)		13.6
Little Brazos River (to be constructed after 2025)		8.7
	SUBTOTAL	544.1
	TOTAL	1,163.1

Source: Corps of Engineers 1/

The runoff for the uncontrolled drainage area between Whitney Reservoir and the mouth of the Brazos River, which is circumscribed by Whitney, Aquilla Creek, Waco, Belton, Stillhouse Hollow, Laneport, Little Brazos, Walnut Creek, Somerville, Millican, and Allens

Creek Reservoirs, was estimated. A discharge-frequency curve was constructed from runoff data of this area for a 31-year period of record. [9-11] The runoff value from this curve, based on a 98 percent recurrence interval, is 202.5 mgd.

Quality of Water Available

The estimated dissolved solids concentrations of the principal reservoirs in the lower Brazos River basin are shown in table V-6. The concentrations were estimated applying the relationship of the quantity of runoff and total dissolved solids concentration for the drainage area of the study reservoir. Using reservoir operation data furnished by the Corps of Engineers, periodic concentrations in the reservoir were determined. In this manner, a total dissolved solids frequency curve was developed and the total dissolved solids concentration of each reservoir was evaluated based on annual low flows.

Table V-6

Estimated Total Dissolved Solids Concentration in Principal Reservoirs in the Lower Brazos River Basin

Reservoir	Total Dissolved Solids Concentration (mg/l) Exceedence Interval		
	50%	80%	98%
Whitney	870	870	870
Aquilla Creek	412	610	795
Waco	255	263	350
Belton	372	428	645
Stillhouse Hollow	410	489	608
Laneport	413	498	668
Somerville	262	370	635
Millican[a]	172	237	330

[a] Assuming correction of oil field pollution in the Navasota River upstream from the reservoir.

The quality of Brazos River waters is unsatisfactory upstream of Possum Kingdom Reservoir* because of natural salt and gypsum

*This reservoir is located on the Brazos River at mile 687.5, which is about 245 river miles upstream of Whitney Reservoir. It is not shown on the Location Map, figure III-1.

pollution, but improves as it flows downstream by dilution from better quality tributary waters. The best recorded quality occurs more than 800 miles downstream from the origin of the river, or some 93 miles from the Gulf of Mexico. Weighted average concentrations of total dissolved solids, chlorides, and sulfates of 20 streamflow sampling stations located in the lower Brazos River basin are shown in table V-7.

As will be noted in Section VIII, the natural mineral pollution of the upper Brazos River basin greatly overshadows all other basin pollution. This pollution consists primarily of chlorides, from natural brine emission areas, and sulfates, picked up by upper basin streams whose drainage areas and beds contain large areas of exposed gypsum. It has been estimated that this area contributes a daily load of 995 tons of chlorides, 12/ 687 tons of sulfates, 12/ and 3,073 tons of total dissolved solids. 12/

The Corps of Engineers and the Public Health Service are currently conducting studies of methods to eliminate or reduce discharges from sources of mineral pollution. If this mineral load can be kept from entering basin waters, the water quality of the entire Brazos River will be greatly improved.

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Table V-7

Characteristic Analysis of Streamflow in the Lower Brazos River Basin

Location of Sampling Station	Samples	Weighted Average Concentration (mg/1)		
		Total Dissolved Solids	Sulfates	Chlorides
Brazos River at Whitney Dam near Whitney	a/	851	175	260
Aquilla Creek at FM Road 1244 near Elm Mott	1	849	325	82
Brazos River at Waco	1	1,240	325	450
Brazos River near Marlin	33	808 b/	204	296
Leon River near Belton	1	272	28	27
Leon River at Bridge on U.S. Highway 81 near Belton	1	505	58	102
Leon River near Temple	3	474	52	96
Nolands Creek at Belton	1	464	56	86
Lampasas River at Fort Hood	4	516	19	188
Lampasas River at U.S. Highway 81 near Belton	1	290	13	73
North San Gabriel River at Georgetown	1	364	22	18
South San Gabriel River at Georgetown	1	311	25	18
San Gabriel River at Georgetown	2	292	26	21
Brushy Creek at Round Rock	1	292	20	15
Little River at Cameron	c/	295	32	30
Brazos River near Bryan	37	853 d/	186	263
Yegua Creek near Somerville	1	803	272	168
Navasota River near Bryan	e/	206	26	71
Navasota River near Navasota	1	435	55	140
Brazos River at Richmond	f/	415	76	101

a/ Continuous sampling from September 9, 1947 through May 16, 1948, and from October 1948 through September 1961.

b/ 31 Samples

c/ Continuous sampling from October 1959 through September 1961.

d/ 35 Samples

e/ Continuous sampling from October 1958 through September 1961.

f/ Continuous sampling from October 1945 through September 1961.

VI. THE ECONOMY

Present

Determination of future water requirements for the study area envolves appraisal of the area's population and industrial growth potential. Estimation of future growth patterns of the study area, therefore, are made by (1) a comparison of past trends between the study area, the State of Texas, and the United States on three basic measures: income, employment, and population, and (2) a detailed analysis of specific economic activity of agriculture, mining, and manufacturing with special emphasis given to those industries which will have the greatest effect on future water requirements of the study area.

Income

As shown in table VI-1, per capita disposable income in the study area is increasing at a faster rate than that of Texas or the United States. In 1960, per capita disposable income was lower for the study area than for Texas or the Nation.

Table VI-1

Per Capita Disposable Income
for the Study Area, Texas, and U.S., 1940 and 1960
(1960 dollars)

	Study Area		Texas		U.S.	
Year	Value	% Change	Value	% Change	Value	% Change
1940	739		936		1,274	
		+100		+85		+52
1960	1,476		1,729		1,937	

Source: Corps of Engineers 1/

Employment

The total labor force in the study area increased 9 percent between 1940 and 1960 compared to a 48 percent increase for Texas and a 32 percent increase for the Nation. This increase was achieved in spite of a loss of 60,000 agricultural workers between 1940 and 1960. As shown in table VI-2, agriculture still employs a larger portion of the labor force in the study area than in Texas or the United States.

Table VI-2

Labor Force and Employment for the Study Area, Texas, and the United States 1940, 1950, 1960

	1940				1950				1960			
	No. of Employees Study Area	Percent of Total Labor Force: Study Area	Texas	U.S.	No. of Employees Study Area	Percent of Total Labor Force: Study Area	Texas	U.S.	No. of Employees Study Area	Percent of Total Labor Force: Study Area	Texas	U.S.
Agriculture, Forestry, and Fisheries	96,081	38.1	26.0	16.1	59,342	23.3	15.0	11.7	36,125	13.2	8.0	6.2
Mining	3,455	1.4	2.5	1.7	3,879	1.5	3.0	1.5	3,108	1.1	2.8	.9
Manufacturing	13,657	5.4	8.6	20.0	27,393	10.7	12.6	24.3	39,504	14.4	14.9	25.1
Chemicals & Allied	719	.2	.4	.8	6,275	2.5	1.0	1.1	11,022	4.0	1.3	1.2
Other Nondurables	2,173	.9	1.9	3.2	4,442	1.7	2.3	2.7	6,350	2.3	2.3	2.5
Food and Kindred	3,124	1.2	1.7	2.1	4,044	1.6	2.0	2.3	5,148	1.9	2.2	2.6
Furniture, Lumber & Wood Products	1,927	.8	1.4	1.7	2,620	1.0	1.5	2.0	3,279	1.2	.9	1.5
Other Manufacturing	5,714	2.3	3.2	12.2	10,012	3.9	5.8	16.2	13,705	5.0	8.2	17.3
Service & Other Employed	108,443	42.9	50.0	47.7	154,801	60.7	65.6	57.8	182,550	66.6	70.0	62.8
Unemployed 1/	30,747	12.2	12.9	14.5	9,805	3.8	3.8	4.7	12,809	4.7	4.3	5.0
Total Labor Force	252,383	100.0	100.0	100.0	255,220	100.0	100.0	100.0	274,096	100.0	100.0	100.0

1/ 1940 includes those employed on public emergency works.

Source: Bureau of the Census 13/

Population

The study area is fairly heavily populated, with 44.8 persons per square mile compared to 36.5 and 60.1 for Texas and the continental United States, respectively. (See table VI-3.) Two SMSA's (Waco and Galveston-Texas City), located at upper and lower extremities of the study area, accounted for more than one-third of the 1960 study area population. The study area contains 9 cities with 1960 populations in excess of 10,000. These 9 cities have a total population of 315,370 or 40 percent of the 1960 study area population. The study area in 1960 had a higher percentage of rural residents than Texas or the Nation. The overall study area population trend since 1910 has been predominately upward with total population increasing 35 percent during this time. The study area urban population grew at a compounded annual rate of 3 percent between 1930 and 1960 while Texas and the Nation urban population grew at 3.7 and 2.0 percent, respectively.

Specific Economic Activity

Agriculture

Total value of all farm products sold increased 84 percent in the study area between 1944 and 1959 compared to a 76 percent for the State of Texas and a 54 percent increase for the United States. (See table VI-4.) The sale of livestock and livestock products was the cause of most of this increase. In 1959 livestock sales accounted for more than 50 percent of the total value of farm products sold. The study area has diversified livestock programs with sales resulting from beef, poultry, hogs, dairy, broilers, sheep, and goats. Cotton is the leading income-producing crop grown in the study area. Annual production of cotton averages over 300,000 bales valued at approximately 10 million dollars. Most of the cotton produced in the study area is ginned in the 187 gins located in the study area. 2/ Irrigated rice is important in the gulf coast region of the study area. Other crops grown include: corn, grain sorghums, oats, peanuts, figs, and truck crops. With 13 percent of the 1960 study area labor force employed in agriculture, farming remains one of the mainstays of the economy. In Texas, 8 percent of the 1960 labor force was employed in agriculture, while 6 percent of the Nation's labor force was employed in agriculture. The study area has continued to increase its output while losing more than 60 percent of its workers between 1940 and 1960.

Table VI-3

Population--Urban and Rural, and Population Per Square Mile for the Study Area, Texas, and the United States, 1910-1960

	Year	Total Population (1,000)	Percent Urban	Percent Rural	Population Per Sq. Mi.
Study Area	1910	587	N/A	N/A	33.4
	1920	619	24.5	75.5	35.2
	1930	671	28.6	71.4	38.1
	1940	670	32.7	67.3	38.1
	1950	715	47.8	52.2	40.6
	1960	789	60.1	39.9	44.8
Texas	1910	3,897	24.1	75.9	14.8
	1920	4,663	32.4	67.6	17.8
	1930	5,825	41.0	59.0	22.1
	1940	6,415	45.4	54.6	24.3
	1950	7,711	62.7	37.3	29.3
	1960	9,580	75.0	25.0	36.5
United States	1910	91,972	45.7	54.3	30.9
	1920	105,711	51.2	48.8	35.5
	1930	122,775	56.2	43.8	41.2
	1940	131,669	56.5	43.5	44.2
	1950	150,697	64.0	36.0	50.7
	1960	179,323	69.9	30.1	60.1

Source: Bureau of the Census 14/

Table VI-4

Agricultural Statistics for the Study Area Compared to Texas and the United States 1944, 1949, 1954, 1959

	1944	1949	1954	1959	Percent Change 1944-1959 Study Area	Texas	U.S.
Number of Farms	53,439	64,481	42,395	32,722	-39	- 41	-38
Acres of Cropland Harvested (1,000)	2,621	2,722	2,567	2,114	-19	- 19	- 3
Acres Irrigated	83,798	140,277	165,932	136,755	+63	+328	+62
Value of Crops Sold 1/	52,010	103,990	91,183	89,609	+72	+ 81	+59
Value of Livestock Sold 1/	48,786	52,022	58,287	95,828	+96	+ 71	+51
Total Value of Farm Products Sold 1/	100,796	156,012	149,470	185,437	+84	+ 76	+54

1/ Values in 1,000's of 1960 dollars.

Source: Bureau of the Census 15/

Mining

The study area's mineral production was valued at 285 million dollars in 1961. The bulk of minerals produced occurred in the gulf coast region of the study area. Brazoria County ranked first in natural gas production and third in total value of minerals produced in the State. Sizable quantities of the minerals extracted are processed by the numerous refineries, chemical and petrochemical installations in the area. A total of 38 million barrels of crude oil were produced in the study area in 1960. 2/ Sulphur is presently being commercially extracted from salt domes on the Texas gulf coast. However, between 1952 and 1961 extraction of sulphur from these sources declined more than 20 percent because of increased competition from other sources of sulphur including domestic and foreign frasch sulphur and domestic sulphur recovered from sour gas. 16/ Large lignite deposits in Milam County are strip-mined and used as a source of power for the aluminum plant at Rockdale.

Manufacturing

In 1960, 39,500 workers were employed in manufacturing in the study area. They accounted for 14.4 percent of the total labor force compared to 14.9 for Texas and 25.1 for the Nation. As shown in table VI-5, a study area value added by manufacturing was 638 million dollars in 1958. This value was 13 percent of the State total. Value added per worker in the study area was $17,527, while value added per worker in Texas was $10,854.

Table VI-5

Manufacturing Data for the Study Area
1939, 1947, 1954, 1959

	1939	1947	1954	1958
Number of Establishments	--	453	541	610
Number of Employees	--	24,471	32,855	36,403
Value Added by Manufacturing 1/ (1,000 1960 Dollars)	66,245	209,063	457,487	638,034
Value Added Per Worker	--	8,543	13,924	17,527

1/ Values estimated for counties where data was withheld to avoid disclosing figures for individual companies.

Source: Bureau of the Census 17/

Chemical production is the largest single manufacturing industry in Texas, as measured in annual net value of products. Chemical production had a net annual worth of more than a billion dollars in 1958. It is the newest, most rapidly growing large Texas industry. It is the leading Texas industry in capital expenditures per employee. By 1961 an estimated 3.7 billion dollars had been invested in gulf coast chemical plants. [2] As shown in table VI-2, 11,000 workers were employed by the chemical industry in the study area in 1960. These workers accounted for 27 percent in the manufacturing employment, compared to 9 and 5 percent respectively for Texas and the Nation. Study area employment in the chemical industry has increased 15-fold since 1940. Over 90 percent of those employed in the production of chemicals were located in Galveston and Brazoria Counties.

The gulf coast region also has numerous petroleum refineries, the largest being located in Texas City. The employment category, other nondurable goods (see table VI-2), contains those employed in petroleum refining. The rubber tire factory in Waco, which employes over 1,000 people, is also included in this category. Petroleum refining and rubber products account for most of those employed in other nondurable goods. Employment in other nondurable goods tripled between 1940 and 1960.

Over 5,000 workers were employed by the food and kindred processing industry in 1960. The larges of these food processors in the study area is the sugarcane refinery located at Sugarland in Fort Bend County. Other food processing includes a brewery, meat processing, canneries, and food processing normally associated with urban areas such as bakeries, dairies, etc.

Other significant manufacturing includes: aluminum reduction, magnesium reduction, tin and tungsten smelting, ship building, furniture and fixtures, apparel, printing and publishing, leather, stone, clay, and glass products.

As described in Chapter IV, the study area was divided into four major subareas to facilitate determination of water requirements to be satisfied from the Navasota River watershed. Significant economic data for each subarea are shown in table VI-6.

Table VI-6

Changes of Major Economic Indicators for Subareas for Period Shown

	Subarea 1	Subarea 2	Subarea 3	Subarea 4
Disposable Per Capita Personal Income (1960 Dollars)				
1940	806	585	618	891
1960	1,537	1,180	1,357	1,617
% Change	+91	+102	+120	+81
Population				
Total 1920	162,470	136,534	167,818	152,035
1960	195,004	110,874	180,795	302,088
% Change	+20	-19	+8	+99
Urban 1920	52,867	17,590	29,265	51,830
1960	135,125	55,068	89,553	194,487
% Change	+156	+213	+206	+275
Value of Farm Products Sold (1,000 1960 Dollars)				
1944	24,442	17,673	32,143	29,348
1959	41,057	35,701	54,260	54,377
% Change	+68	+102	+69	+85
Value of Minerals Produced (1,000 1960 Dollars)				
1952	2,896	2,647	584	242,954
1961	4,621	6,527	6,387	261,832
% Change	+60	+147	+994	+8
Value Added by Manufacturing (1,000 1960 Dollars)				
1939	18,501	2,803	6,328	38,613
1958	94,401	10,792	41,805	491,037
% Change	+410	+285	+561	+1,172

Source: Corps of Engineers 1/, Bureau of the Census 14 15 17/
Bureau of Mines 16/

Future

Future economic growth of the Navasota River study area will be determined by the conditions of the national economy, the development of natural and human resources in the study area, and the development and protection of the water resources of the lower Brazos River basin.

The Nation's expected economic growth can best be expressed by indicators of income, employment, and population. Gross national product (GNP) is expected to exceed 5 trillion dollars by 2025, with per capita disposable income rising from less than $2,000 in 1960 to about $6,700 per capita by 2025. Present indications are that the total employment will be over 200,000,000 and the total population will reach nearly 550,000,000 by 2025. 18/ These indications reflect a thriving national economy in which the lower Brazos River basin will participate. Since the growth of the study area is expected to be closely related to national growth, the degree in which growth will occur in the study area will depend on its ability to compete with other regions of the United States in the production of goods and services.

In response to increasing regional and national demands for its products, agriculture in the study area is expected to increase its output. Continued emphasis on specialized crops and livestock programs will enable the study area to continue to increase its output while losing agricultural workers.

Oil and gas production in the study area is expected to continue to provide feed stocks for the expanding gulf coast refineries and petrochemical industries. Continuing production is possible with presently known reserves and secondary recovery by gas and water injection.

Manufacturing will be a major factor in the future growth of the study area. By 2025, manufacturing employment is expected to account for about 20 percent of the total labor force, which approaches the present proportion of manufacturing employment in industrial cities of the south-central States. This increased manufacturing activity will be a result of continued development of resource-oriented industries, as well as increased processing of imported products. Growth will also occur in market-oriented manufacturing to serve the increasing local and regional demands caused by continued growth of the study area and the rapidly expanding southwestern markets.

Significant growth in the petrochemical industry is expected in the study area. According to Resources for the Future's medium projection 19/, national requirements for petroleum based intermediates used in manufacturing of synthetics will increase 8-fold between 1960 and 2000. The study area has a definite advantage in the production of these intermediates with large amounts of petroleum and natural gas available to be used as inputs for the petrochemical process. The study area also has advantages of water transportation in import and export of products to be processed in the petrochemical industry. These factors, plus the fast growing southwestern market, indicate a high level of production for petrochemicals in the study area. Petrochemical employment is expected to more than double by 2025.

Food processing is projected to expand with industrialization and urbanization of the study area. Total employment in food and kindred processing is expected to reach approximately 23,000 by 2025. Most of this growth is expected to occur near the urban complexes in the upper and lower portions of the study area.

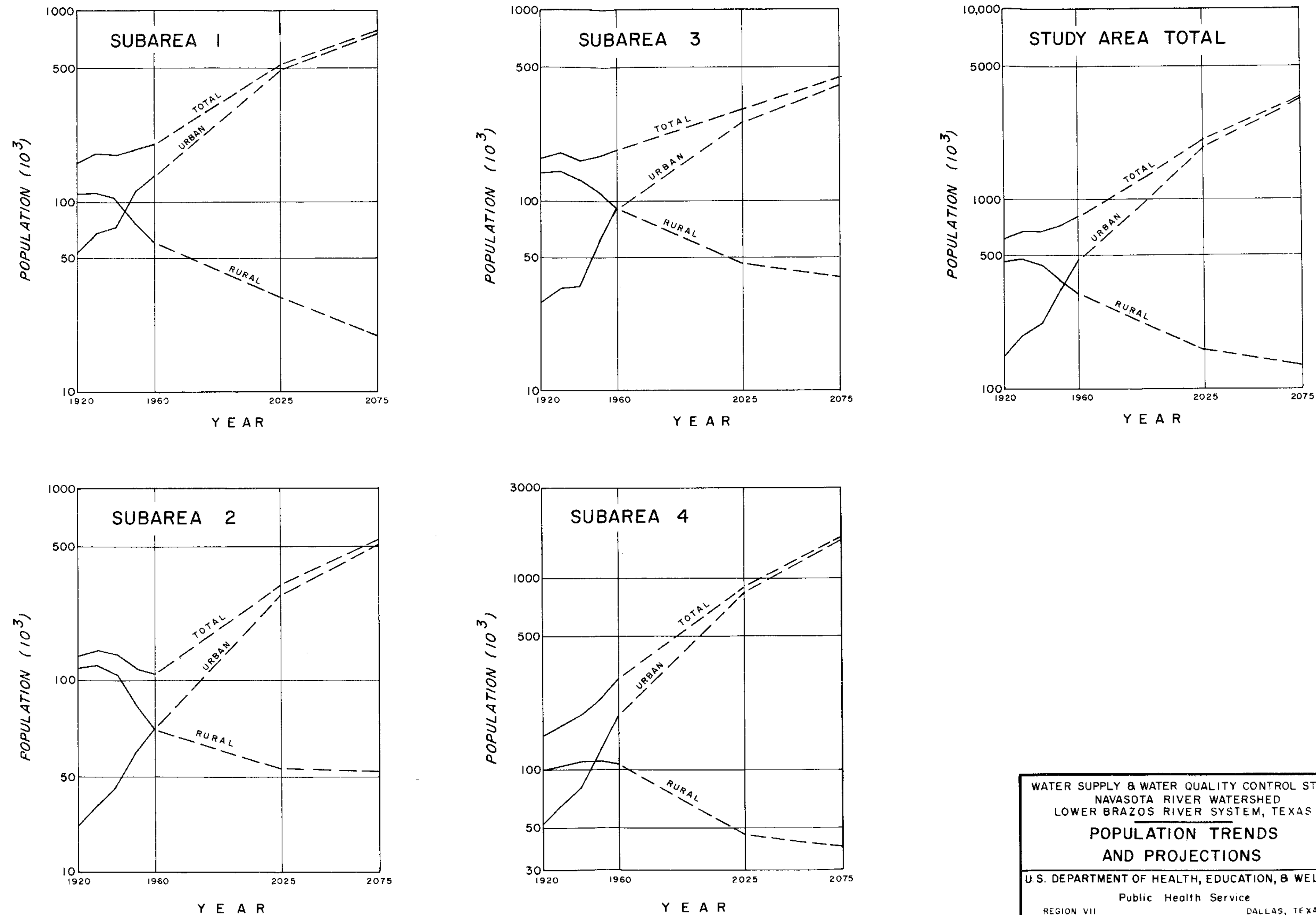
Significant increases of other manufactured products are expected. Much of these increases will be experienced in industries which regard market, transportation, and labor as the most important factors of production. Fabricated metals, machinery, transportation equipment, apparel, and other durable goods are examples of this type of manufacturing. Since many of these industries depend on imported materials, the gulf coast portion of the study area enjoys a competitive advantage to attract more of these manufacturers. The Galveston shipbuilding industry will form a nucleus for this type of growth.

To facilitate determination of municipal and industrial water requirements, employment and population projections were made for each of the 4 subareas shown in figure III-1. Employment projections to 2025 and 2075 for each subarea appear in table VI-7. Table VI-8 and figure VI-1 depict the anticipated population growth of the 4 subareas to 2075.

Table VI-7

Subarea Labor Force Projections
1960, 2025, 2075 (Part 1 of 4 - Subarea 1)

	1960		2025		2075	
	Number	Percent	Number	Percent	Number	Percent
Agriculture (Forestry & Fisheries)	7,541	10.6	2,800	1.4	2,800	.9
Mining, Total (SIC 13, 14)	76	.1	150	.1	250	.1
Manufacturing	11,243	15.8	32,450	16.7	52,350	17.5
Resource Oriented	6,983	9.8	19,200	9.9	29,700	9.9
Furn., Lbr., Wood (24, 25)	1,278	1.9	2,900	1.5	5,200	1.7
Pri. Metals (SIC 33)	12	-	250	.1	550	.2
Food & Kindred (SIC 20)	1,835	2.6	5,900	3.0	8,500	2.8
Chem. & Allied (SIC 28)	309	.4	700	.4	1,400	.5
Stone, Clay, Glass (SIC 32)	1,442	2.0	3,500	1.8	6,150	2.1
Other Nondurables (SIC 26, 29, 30, 31)	2,107	2.9	5,950	3.1	7,900	2.6
Nonresource Oriented	4,260	6.0	13,250	6.8	22,650	7.6
Fab. Metal (SIC 34, 35, 36, 37, 38)	1,329	1.9	5,700	2.9	9,400	3.1
Textiles (SIC 22, 23)	2,037	2.9	6,400	3.3	11,700	3.9
Print., Publ., NEC (SIC 27, 39)	894	1.2	1,150	.6	1,550	.6
Service and Other	48,745	68.6	151,360	77.8	232,600	77.5
Unemployed	3,474	4.9	7,740	4.0	12,000	4.0
TOTAL LABOR FORCE	71,079	100.0	194,500	100.0	300,000	100.0



WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

POPULATION TRENDS AND PROJECTIONS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE VI-1

96-129 O-68 (Face p. 162)

Table VI-7

Subarea Labor Force Projections
1960, 2025, 2075 (Part 2 of 4 - Subarea 2)

	1960		2025		2075	
	Number	Percent	Number	Percent	Number	Percent
Agriculture (Forestry & Fisheries)	7,386	19.5	4,100	3.4	4,100	2.0
Mining, Total (SIC 13, 14)	241	.6	400	.3	650	.3
Manufacturing	2,648	7.0	34,600	28.6	58,700	28.5
Resource Oriented	1,830	4.8	28,000	23.1	47,000	22.8
Furn., Lbr., Wood (SIC 24, 25)	518	1.4	4,600	3.8	7,950	3.9
Pri. Metlas (SIC 33)	52	.1	4,300	3.6	7,000	3.4
Food & Kindred (SIC 20)	618	1.6	7,450	6.2	13,150	6.4
Chem. & Allied (SIC 28)	146	.4	3,700	3.0	5,600	2.7
Stone, Clay, Glass (SIC 32)	150	.4	1,300	1.0	2,300	1.1
Other Nondurables (SIC 26, 29, 30, 31)	346	.9	6,650	5.5	11,000	5.3
Nonresource Oriented	818	2.2	6,600	5.5	11,700	5.7
Fab. Metal (SIC 34, 35, 36, 37, 38)	203	.6	3,150	2.6	5,550	2.7
Textiles (SIC 22, 23)	370	1.0	1,500	1.2	2,800	1.4
Print., Publ., NEC (SIC 27, 39)	245	.6	1,950	1.7	3,350	1.6
Service and Other	25,819	68.1	77,100	63.7	134,300	65.2
Unemployed	1,837	4.8	4,800	4.0	8,250	4.0
TOTAL LABOR FORCE	37,931	100.0	121,000	100.0	206,000	100.0

Table VI-7

Subarea Labor Force Projections
1960, 2025, 2075 (Part 3 of 4 - Subarea 3)

	1960		2025		2075	
	Number	Percent	Number	Percent	Number	Percent
Agriculture (Forestry & Fisheries)	10,708	19.2	5,150	4.5	5,150	3.1
Mining, Total (SIC 13, 14)	550	1.0	1,050	.9	1,650	1.0
Manufacturing	5,412	9.7	18,050	15.9	32,250	19.5
Resource Oriented	3,939	7.1	13,700	12.0	24,450	14.8
Furn., Lbr., Wood (SIC 24, 25)	1,144	2.1	4,000	3.5	7,500	4.5
Pri. Metals (SIC 33)	915	1.6	2,800	2.4	4,950	3.0
Food and Kindred (SIC 20)	642	1.2	2,900	2.5	4,850	2.9
Chem. & Allied (SIC 28)	170	.3	450	.4	950	.6
Stone, Clay, Glass (SIC 32)	643	1.1	2,100	1.8	3,800	2.3
Other Nondurables (SIC 26, 29, 30, 31)	434	.8	1,450	1.4	2,400	1.5
Nonresource Oriented	1,473	2.6	4,350	3.9	7,800	4.7
Fab. Metal (SIC 34,35, 36, 37, 38)	559	1.0	2,050	1.8	3,500	2.1
Textiles (SIC 22, 23)	350	.6	1,450	1.4	2,900	1.8
Print., Publ., NEC (SIC 27, 39)	564	1.0	850	.7	1,400	.8
Service and Other	36,367	65.4	85,000	74.7	119,600	72.4
Unemployed	2,616	4.7	4,500	4.0	6,550	4.0
TOTAL LABOR FORCE	55,653	100.0	113,750	100.0	165,200	100.0

Table VI-7

Subarea Labor Force Projections
1960, 2025, 2075 (Part 4 of 4 - Subarea 4)

	1960		2025		2075	
	Number	Percent	Number	Percent	Number	Percent
Agriculture (Forestry & Fisheries)	10,490	9.6	6,600	2.0	6,600	1.0
Mining, Total (SIC 13, 14)	2,241	2.0	6,050	1.8	10,000	1.6
Manufacturing	20,201	18.5	77,550	22.9	118,800	18.6
Resource Oriented	16,935	15.5	54,350	16.0	75,550	11.8
Furn., Lbr., Wood (SIC 24, 25)	339	.3	1,050	.3	2,250	.4
Pri. Metals (SIC 33)	399	.4	6,000	1.8	11,600	1.8
Food & Kindred (SIC 20)	2,053	1.9	6,900	2.0	14,650	2.3
Chem. & Allied (SIC 28)	10,397	9.5	31,850	9.4	32,150	5.0
Stone, Clay, Glass (SIC 32)	284	.3	3,350	1.0	6,800	1.1
Other Nondurables (SIC 26, 29, 30, 31)	3,463	3.1	5,200	1.5	8,100	1.2
Nonresource Oriented	3,266	3.0	23,200	6.9	43,250	6.8
Fab. Metal (SIC 34, 35, 36, 37, 38)	2,269	2.1	17,250	5.1	32,500	5.1
Textiles (SIC 22, 23)	318	.3	4,200	1.3	8,800	1.4
Print., Publ., NEC (SIC 27, 39)	679	.6	1,750	.5	1,950	.3
Service and Other	71,619	65.4	234,700	69.3	476,350	74.8
Unemployed	4,882	4.5	13,550	4.0	25,550	4.0
TOTAL LABOR FORCE	109,433	100.0	338,450	100.0	637,300	100.0

Table VI-8

Subarea Population Projections
1960, 2025, 2075 (1,000's)

Subarea Year	Urban	Rural	Total
I			
1960	135	60	195
2025	480	33	513
2075	751	20	771
II			
1960	55	56	111
2025	286	36	322
2075	510	34	544
III			
1960	90	91	181
2025	255	47	302
2075	395	40	435
IV			
1960	194	108	302
2025	857	46	903
2075	1,611	40	1,651
TOTAL			
1960	474	315	789
2025	1,878	162	2,040
2075	3,267	134	3,401

VII. WATER REQUIREMENTS

General

The term water requirements, as applied to an area the size of the lower Brazos River basin, encompasses several uses which are dependent upon a large number of variables. Although primarily concerned with water requirements for municipal, industrial, and water quality control purposes, this study examines all of the consumptive uses of water as they affect the supply and demand for water within the basin.

Types of Water Use

Municipal

Municipal water as defined here includes residential, commercial, public, and those industrial uses which can reasonably be reflected in a per capita use figure. Also included in the per capita quantities are losses in distribution systems and treatment plant attentuation.

Industrial

The definition of industrial water use in this study refers to all water except that supplied from municipal systems which is used by the manufacturing industries (Standard Industrial Classification Categories 13, 14, and 20 through 39). 20/

Power Generation

Use of water for thermal power generation is a part of the industrial requirement that has been determined separately. Although withdrawal for this purpose is very large, only the consumptive use is studied.

Rural

An estimate of the rural water use was made so as not to understate the total study area water requirements. As referred to in this investigation, rural water requirements are assumed to consist of domestic water for that portion of the population not served by municipal water systems and water for the maintenance of livestock.

Irrigation

Another important water use in the study area is irrigation. These requirements are included, since (1) return flows from this use affect the quality of the study area's water, and (2) a fully integrated water supply plan must include irrigation, especially in

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an area where it represents a considerable portion of the demand on the potential water resource. Historic as well as projected quantities of water for this use were provided by the Corps of Engineers based on U.S. Study Commission-Texas values. [1/]

Base Year Water Use

The year 1958 was selected as the base for the water use study because it was the most recent year for which reliable data from served sources were available. The 1958 study area water use by type is shown in table VII-1.

Table VII-1

Study Area Base Year Water Use

Subarea	1958 Water Use in MGD: Municipal	Industrial[a/]	Rural	Irrigation	Total
1	19.4	3.8	6.0	6.0	35.2
2	10.9	1.5	5.6	39.1	57.1
3	14.9	5.9	9.1	12.2	42.1
4	29.9	252.1	10.8	269.7	562.5
Total Study Area	75.1	263.3	31.5	327.0	696.9

a/ Includes consumptive use for thermal power generation.

Source: Public Health Service [21/], Texas Board of Water Engineers [4 22 23/] University of Texas [3/], and Census of Manufactures [24/]

Similar estimates by basin and subbasins are shown in table VII-2.

Table VII-2

Basin and Subbasin Base Year Water Use

Basin	1958 Water Use in MGD: Municipal	Industrial[a/]	Rural	Irrigation	Total
Lower Brazos*	53.2	123.2	22.4	190.2	389.0
Navasota	8.1	0.3	2.5	7.6	18.5
Aquilla Creek	1.6	Negligible	0.7	0.1	2.4
Intervening Coastal Area	18.9	115.7	3.3	118.8	256.7

a/ Includes consumptive use for thermal power generation.
* Includes the Navasota River and Aquilla Creek basins.

Future Water Requirements

Estimates of water requirements for the years 2025 and 2075 for the several types of water use (excluding irrigation) in the study area were made using the technique of combining projected unit uses with economic and population projections. Rural per capita use was assumed to remain constant from 2025 to 2075. Irrigation requirements were furnished by the Corps of Engineers based on U.S. Study Commission-Texas values. 1/

Municipal

The several items considered in making projections of per capita municipal water use for this study are as follows:

1. Past Trends - analysis of records from municipalities and industries.

2. Characteristics of the Subarea - factors peculiar to an area such as per capita income and precipitation.

3. Analysis of Projections by Others - projections made by other governmental agencies, consulting engineers, and the municipalities themselves.

4. Judgment - after considering and weighing the above factors, discrepancies which existed were resolved by judgment.

Present and projected values of per capita municipal use are shown in table VII-3.

Table VII-3

Municipal Per Capita Water Use
(in gal/day)

Subarea	1958	2025	2075
1	121	170	185
2	98	165	180
3	111	170	185
4	101	150	165

Industrial

Base year data on industrial water use were combined with employment data and resulted in a unit water use per employee for each of the industrial categories (Standard Industrial Classification 13, 14, and 20-39). Considerations involved in economic projections of the labor force required consolidation of some of the industrial categories into groups, as shown in table VII-4.

In order to project unit industrial water use, the following assumptions were made:

1. In presently undeveloped counties where large future developments are projected, the base year unit employee water uses were adjusted to those of surrounding counties where present conditions approach those forecasted for the undeveloped counties.

2. An average net productivity factor (i.e., the multiplier to obtain unit employee use for the years 2025 and 2075 from 1958 data) was determined as follows: Unit employee industrial water use projections of Resources for the Future, Inc., and the Business and Defense Services Administration prepared for the Senate Select Committee on National Water Resources [25] were extrapolated and an average curve constructed. The ratio of the 2025 and 2075 values to the 1958 value on the average curve gave the productivity factors of 2.1 and 2.6 for 2025 and 2075, respectively.

Special consideration was given to the water requirements for the chemical industry along the gulf coast. It was decided to determine a range of values based on the amount of in-plant recirculation. The amount of recirculation in this case is a function of the availability and cost of water. It seems reasonable to assume that as long as water is available at present prices, the recirculation practices will not be changed. This condition is represented by the high figures in table VII-4 and the upper curve of figure VII-1.

On the other hand, restrictions in the availability of water and increases in water costs will result in reduced requirements. These conditions are inducive to in-plant water conservation (recirculation and/or air cooling) and are dictated by the industry's economy. This condition is represented by the low figures in table VII-4 and the lower curve of figure VII-1.

It is expected that a transition from the high to low requirements will take place over a period of time as water availability and costs change. This transition is shown on figures VII-2, VII-3, and VII-6, and will be further discussed in Section IX of this report.

Unit industrial water use by subareas for all industries in the years 2025 and 2075 is shown in table VII-4.

In addition to fresh water, the chemical industry along the gulf coast uses about 2,500 mgd of brackish water for cooling.

Power Generation

Consumptive use of water for thermal power generation is considered to be a part of the industrial requirement but is determined separately. Information on future water use was gathered from power companies in the area and combined with data developed by the Federal Power Commission and the Edison Electric Institute for the Senate Select Committee on National Water Resources. Consideration was given to the general locations of future power generation installations and the projected needs apportioned throughout the study area using hypothetical service areas for the several generating plants.

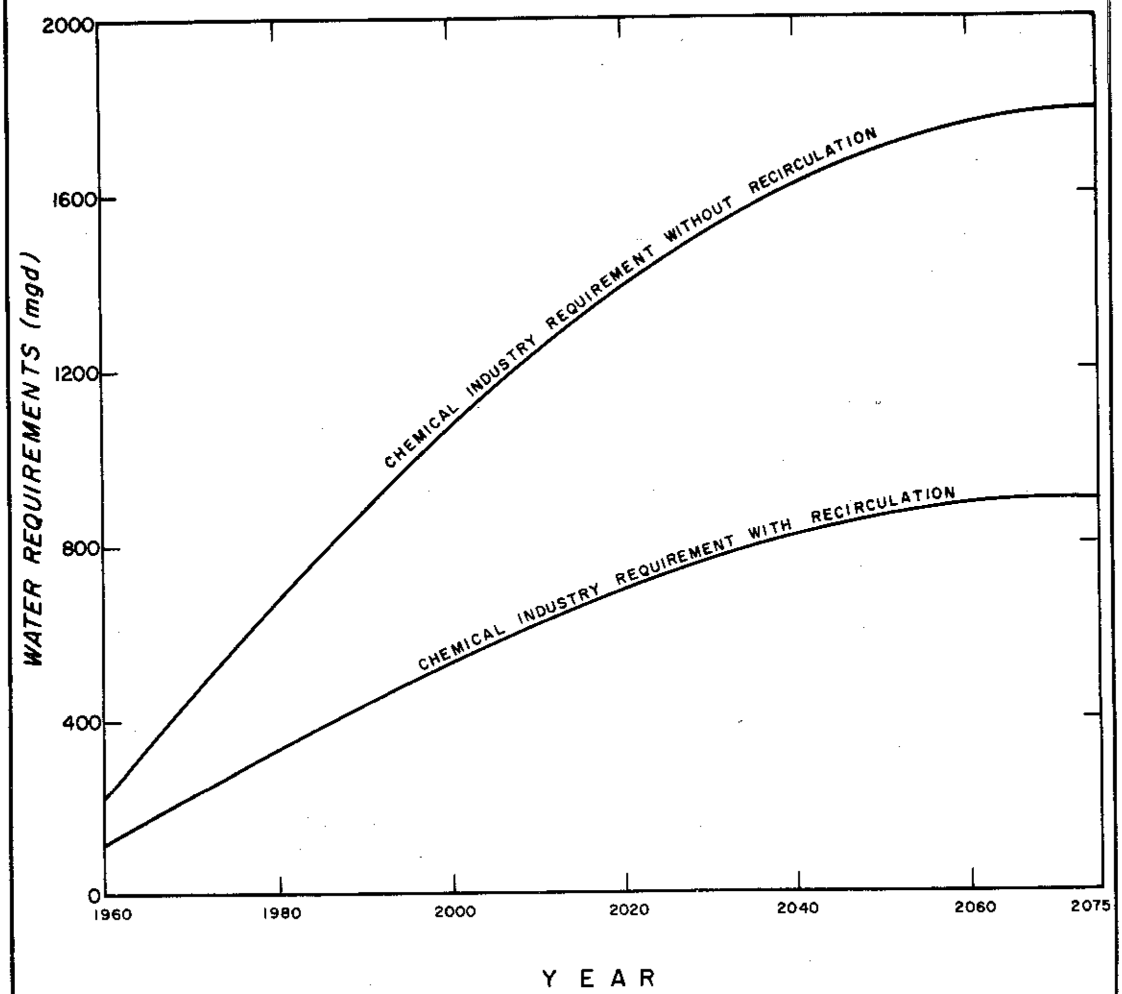
Rural

For purposes of this study, the rural water requirements are assumed to consist of domestic water for that portion of the population not served by municipal water systems and water for the maintenance of livestock. The 2025 and 2075 requirements for rural water are based on a rural per capita use of 180 gallons per day, of which 80 gpcd is for the maintenance of livestock.

The estimated future study area water requirements by subareas are shown in table VII-5.

Similar estimates of future water use for the basin and subbasins are shown in table VII-6.

Graphic illustrations of the water requirements for the study area, basin, and subbasins are shown in figures VII-2 through VII-6.

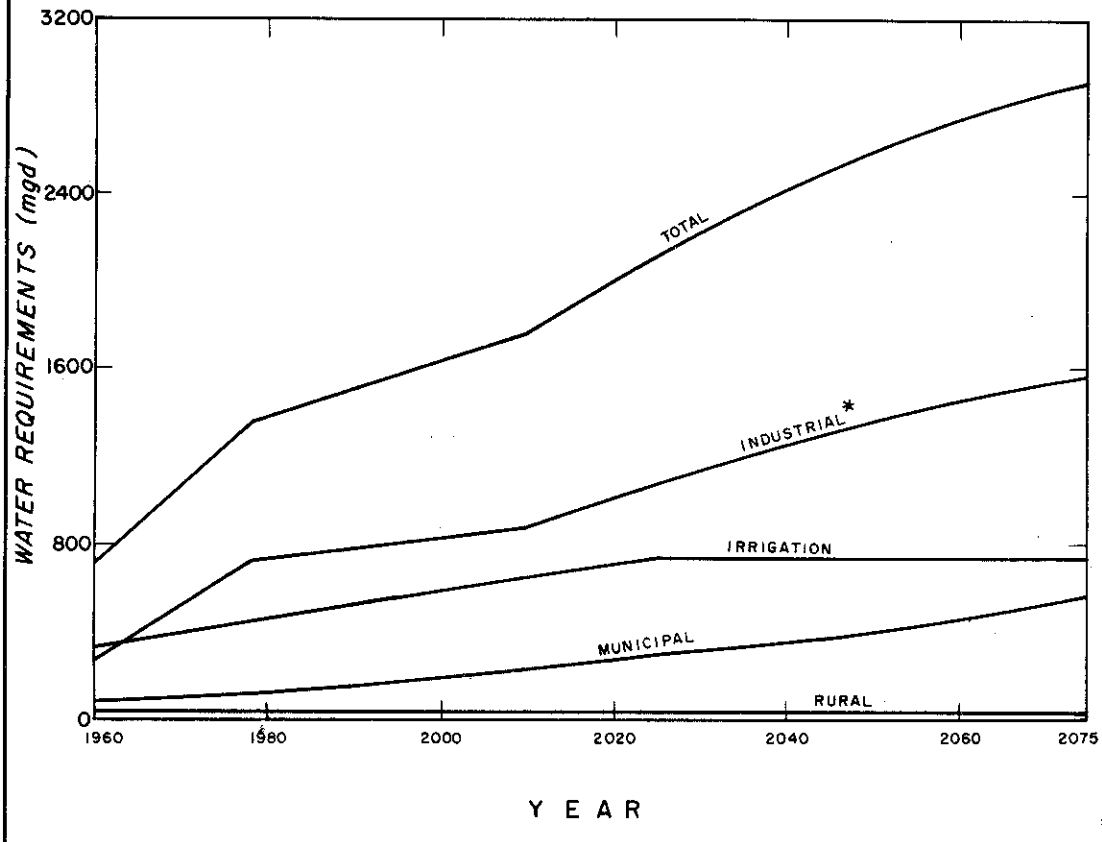


WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

CHEMICAL INDUSTRY WATER REQUIREMENTS LOWER BRAZOS BASIN BELOW NAVASOTA RIVER (INCLUDES INTERVENING COASTAL AREA)

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE VII-1



* INCLUDES CONSUMPTIVE USE FOR THERMAL POWER GENERATION

WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

STUDY AREA
WATER REQUIREMENTS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
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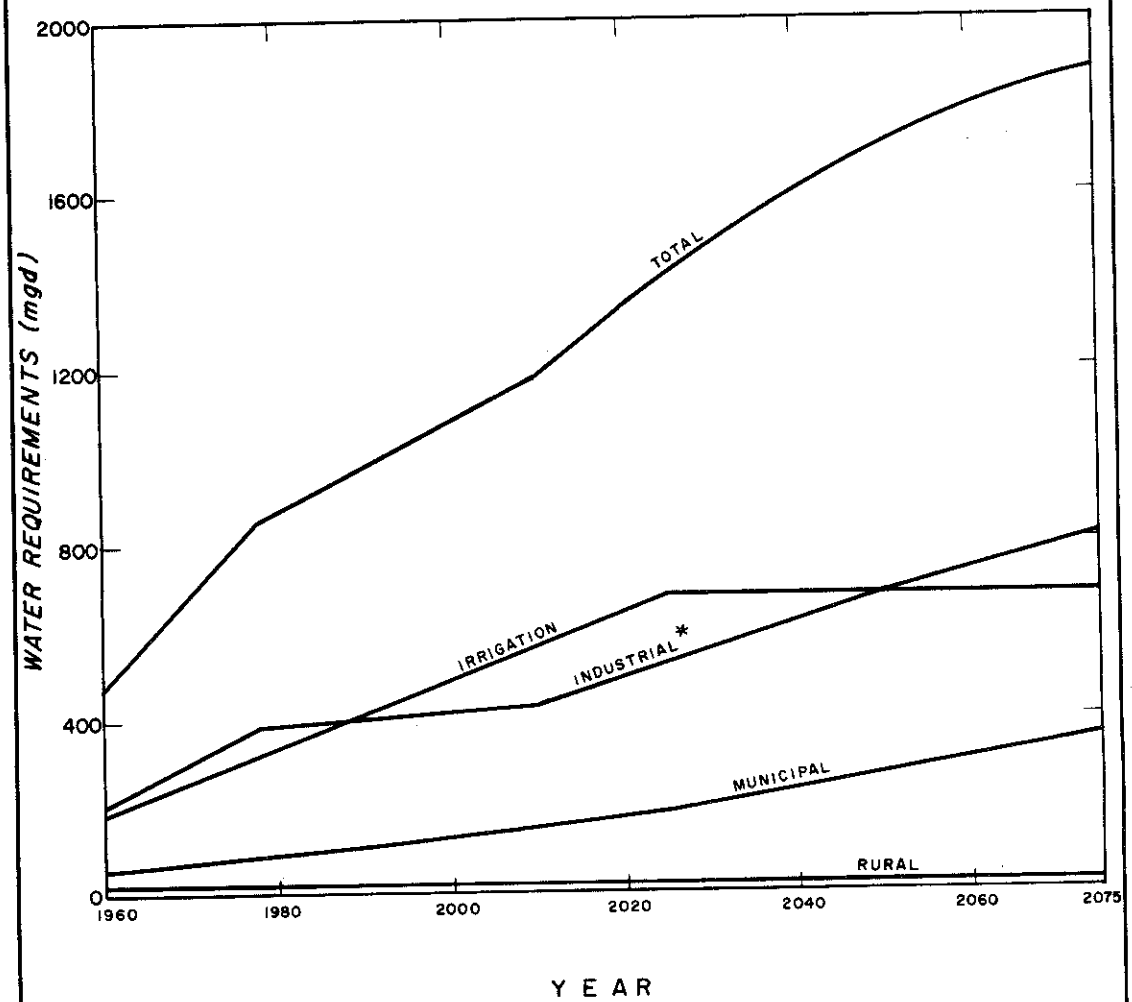
FIGURE VII-2



* INCLUDES CONSUMPTIVE USE FOR THERMAL POWER GENERATION

a/ INCLUDES NAVASOTA RIVER AND AQUILLA CREEK WATERSHEDS

WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

LOWER BRAZOS RIVER BASIN a/
WATER REQUIREMENTS

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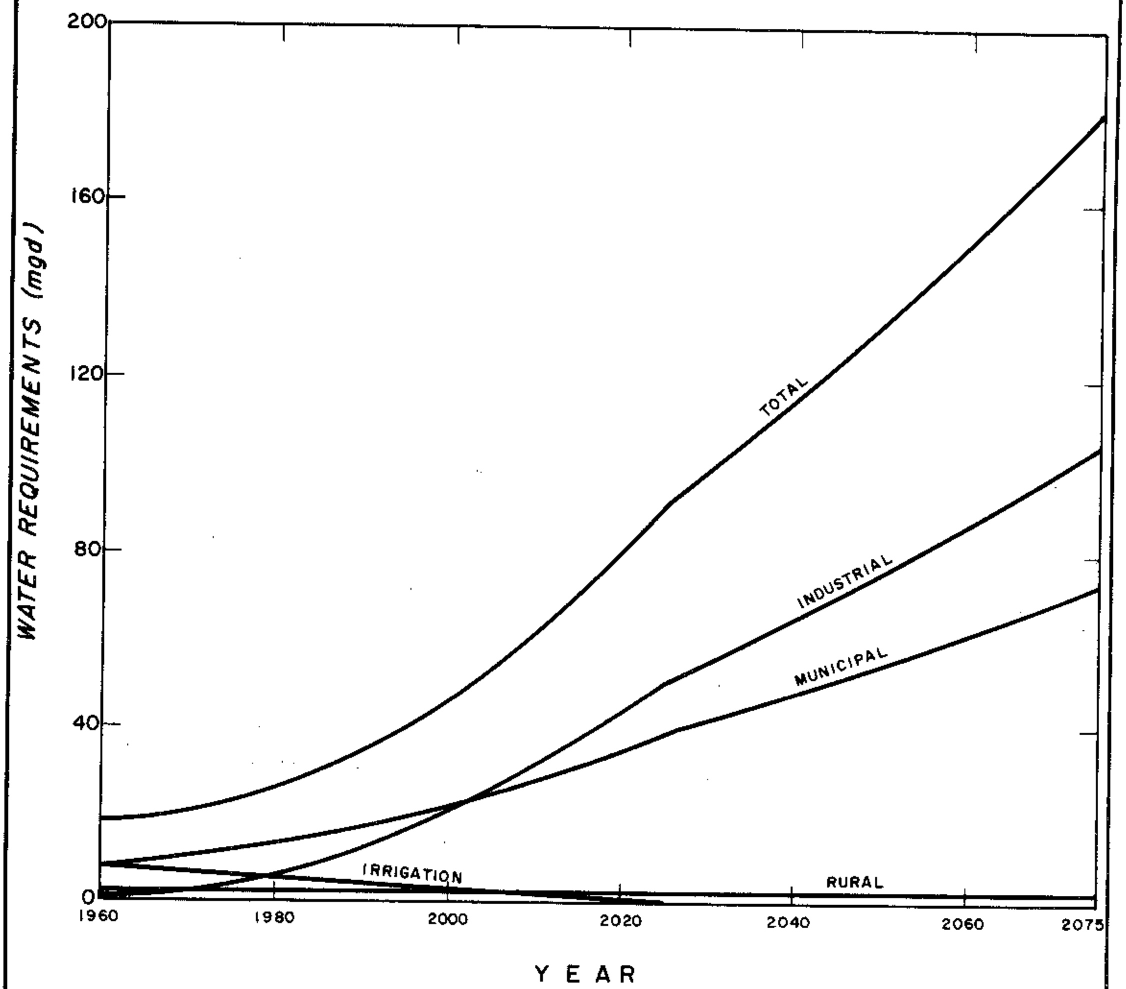
FIGURE VII-3



WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

NAVASOTA RIVER WATERSHED
WATER REQUIREMENTS

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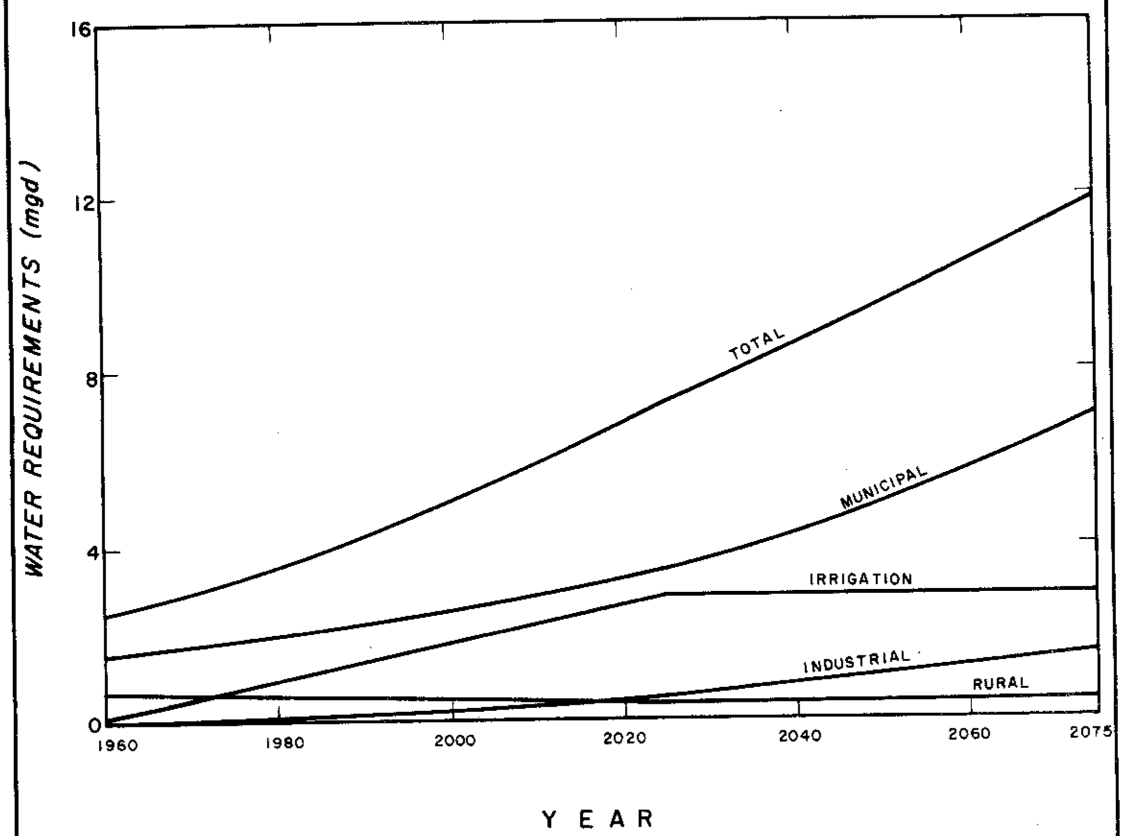
FIGURE VII-4

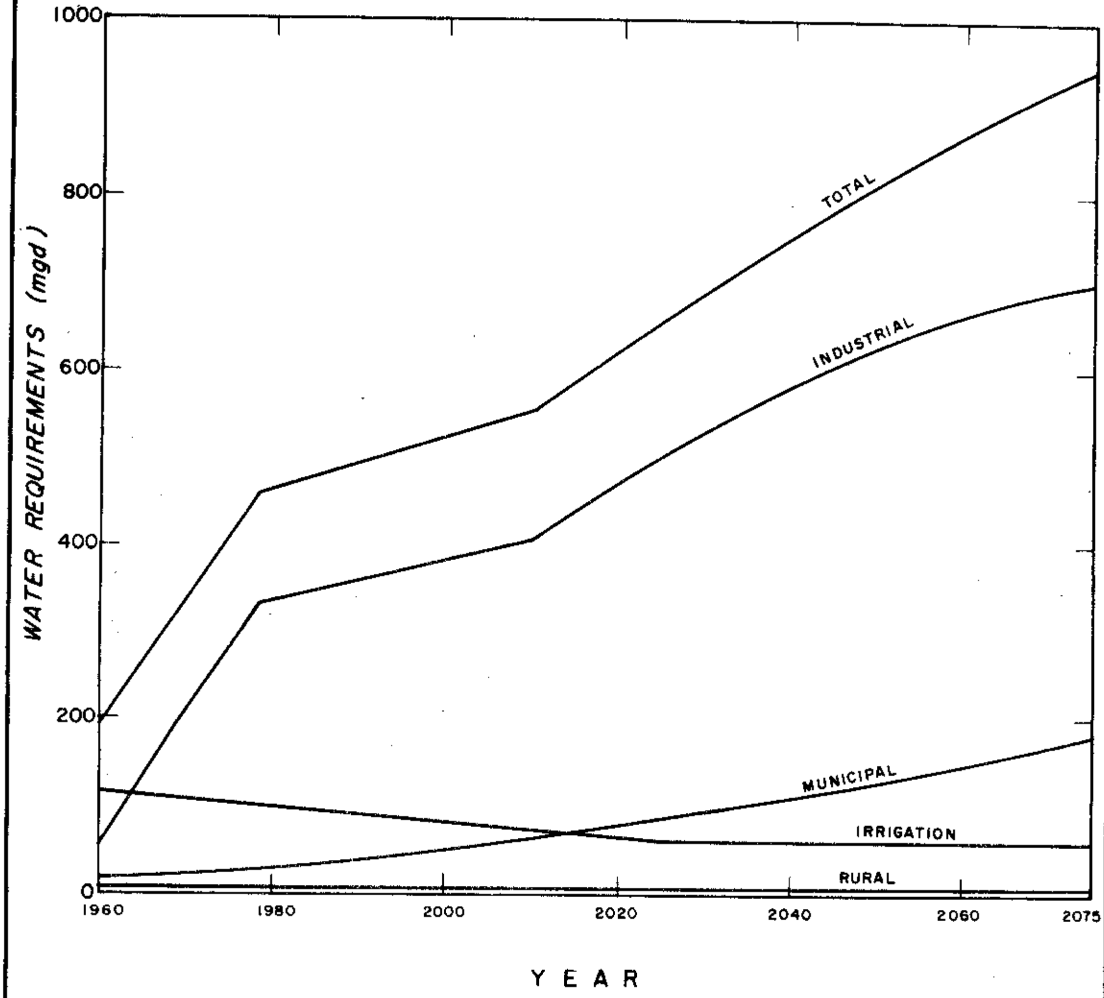


WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

AQUILLA CREEK WATERSHED
WATER REQUIREMENTS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE VII-5



WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

INTERVENING COASTAL AREA
WATER REQUIREMENTS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE VII-6

Table VII-4

Future Unit Industrial Water Use
(gal. per employee day)

Item	Subarea 1		Subarea 2		Subarea 3		Subarea 4	
	2025	2075	2025	2075	2025	2075	2025	2075
Mining (SIC 13, 14)	50	70	203	250	132	164	2,260	2,800
Manufacturing								
Furniture, Lumber & Wood(SIC 24, 25)	190	230	228	280	175	217	670	830
Primary Metals (SIC 33)	1,650	2,040	1,593	1,970	1,400	1,700	4,410	5,450
Food & Kindred (SIC 20)	450	560	1,446	1,790	530	660	2,680	3,320
Chemicals & Allied Products (SIC 28)	1,050	1,300	198	250	1,010	1,250	23,100-* 56,000	28,600- * 57,000
Stone, Clay, and Glass Products (SIC 32)	880	1,090	44,965	55,670	2,670	3,300	3,080	3,810
Petroleum (SIC 29)	530	660					10,400	12,880
Pulp and Paper (SIC 26)	210	280	491	610	500	620	5,250	6,500
Other Nondurables (SIC 30, 31)	510	630					320	390
Fabricated Metals (SIC 34, 35, 36, 37, 38)	170	210	163	200	150	186	210	270
Textile & Apparel (SIC 22, 23)	160	190	150	190	143	177	140	180
Printing & Publishing and Not Elsewhere Classified (SIC 27, 39)	40	50	40	50	40	50	40	50

* Exact value is dependent upon prevailing recirculation practices of the chemical industry on the gulf coast. See discussion on page 170

Table VII-5

Future Study Area Water Requirements
(mgd)

Subarea	Municipal	Industrial*	Rural	Irrigation	Total
		For the Year 2025			
1	81.7	18.1	5.9	122.5	228.2
2	47.2	82.5	6.6	162.8	299.1
3	43.6	38.0	8.5	204.7	294.8
4	129.4	809.5 - 1614.4**	8.3	256.9	1204.1 - 2009.0**
TOTAL	301.9	948.1 - 1753.0**	29.3	746.9	2026.2 - 2831.1**
		For the Year 2075			
1	139.0	59.0	3.6	122.5	324.1
2	91.6	177.8	6.1	162.8	438.3
3	73.3	81.7	7.1	204.7	366.8
4	267.3	1247.5 - 2142.1**	7.2	256.9	1778.9 - 2673.5**
TOTAL	571.2	1566.0 - 2460.6**	24.0	746.9	2908.1 - 3802.7*

* Includes consumptive use for thermal power generation.
** Exact value is dependent upon prevailing recirculation practices of the chemical industry on the gulf coast. See discussion on page 170

Table VII-6

Future Basin and Subbasin Water Requirements
(mgd)

Basin	Municipal	Industrial[a]	Rural	Irrigation	Total
For the Year 2025					
Lower Brazos[b]	201.2	510.4 - 819.6[c]	21.4	685.4	1418.4 - 1727.6[c]
Navasota	38.5	50.1	2.5	0	91.1
Aquilla Creek	3.4	0.6	0.5	2.9	7.4
Intervening Coastal Area	87.6	503.1 - 915.3[c]	2.0	61.5	654.2 - 1066.4[c]

Municipal, industrial, and rural water requirements for the lower Brazos River basin, including the intervening coastal area, are 1,325.7 mgd in 2025.

Basin	Municipal	Industrial[a]	Rural	Irrigation	Total
For the Year 2075					
Lower Brazos[b]	363.4	819.6 - 1203.0[c]	16.5	685.4	1884.9 - 2268.3[c]
Navasota	73.0	105.7	2.3	0	181.0
Aquilla Creek	7.0	1.6	0.5	2.9	12.0
Intervening Coastal Area	182.0	704.8 - 1215.9[c]	2.0	61.5	950.3 - 1461.4[c]

Municipal, industrial, and rural water requirements for the lower Brazos River basin, including the intervening coastal area, are 2,088.3 mgd in 2075.

a/ Includes consumptive use for thermal power generation.
b/ Includes the Navasota River and Aquilla Creek basins.
c/ Exact value is dependent upon prevailing recirculation practices of the chemical industry on the gulf coast. See discussion on page 170

VIII. WATER QUALITY CONTROL

General

Water quality control is defined as any measure employed to enhance the utility, value, and attractiveness of waters used for purposes which are affected by changes in water quality. Waters in nature are never PURE in the strict chemical sense of the word. More often than not, however, natural waters are fit for use by man in his pursuit of normal endeavors. This use and subsequent return of waste almost always causes some degradation of water quality downstream, even after provision of secondary waste treatment. As population and the associated demand for water increase, this degradation of the water resource increases. Presently, water quality is controlled by providing the best available waste treatment. When further water quality improvement is needed, this treatment is supplemented by the provision of additional water to dilute the treated wastes. This, then, is the method of water quality control with which this report is concerned.

Municipal, Industrial, and Agricultural Pollution

Stream Loading

The determination of the quantity and quality of return flows expected to reach a stream is the first step necessary in analyzing water needs for quality control.

The quantity of municipal and industrial return flows is estimated as a percentage of water use. The municipal return flow percentages used vary from 34.5 percent to 76.0 percent, 26/ while industrial return flow percentages vary from 23 percent to 90 percent. 9/

The quality of municipal return flow is based on assumed per capita contributions of 0.23 pounds per day of total dissolved solids and 0.25 pounds per day of ultimate first-stage BOD.

The contribution of total dissolved solids resulting from industrial use varies from 1.2 tons per million gallons to 12.2 tons per million gallons of return flow. 9/ For the BOD contribution from industry, it was assumed that final industrial effluents which discharge wastes containing BOD would have the same concentration as a municipal sewage that has been treated to remove 85 percent of the BOD. This concentration is 56 mg/l ultimate first-stage BOD assuming a typical municipal sewage has an untreated concentration of 370 mg/l ultimate first-stage BOD.

It was assumed that there would be no return flow resulting from rural water use.

Irrigation return flows were assumed to be one-third of the water applied for that purpose, and it was further assumed that all of the dissolved solids in the irrigation source water would be returned to the stream. 27/

Present and projected municipal and industrial return flows, population equivalents, and total dissolved solids loads are shown in Appendix A of this report.

Water Quality Objectives

Of the indicators presently available as a measure of water quality, dissolved oxygen and total dissolved solids were chosen for use in this study. The principal causes of pollution in this river basin are (1) natural mineral pollution of the upper watershed which contributes a variety of chemical constituents that can best be described as total dissolved solids*; (2) domestic sewage and a large variety of industrial wastes, both of which contribute BOD and total dissolved solids; and (3) irrigation return flows. Water quality control requirements are based on the assumption that sufficient waste treatment will be provided for the manmade portion of the pollution to remove 85 percent of the BOD and none of the total dissolved solids.**

Water to regulate quality is assumed to be needed when the dissolved oxygen content of the stream drops below 4 mg/l# and/or when the total dissolved solids reach 1,000 mg/l.##

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* This source of pollution is much greater than all other pollution sources in the Brazos River basin and was previously discussed in Section V.

**With conventional treatment methods currently used, removal of some of the total dissolved solids probably occurs; however, this removal can be considered as incidental rather than planned and no reliable estimates of the quantity so removed are available.

\# The lower limit of 4 mg/l of dissolved oxygen was used since (1) it provides an acceptable environment for most aquatic life native to this area; and (2) it provides a buffer zone in the event unforeseen spills of waste occur.

##U.S. Public Health Service Drinking Water Standards 28/ restrict total dissolved solids concentration to 500 mg/l. A concentration of 1,000 mg/l, although it is not desirable, was used in this study because basin conditions make the limit of 500 mg/l unattainable. Further discussion of this situation appears in Sections V and VIII of this report.

Flow Regulation

Allowance for Streamflow

In determining the draft-on-storage required to preserve the quality of the stream, it is necessary to make allowances for natural flows that can be expected to occur in the stream. Discharge frequency analyses of the streams in the basin were made from Corps of Engineers' streamflow data, which included adjustments to reflect conditions in the basin in 2025. Calculations were then performed to determine the amount of regulation water from storage needed to maintain stream quality for hydrologic conditions that can be expected to recur in the basin streams every 50 years. This hydrologic condition was used since the downstream use of the water is for municipal and industrial purposes.

Quality Control Requirements

The analyses of the basin waters, one of organic pollution (BOD), and one of chemical pollution (total dissolved solids), were made utilizing electronic computational methods where applicable. These studies were made for the entire lower Brazos River basin by constructing a mathematical model of the basin containing all reservoirs and points of withdrawal and inflow to the system. Special emphasis was placed on conditions in the main stem of the Brazos at the point of confluence of the Navasota River. This approach was used, since this investigation is primarily concerned with water resource development in the Navasota River basin, and any benefits for water quality control attributable to this development would logically accrue downstream.

Computations of organic pollution indicated that the surface waters of the basin will not be degraded below acceptable limits within the time horizon of the study (2075).

On the other hand, concentration of the stable pollutants (total dissolved solids) in the stream below the confluence of the Navasota River will reach undesirable levels in the future. Since the amount of water required to lower these concentrations is dependent on the quality of water used for dilution, the amounts required and the provisions made for satisfying this need will be discussed in Section IX, Water Supply and Water Quality Control Plan.

An investigation was made to determine the effect of discharge of adequately treated sewage effluent from the cities of Bryan and College Station on the water quality in the proposed Millican Reservoir. 29/ (See Appendix C.) The quality of the water in Millican Reservoir is not expected to be adversely affected by these waste discharges.

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IX. WATER SUPPLY AND WATER QUALITY CONTROL PLAN

General

In order to supply the water needs shown in Section VII, a plan is presented utilizing all available water resources in the lower Brazos River basin.

Water Availability

With existing and proposed reservoirs in operation, the water resources of the lower Brazos River basin (including the intervening coastal area) in the years 2025 and 2075 will be as shown in table IX-1.

An overplot of these resources on the total water requirement* for the basin and coastal area shows that the area's water resources will satisfy the total water requirements until about the year 2028, as shown in figure IX-1.

Closer examination reveals that the lower Brazos River basin above the confluence of the Navasota River and the Navasota River watershed have resources adequate to meet requirements through the terminal year of the study (2075). (See figures IX-2 and IX-3.) On the other hand, the Brazos basin below the confluence of the Navasota River and the associated intervening coastal area can be expected to become deficient by the year 2028, as shown in figure IX-4.

It should be noted that the greatest needs for water supply are now and can in the future be expected to be concentrated in the area downstream from the confluence of the Navasota River.

Water Quality Control Plan

The total requirement curves in figures IX-1 through IX-4 do not include any water quality control needs. There is, however, a need to control the total dissolved solids concentration in the Brazos River water downstream from the confluence of the Navasota River as was previously discussed in Sections VII and VIII.

A time plot of expected total dissolved solids concentrations in this reach of the stream under assumed hydrologic conditions is

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*Calculated by addition of totals on figures VII-3 and VII-6. Totals do not include water quality control needs.

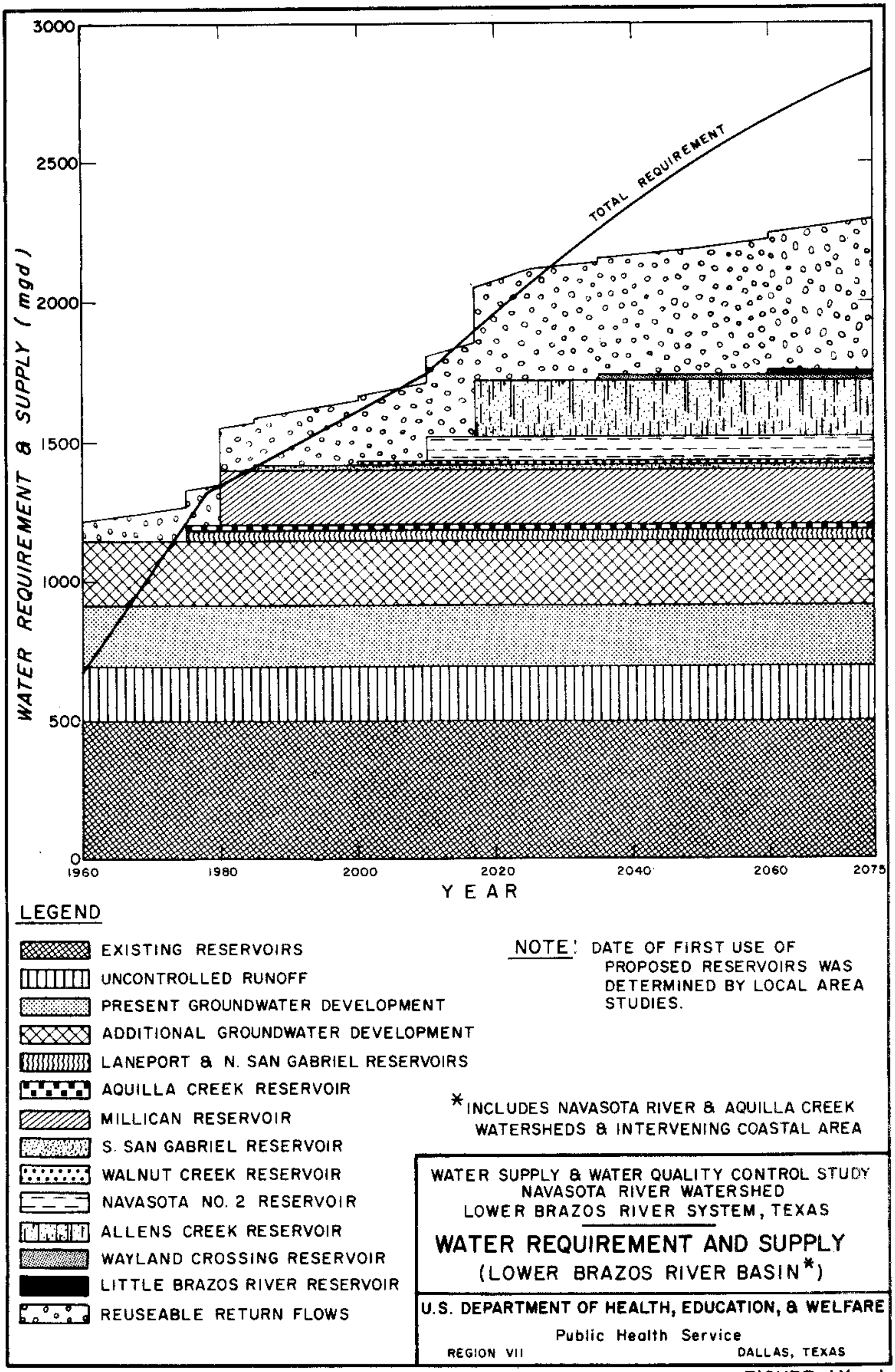
Table IX-1

Future Water Resources of the Lower Brazos River Basin

	Dependable Yield (mgd)
Surface:	
Existing reservoirs and reservoirs under construction	
Whitney	237.5*
Belton	104.7
Waco	54.9
Stillhouse Hollow	63.3
Somerville	36.2
Bistone	3.5
Authorized Reservoirs	
North San Gabriel	19.4
South San Gabriel	11.0
Laneport	22.0
Reservoirs to be completed prior to 2025	
Navasota II and Millican system	307.0
Aquilla Creek	9.7
Walnut Creek	19.4
Allen's Creek	185.7
Use of uncontrolled runoff based on 98 percent low flow conditions	202.5
Reuse of municipal, industrial, and irrigation return flows - varying quantity 1960 - 2025	66.3 - 384.2
Ground Water	450.0
Total resources in 2025	2,111.9
Additional resources available after 2025	
Surface	
Little Brazos River Reservoir	8.7
Wayland Crossing Reservoir	13.6
Reuse of additional municipal, industrial and irrigation return flows - varying quantity 2025 - 2075 (gross 384.2 - 545.5)	net 0 - 161.3
Total resources in 2075	2,295.5

*This is the effective yield of Whitney Reservoir as calculated by the Public Health Service which is reduced from the 304.0 mgd areal yield since power releases do not always coincide with downstream needs. The difference of 66.5 mgd is considered lost to the basin and wasted to the Gulf of Mexico.

Source: Corps of Engineers 1/



WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

WATER REQUIREMENT AND SUPPLY
(LOWER BRAZOS RIVER BASIN*)

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
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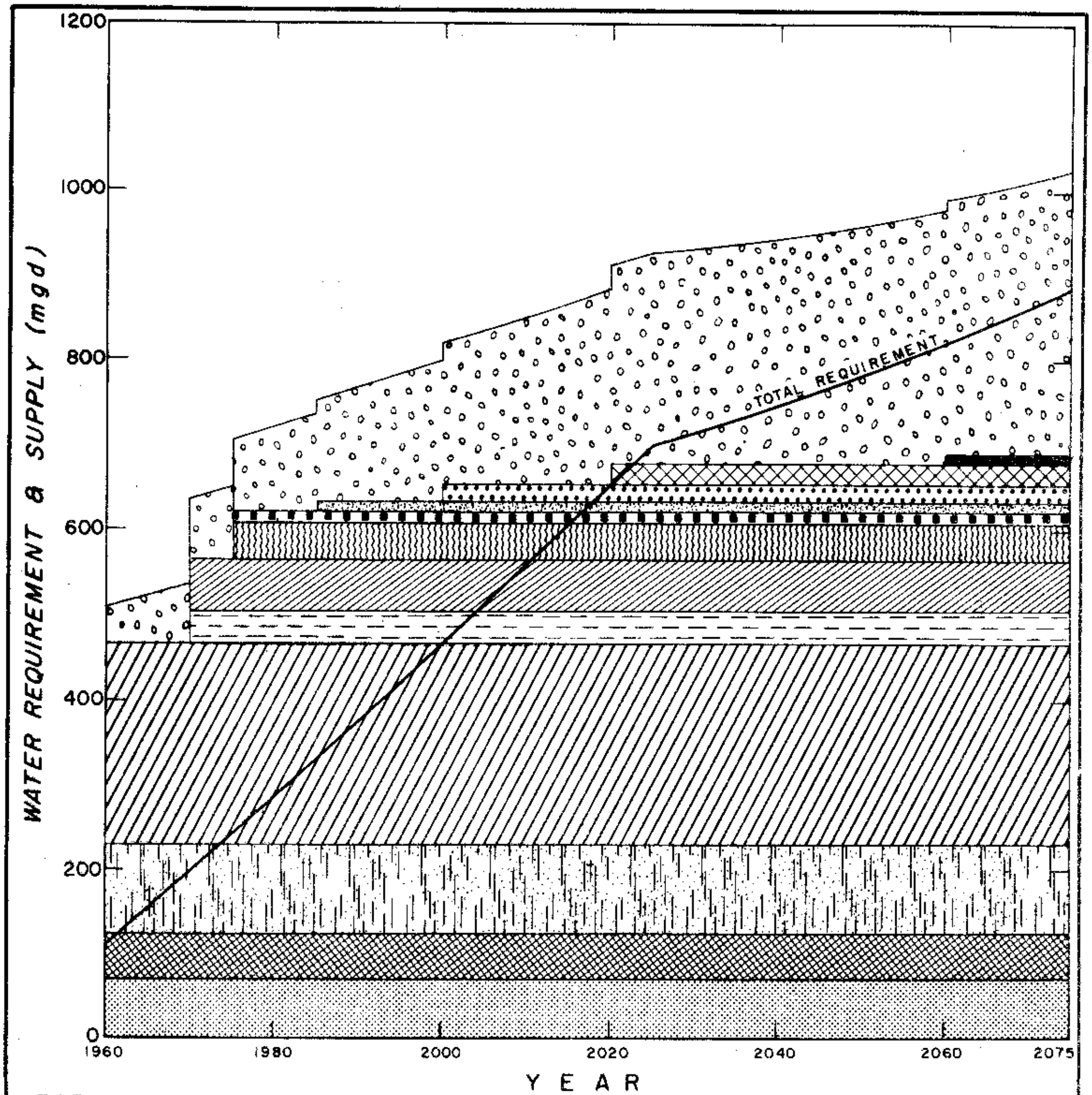
REGION VII DALLAS, TEXAS

FIGURE IX-I



LEGEND

- PRESENT GROUNDWATER DEVELOPMENT
- WACO RESERVOIR
- BELTON RESERVOIR
- WHITNEY RESERVOIR
- SOMERVILLE RESERVOIR
- STILLHOUSE HOLLOW RESERVOIR
- LANEPORT & N. SAN GABRIEL RESERVOIRS
- AQUILLA CREEK RESERVOIR
- S. SAN GABRIEL RESERVOIR
- WALNUT CREEK RESERVOIR
- ADDITIONAL GROUNDWATER DEV.
- LITTLE BRAZOS RIVER RES.
- REUSEABLE RETURN FLOWS

*DOES NOT INCLUDE NAVASOTA RIVER WATERSHED.

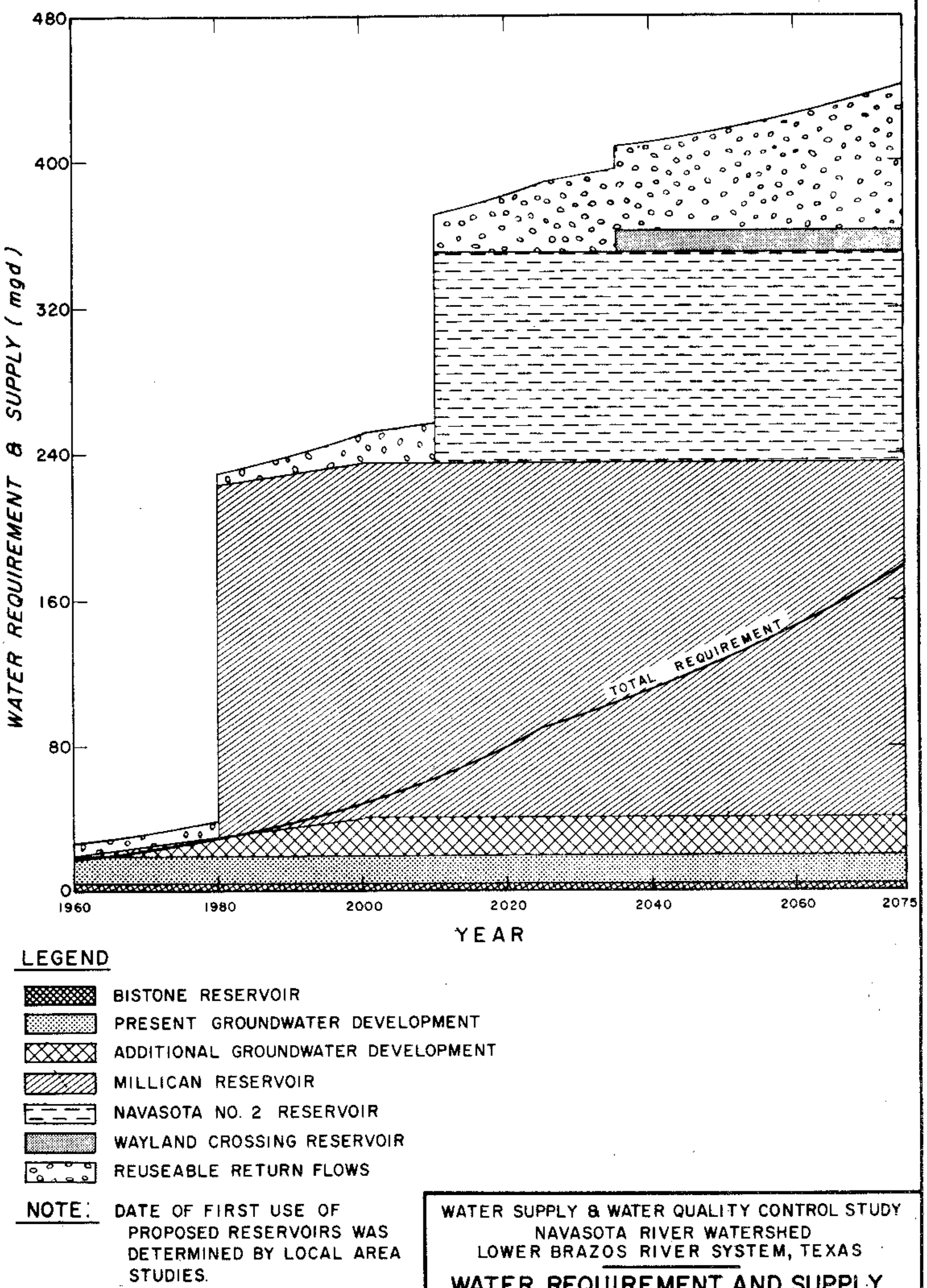
NOTE: DATE OF FIRST USE OF PROPOSED RESERVOIRS WAS DETERMINED BY LOCAL AREA STUDIES.

WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

WATER REQUIREMENT AND SUPPLY
(LOWER BRAZOS ABOVE NAVASOTA RIVER*)

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE IX—2



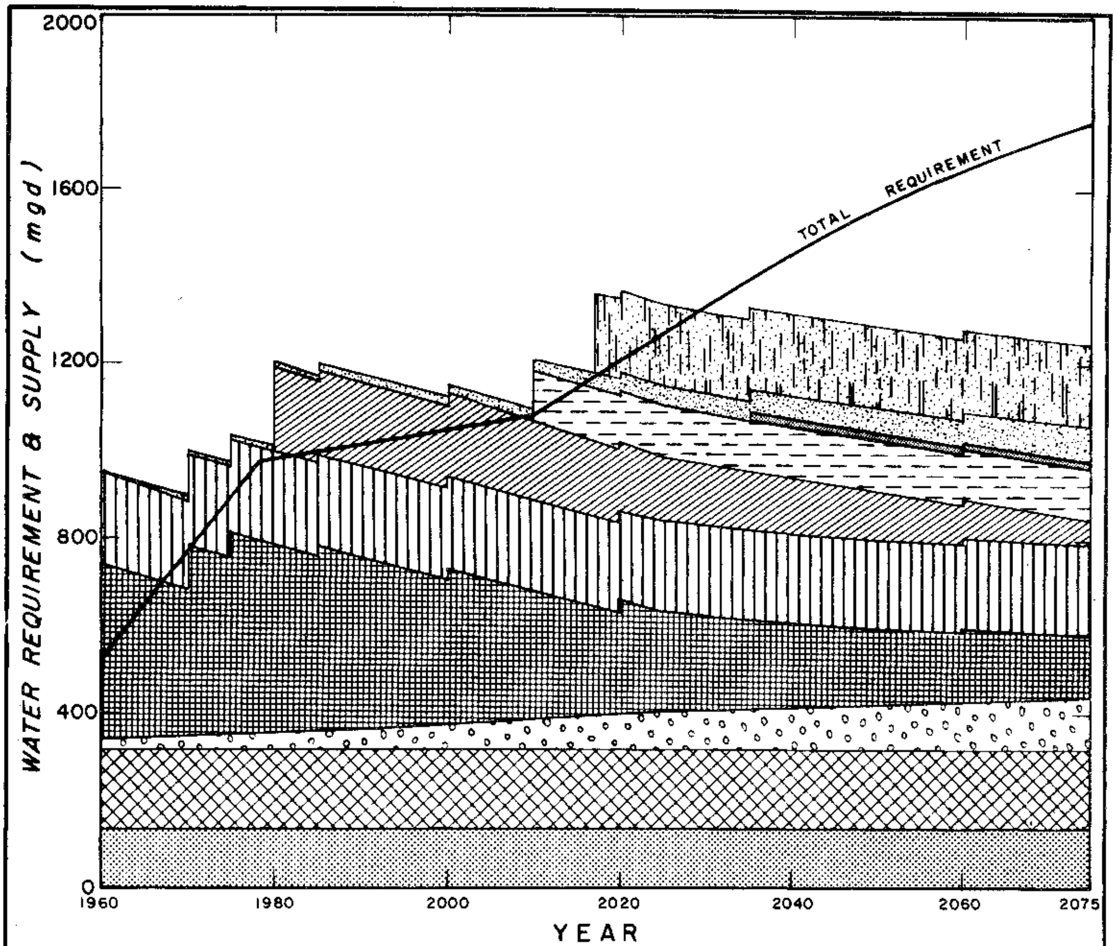
WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

WATER REQUIREMENT AND SUPPLY

(NAVASOTA RIVER WATERSHED ONLY)

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE IX—3



LEGEND

- PRESENT GROUNDWATER DEVELOPMENT
- ADDITIONAL GROUNDWATER DEVELOPMENT
- REUSEABLE RETURN FLOWS
- SURPLUS WATERS FROM BRAZOS RIVER ABOVE CONFLUENCE OF NAVASOTA RIVER
- UNCONTROLLED RUNOFF AVAILABLE (98% LOW FLOW CONDITIONS)
- SURPLUS WATER FROM MILLICAN RESERVOIR
- NAVASOTA NO. 2 RESERVOIR
- WAYLAND CROSSING RESERVOIR
- RETURN FLOWS FROM NAVASOTA RIVER WATERSHED
- ALLENS CREEK RESERVOIR

NOTE: DATE OF FIRST USE OF PROPOSED RESERVOIRS WAS DETERMINED BY LOCAL AREA STUDIES

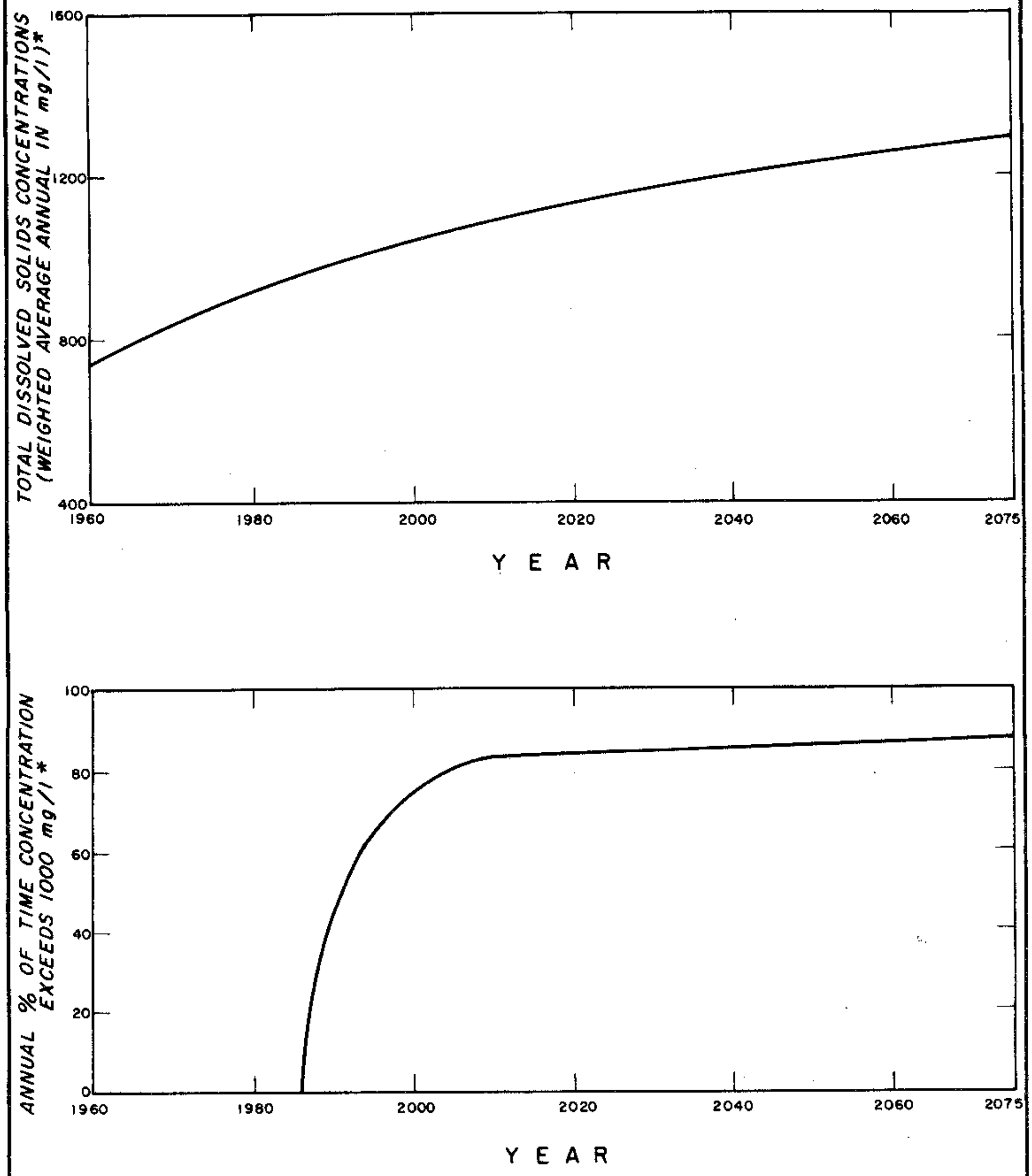
*INCLUDES INTERVENING COASTAL AREA

WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

WATER REQUIREMENT AND SUPPLY
(LOWER BRAZOS BELOW NAVASOTA RIVER*)

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE IX-4



* BASED ON MONTHLY VALUES

WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

WATER QUALITY CONTROL PLAN (PART I)

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
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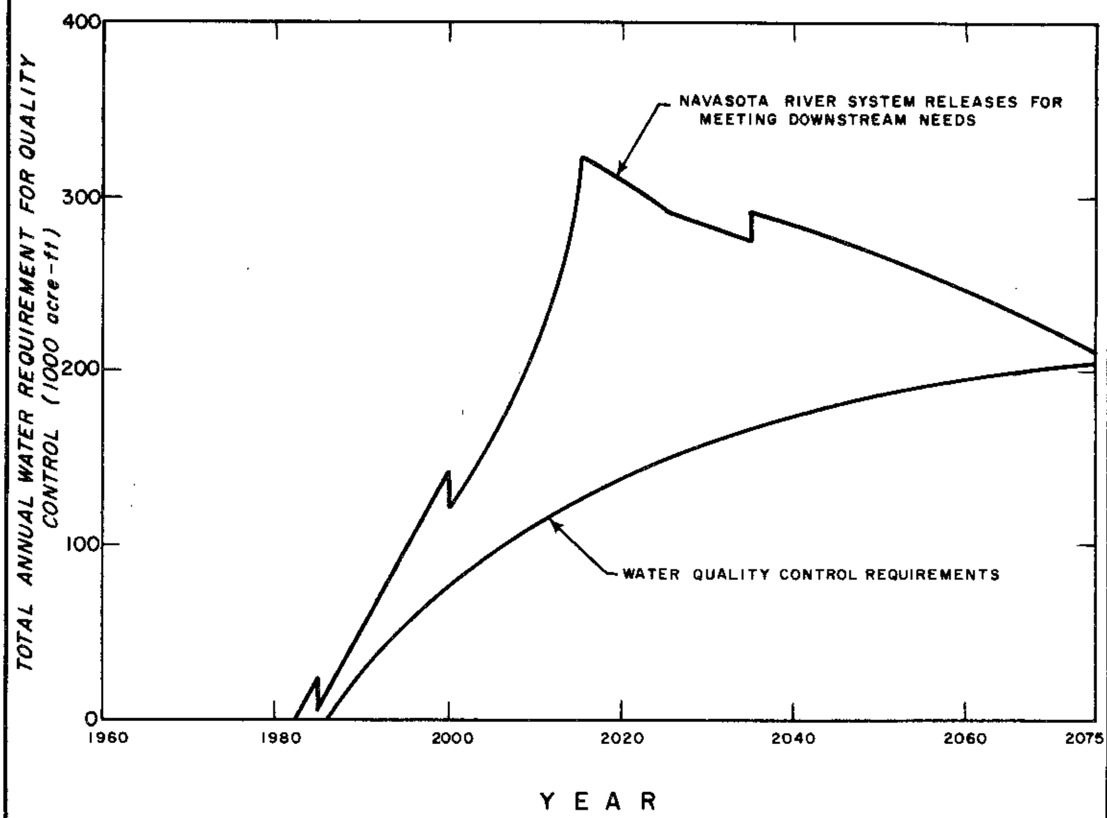
REGION VII DALLAS, TEXAS

FIGURE IX-5

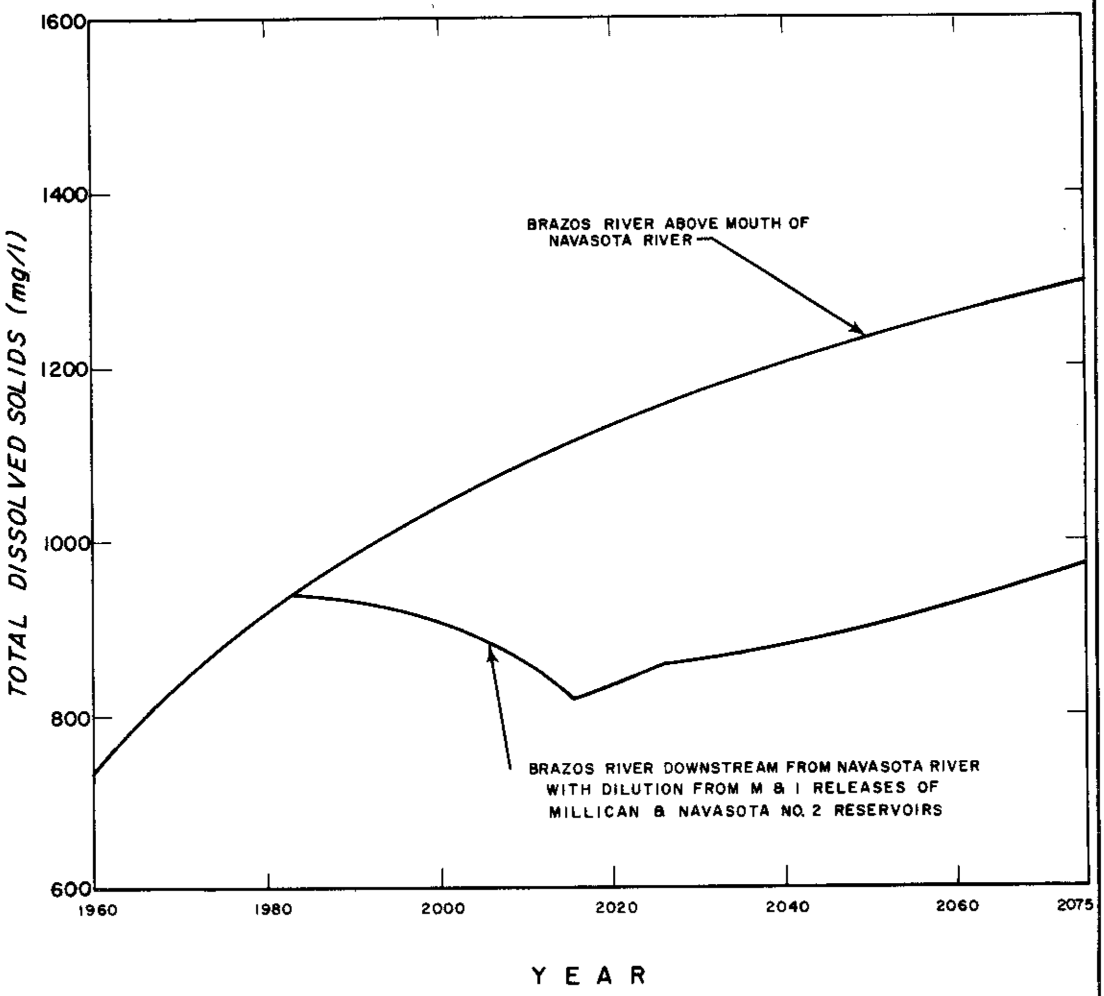


WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

WATER QUALITY CONTROL PLAN
(PART 2)

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE IX-6



WATER SUPPLY & WATER QUALITY CONTROL STUDY
NAVASOTA RIVER WATERSHED
LOWER BRAZOS RIVER SYSTEM, TEXAS

WATER QUALITY CONTROL PLAN (PART 3)

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE
Public Health Service
REGION VII DALLAS, TEXAS

FIGURE IX-7

shown in figure IX-5. Also shown is the annual percent of time (based on a monthly analysis) that the concentration will exceed 1,000 mg/l.

A total annual requirement curve for diluting these waters sufficiently to maintain concentrations below 1,000 mg/l with water from the Navasota River system is shown in figure IX-6. Included on the same figure is a curve showing Navasota River system releases for meeting downstream municipal and industrial water supply needs. From these curves it is concluded that there is no need for storage of water for quality control purposes during the study period.

Figure IX-7 shows the expected total dissolved solids concentration under 98 percent low flow condition in the Brazos River downstream from the Navasota River with the municipal and industrial releases from the Navasota River system. This curve shows that after the system is placed into operation, the total dissolved solids concentration will vary from 818 mg/l in the year 2015 to 976 mg/l in the year 2075. The reduction in total dissolved solids concentrations achieved by these releases is not considered sufficient to create significant benefits to water users in the lower Brazos basin.

If current studies of the upper Brazos River show that containment of the natural mineral pollution load is feasible, the mineral quality of the waters of the lower Brazos River will be greatly improved.

Project Construction Sequence

The sequence of construction for the proposed Federal reservoir developments was determined from local area requirement and supply studies. There is a need in the Navasota River basin for the first stage of Millican - Navasota II Reservoir system in the year 1980. (See figure IX-3.) The second stage, Navasota II Reservoir, is needed to meet needs of the Brazos basin and coastal area below the Navasota River in the year 2010. (See figure IX-4.)

Present practice in the southwest is to plan construction about 10 years ahead of actual needs. On this basis, the benefits for Millican Reservoir need not be discounted, while the discount period for the Navasota II Reservoir will be 25 years, using the year 1975 as "present" for purposes of benefit calculations.

Alternatives

After consideration of several other reservoir sites as well as ground water development, it is concluded that the most reasonable alternative to the multiple-purpose two-stage development in the Navasota River basin is a single-purpose two-stage development at the same locations.

X. BENEFITS

Method of Evaluation

Senate Document No. 97 (87th Congress, 2nd session) makes the following statement concerning evaluation of benefits of municipal and industrial water supply storage in Federal reservoirs:

> "The amount water users should be willing to pay for such improvements in lieu of foregoing them affords an appropriate measure of this value. In practice, however, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in the absence of the project."

This alternative cost method was used to evaluate storage requirements for municipal and industrial use in the multiple-purpose reservoir projects proposed to be developed in the Navasota River basin. The values determined in this way are considered to be minimum annual benefits.

Costs

For purposes of comparison of alternatives, capital costs were converted to equivalent annual costs and added to the estimated annual operation and maintenance costs. The costs were determined for the date of first use of the project and, when necessary, discounted to "present" 1975 values.

Water Supply Benefits

A summary of the annual project benefits is shown in table X-1. The methods of calculation used for the benefit evaluation are shown in Appendix B. Values shown represent present worth in 1975. Since Navasota II Reservoir is not needed until the year 2010, the benefit was discounted 25 years.

Table X-1

Summary of Project Water Supply Benefits

		Benefits	
Reservoir	Yield (mgd)	Annual (1975 $)	Equivalent Cents per 1,000 gal.
Millican	193.8	$1,418,000	2.0
Navasota II	113.1	$ 914,000	2.2

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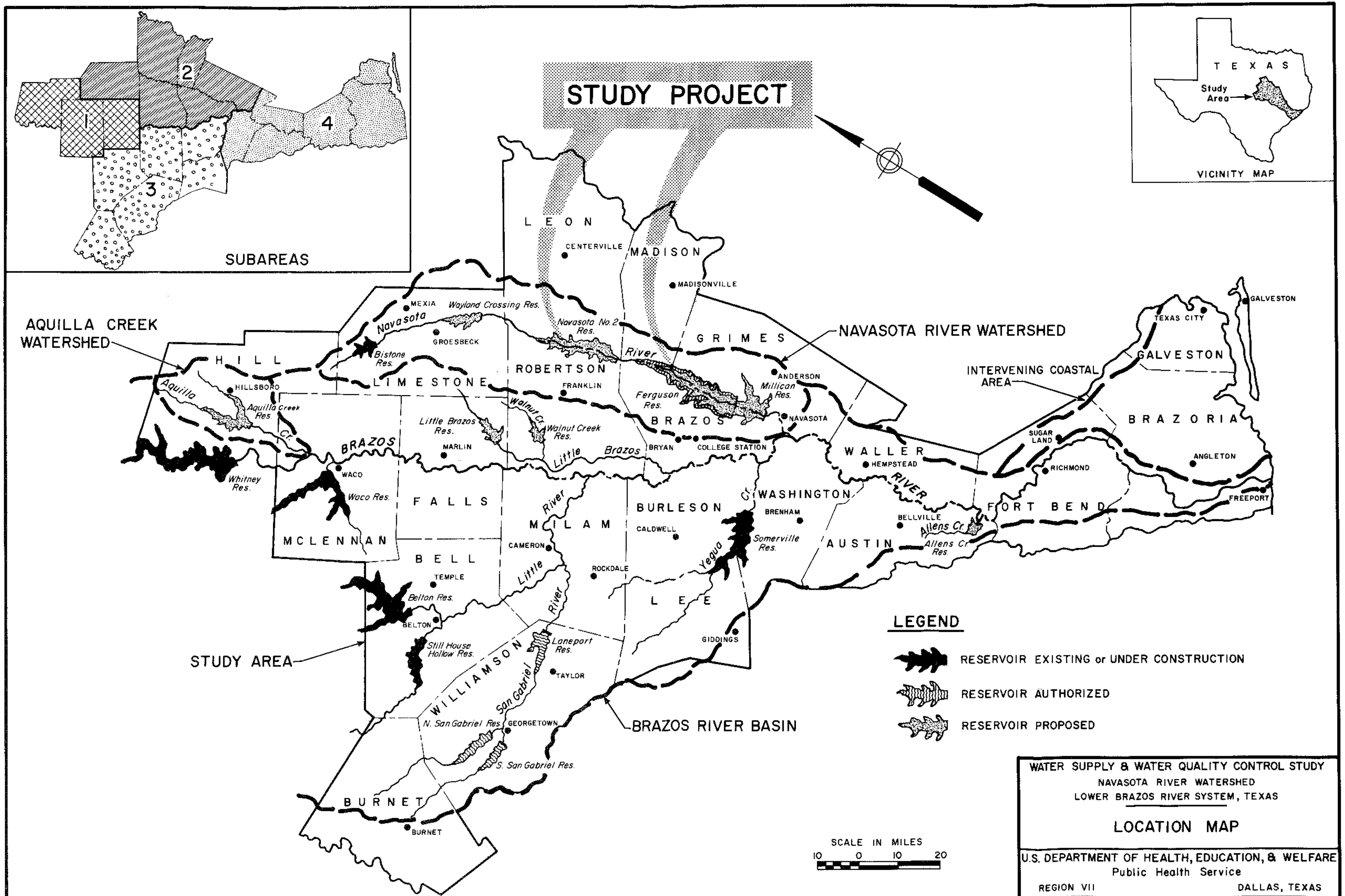

FIGURE III-1

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APPENDIX A

Present and Projected Study Area
Municipal and Industrial Return Flows and Waste Loads

	1962*			2025			2075		
Subarea and County	Return Flow (mgd)	P.E. (BOD) Discharged	Total Dissolved Solids Discharged (tons/day)	Return Flow (mgd)	P.E. (BOD) Discharged	Total Dissolved Solids Discharged (tons/day)	Return Flow (mgd)	P.E. (BOD) Discharged	Total Dissolved Solids Discharged (tons/day)
Subarea 1									
Falls	0.58	3,510	0.99	3.27	4,368	5.56	7.50	9,804	12.53
Hill	0.79	1,370	1.10	3.35	4,620	4.65	7.14	9,144	10.39
McLennan	11.54	16,150	15.44	52.43	70,248	71.05	87.04	112,968	111.98
Subtotal	12.91	21,030	17.53	59.05	79,236	81.26	101.68	131,916	134.90
Subarea 2									
Brazos	2.66	1,590	7.98	32.97	46,908	98.81	66.55	88,080	201.34
Grimes	0.18	730	0.43	1.83	2,244	4.33	3.75	3,624	8.78
Leon	0.17	400	0.35	7.32	5,076	14.96	15.13	9,828	30.72
Limestone	0.59	2,360	1.17	3.52	3,912	7.00	7.46	7,836	14.45
Madison	0.15	440	0.46	3.09	2,676	9.42	7.64	5,268	19.56
Robertson	0.56	385	1.28	7.11	5,232	16.26	15.63	11,832	37.36
Subtotal	4.31	5,905	11.67	55.84	66,048	150.78	116.16	126,468	312.21
Subarea 3									
Bell	8.56	7,515	11.38	15.55	21,624	20.63	22.16	28.236	28.75
Burleson	0.19	940	0.41	2.49	2,100	5.33	13.01	9,456	27.16
Burnet	0.23	100	0.45	1.42	1,860	2.80	2.45	3,072	4.95
Lee	0.21	200	0.50	0.41	972	0.98	0.83	1,800	1.94
Milam	0.42	730	1.01	8.19	10,308	19.77	12.75	15,288	32.59
Williamson	1.21	440	2.78	2.57	5,820	5.91	5.64	11,556	13.47
Subtotal	10.82	9,925	16.53	30.63	42,684	55.42	56.84	69,408	108.86
Subarea 4									
Austin	0.22	200	0.82	2.14	3,288	8.01	3.99	5,784	17.75
Brazoria	4.10	4,110	6.15	161.30	291,564	242.41	328.86	587,976	501.41
Fort Bend	1.39	5,180	5.06	23.93	36,948	87.14	54.28	79,524	203.00
Galveston	11.35	8,340	18.97	248.28	429,444	414.90	540.60	918,312	928.41
Waller	0.26	30	0.87	2.02	3,108	6.73	3.05	4,440	10.02
Washington	0.50	50	1.32	2.36	3,396	6.23	4.35	5,736	12.71
Subtotal	17.82	17,910	33.19	440.03	767,748	765.42	935.13	1,601,772	1,673.30
TOTAL	45.86	54,770	78.92	585.55	955,716	1,052.88	1,209.81	1,929,564	2,229.27

*Source: Texas State Department of Health 8/, and Public Health Service 30/

APPENDIX B

Benefit Calculations

Millican Reservoir Project

Estimated first cost	$34,200,000
Estimated interest during construction	$ 3,206,250
Estimated total investment	$37,406,250

Amortize private investment for 25 years
at 4 percent (37,406,250)(0.06401) = $2,394,374
per year.

Convert to equivalent Federal investment
to provide for same annual payment.

Present worth of 1 per period
at 3 1/8 percent = 17.17308

Then, equivalent Federal investment =
(2,394,374)(17.17308) = $41,118,776

Amortize Federal investment for 100 years
at 3 1/8 percent

Annual Cost = (41,118,776)(0.03276)	=	$1,347,051
Estimated annual operation and maintenance	=	$ 70,000
Total annual cost	=	$1,417,051
	Say	$1,418,000

Therefore, annual value of benefits = $1,418,000

Navasota II Reservoir Project

Estimated first cost	$47,190,000
Estimated interest during construction	$ 5,161,406
Total investment	$52,351,406

Amortize private investment for 25 years
at 4 percent (52,351,406)(0.06401) = $3,351,013
per year

Convert to equivalent Federal investment
to provide for same annual payment.

Present worth of 1 per period
at 3 1/8 percent = 17.17308

Then, equivalent Federal investment =
(3,351,013)(17.17308) = $57,547,214

Amortize Federal investment for 100 years
at 3 1/8 percent

Annual Cost = (57,547,214)(0.03276)	=	$1,885,247
Estimated annual operation and maintenance	=	$ 87,000
Total annual cost	=	$1,972,247

Discounting the project for 25 years

Present worth of 1 for 25 years
at 3 1/8 percent = 0.46334

Annual cost = (1,972,247)(0.46334)	=	$913,821
	Say	$914,000
Therefore, annual value of benefits		$914,000

APPENDIX C

Effect of Discharge of Treated Sewage on the Quality of Water in Millican Reservoir

General

An investigation has been carried out to determine the effect of the discharge of adequately treated sewage effluent on the water quality in the proposed Millican Reservoir. The cities of Bryan and College Station discharge treated waste to Carter's Creek, a tributary stream of the proposed impoundment. After the reservoir fills, these wastes will flow into a bay formed along Carter's Creek having a width of about 3,000 feet and a length of about 3 miles. This bay will open into the main body of the reservoir approximately 8 miles upstream of the dam.

Effluent Quality

For planning purposes, it was assumed that the effluent from both of the present treatment plants and any proposed plants would comply with State design criteria concerning maximum permissible concentrations of biochemical oxygen demand (BOD) and suspended solids. It was further assumed that the treated waste effluent would be chlorinated.

Water Quality Objectives

Indicators of water quality consistent with water quality requirements of the various reservoir purposes were chosen for this study. The multiple purposes and the more important water quality indicators are summarized below.

Purpose	Water Quality Indicators
Municipal and industrial water supply	Coliform organisms, hardness, dissolved solids, pH, alkalinity, color, odor, turbidity, algae, temperature.
Fish and wildlife	Dissolved oxygen, pH, dissolved solids, algae, other biological forms, turbidity, toxins.
Recreation	Coliform organisms, floating solids, oil, sludge deposits.

The indicators most likely to be affected by the discharge of treated waste effluent are coliform organisms, dissolved oxygen, turbidity, odor, and algae.

Dynamics of Waste Dispersion in Reservoirs

Much has been written in the sanitary engineering and limnology literature that bears on the dynamics of mixing and dispersion of wastes in receiving waters. Ideally the objective of waste disposal in natural water is to allow it to mix and disperse in the receiving water and to be diluted to the extent that bacterial concentrations are reduced to noninjurious and acceptable levels, deleterious substances are maintained at levels that are not toxic to plant and fishlife and do not upset the general ecological balance which may be established in the assimilating system, and undesirable appearance of the wastes are eliminated. The basic problem in reservoirs, therefore, becomes one of concern with the temporal and spatial conveyance and dispersion of the waste throughout the impoundment.

A mathematical model of the Millican Reservoir system was constructed utilizing formulations and data obtained from similar reservoirs. In general, this model permits calculation of dilution ratios which can be expected at various points in the system taking into account (1) the rate of waste discharge, (2) configuration of the reservoir, (3) mixing currents induced by wind, (4) the ratio of concentration of various substances in the natural water to concentration in the waste, and (5) natural biological self-purification mechanisms in the case of organically degradable substances. These studies were made for waste discharge rates varying from the present 2.8 mgd, to the projected 2075 discharge of 50 mgd. Calculations were also made for the intermediate years of 1975 and 2025.

Results

The above calculations showed that dilution ratios ranging from 6:1 to 23:1 can be expected as the wastes move through the reservoir. Profiles showing expected concentrations of the various waste constituents at the selected discharge rates were plotted.

An overplot of threshold concentrations indicated that all of the waste constituents investigated would be reduced to safe levels by naturally occurring dilution. The following comments apply to each of the pollution indicators investigated.

Coliform Organisms - Chlorination of the waste treatment plant effluent coupled with the natural death rate of the coliform indicator organisms and the dilution factors are expected to maintain bacterial concentrations within the accepted limits for body contact water sports even in most of the length of the bay formed along Carter's Creek.

Bacterial concentrations detrimental to water supply are not expected, since any water supply intake would certainly not be located in the vicinity of the waste discharge area.

Dissolved Oxygen - The dissolved oxygen concentrations necessary for maintenance of fish will not be affected by this waste discharge. Biochemical oxygen demand (BOD) was the indicator used to determine the dissolved oxygen. Assuming that the state recommended design criteria of 20 mg/1, 5 day, 20°C. BOD is satisfied, concentrations in the reservoir will be reduced by dilution and natural self-purification to levels found in natural waters.

Turbidity - Again, maintenance of the recommended state criteria of 20 mg/1 of suspended solids is expected to prevent any buildup of this physical characteristic to levels above the accepted drinking water standard.

Odor - Any odor resulting from the treated waste discharge would most probably be related to algae production which is discussed below.

Algae - To indicate algae growth in the reservoir, an analysis of the nutrients was made. Nitrogen and phosphorous levels are expected to remain below the generally accepted threshold concentrations which result in algal blooms.

The discharge of treated waste effluents into reservoirs is a common occurrence. Cases of reservoir pollution have occurred, but most of these have been the result of discharge of improperly treated wastes, or discharge of large quantities of waste into relatively small reservoir pools. Considering the size of the proposed reservoir, the magnitude of the projected waste discharges, the degree of treatment provided by both the cities of Bryan and College Station, and the dilutions expected to occur in the reservoir, no appreciable degradation of water quality in Millican Reservoir is expected to result from this source.

APPENDIX VI

VIEWS AND COMMENTS OF OTHER AGENCIES

REVIEW OF REPORTS
ON
BRAZOS RIVER AND TRIBUTARIES, TEXAS
COVERING
NAVASOTA RIVER WATERSHED

CONTENTS

CONTENTS (Continued)

RESOLUTION

REGARDING FORT WORTH DISTRICT ENGINEER'S RECOMMENDED PLAN FOR PROJECTS ON THE NAVASOTA RIVER

WHEREAS it has long been the policy of the Brazos River Authority, as an agency of the state of Texas charged with certain statutory responsibilities for the conservation, control and development of the water resources of the Brazos River Basin, to accept responsibility for fulfilling the requirements of local cooperation with regard to conservation storage space in Corps of Engineers' reservoir projects throughout the Brazos River Basin; and

WHEREAS the District Engineer, Fort Worth District, U. S. Army Corps of Engineers, in 1961 completed a report entitled "Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed," in which he recommended a reservoir project at the Millican site on the Navasota River containing 2,359,800 acre-feet of conservation storage space, for which the Brazos River Authority, in behalf of the state and local interests, offered to enter into an agreement with the Federal Government at the appropriate time to fulfill the requirements of local cooperation; and

WHEREAS the Brazos River Authority, by resolution of its Board of Directors adopted October 14, 1963, stated, "That the Authority recognizes the desirability of giving further consideration to possible stage construction and that the previous resolutions and correspondence of the Authority in regard to the Millican project are not to be taken as indicating a preference for a single large project on the Navasota as against stage development; that the officers and the General Manager of the Authority be directed to consult and work with the Corps of Engineers, the Texas Water Commission and other interested agencies and individuals to develop recommendations to this board as to the desirability of stage development of the project;" and

WHEREAS the District Engineer, Fort Worth District, U. S. Army Corps of Engineers, has developed proposed revised recommendations based on a restudy of this report of 1961, which restudy was undertaken in accordance with comments of the Governor of Texas, the Texas Water Commission and the Brazos River Authority; and

WHEREAS the results of the restudy and the proposed revised recommendations of the District Engineer, Fort Worth District, U. S. Army Corps of Engineers, are summarized in his "Notice of Public Hearing, Brazos River and Tributaries, Texas, Navasota River Watershed," dated 1 February 1965, and were further explained by the District Engineer in an oral presentation to the Board of Directors of the Brazos River Authority; and

WHEREAS the District Engineer, Fort Worth District, U. S. Army Corps of Engineers, needs an expression of the views of the Brazos River Authority with regard to his proposed report;

NOW THEREFORE BE IT RESOLVED BY THE BOARD OF DIRECTORS OF THE BRAZOS RIVER AUTHORITY:

That the Brazos River Authority considers the plan proposed by the District Engineer, Fort Worth District, U. S. Army Corps of Engineers, in his "Notice of Public Hearing, Brazos River and Tributaries, Texas, Navasota River Watershed," dated 1 February 1965, to be a logical and reasonable plan for properly phased, optimum development of the water resources of the Navasota River in the interest of water conservation, flood control and other beneficial purposes, giving due regard to the present and anticipated future needs for water in the Brazos Basin and adjoining areas and to the timing of the development by stages of the water resources of the Navasota River watershed to help meet these needs; and

That the Brazos River Authority, in furtherance of its responsibility to the state of Texas for water conservation and water resource development in the Brazos Basin, is willing to assume the obligations and requirements of the local cooperation for the water conservation portion of the project, and, at the proper time after authorization of the project by the Congress, will enter into an appropriate agreement with the Federal Government setting forth the terms and conditions for fulfilling such obligations and requirements; and

That the Brazos River Authority sincerely appreciates the fine cooperation extended by the Corps of Engineers in all phases of the study of the Navasota River watershed.

ADOPTED AND APPROVED this the 8th day of February, 1965.

W. E. Gregory
President, Board of Directors
Brazos River Authority

(SEAL)

ATTEST:

Secretary, Board of Directors
Brazos River Authority

COMMISSION
HERBERT C. PETRY, JR., CHAIRMAN
HAL WOODWARD
J. H. KULTGEN

STATE HIGHWAY ENGINEER
D. C. GREER

TEXAS HIGHWAY DEPARTMENT

AUSTIN, TEXAS 78701

June 15, 1965

IN REPLY REFER TO
FILE NO. D-5

Brazos and Grimes Counties
Millican Reservoir

District Engineer
U. S. Army Engineer District, Ft. Worth
Corps of Engineers
P. O. Box 1600
Ft. Worth, Texas 76101

Dear Sir:

Reference is made to your letter dated April 8, 1965 requesting our current thinking regarding the possibility of connecting F. M. Road 244 with State Highway 6 across the proposed Millican Dam.

Based on the limited information on the dam at this time, we are still of the same opinion as expressed in our earlier letter of June 15, 1960 that the need of such a connection still exists. We see no future need at this time for a similar highway crossing over Navasota No. 2 Dam.

Yours truly,

D. C. Greer
State Highway Engineer

By: Clyde F. Silvus

Clyde F. Silvus
Bridge Engineer

MLY:gk

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA IV
Mineral Resource Office

Office of
AREA DIRECTOR

ROOM 204 FEDERAL BUILDING
BARTLESVILLE, OKLAHOMA 74004

July 27, 1965

Mr. C. F. Swenson, Chief
Engineering Division
U.S. Army Engineer District, Fort Worth
P.O. Box 1600
Fort Worth, Tex. 76101

Refer to: SWFGB

Dear Mr. Swenson:

Referring to your letter of April 2, 1965, this office has completed the mineral review of the Millican Reservoir project, Navasota River Watershed, Grimes, Brazos, and Madison Counties, Tex.

On August 17, 1960, and May 16, 1962, we reviewed reports on other proposed Millican Dam and Reservoir sites. Conditions reported at that time have changed. See table 1 for changes in the three proposed reservoir sites.

The proposed Millican Reservoir site on Navasota River extends 30 miles upstream from the damsite. The damsite in Grimes and Brazos Counties, Tex., is approximately 7 miles north of Navasota, Tex. It is a multipurpose project to provide for flood control, water supply, and recreation benefits. The reservoir will have a potential total volume of 2,199,100 acre feet, comprising 1,557,400 acre feet for flood control at pool elevation of 234.0 feet, and 1,193,500 acre feet (ultimate) at normal pool elevation of 228.0 feet. The normal pool will provide for a lake of approximately 55,500 acres. The flood control pool will cover 66,000 acres at elevation 234.0 feet.

The purpose of the study is to determine the effects of existing and potential mineral resource development in the proposed Millican Reservoir area. It is not the purpose of this report to evaluate the petroleum and mineral properties and existing facilities.

A study of office maps and other information on hand shows there are 13 dry holes, one abandoned gas well, one shut-in gas well, and two producing gas wells within the limits of the flood-control pool (elevation 234.0 feet). The shut-in gas well is in the Ferguson Crossing field. The two producing gas wells are in the East Millican gasfield in Brazos County.

Four pipelines ranging in diameter from 10 to 12 inches cross the conservation storage pool. These pipelines will require relocation or protection in place. The gas-gathering lines in the East Millican field will also require protection in place. Deposits of sand, gravel, and clay have been reported in the immediate area of the proposed Millican Reservoir.

Present practices of the oil industry make it possible to produce gas on inundated land by operating from elevated platforms. These operating measures on inundated land would add to both the development and the producing cost.

The Bureau of Mines does not object to the possible construction, providing a detailed field examination is made by a qualified petroleum engineer during preconstruction planning for the purpose of recommending adequate protective measures for existing petroleum and natural gas resources and developments in the Millican Reservoir area.

Sincerely yours,

Robert S. Sanford

Robert S. Sanford
Area Director

Attachment

TABLE 1.--Comparison of Changes to Millican Dam and Reservoir

Item	July 1960 Report	March 1962 Report	July 1965 Report
Flood control pool elevation (ft.)	237.1	256.1	234.0
Conservation " " "	218.0	245.0	228.0*
Dam crest " " "	243.0	263.0	242.6*
Length of earthfill & concrete dam (ft.)	15,300	27,820	25,300
Height " " "	76	96	83
Pipelines to be relocated (miles)	19	45	27.8
Land acquisition fee simple (acres)	55,250	100,310	80,800
" " flood easement (acres)	14,860	15,400	3,000
Conservation pool areal extent "	40,820	88,200	55,500*
Flood control " " "	72,200	113,880	66,000

* Ultimate stage.

Office of
AREA DIRECTOR

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA IV
Mineral Resource Office

ROOM 204 FEDERAL BUILDING
BARTLESVILLE, OKLAHOMA 74004

July 27, 1965

Mr. C. F. Swenson, Chief
Engineering Division
U.S. Army Engineer District, Fort Worth
P.O. Box 1600
Fort Worth, Tex. 76101

Refer to: SWFGB

Dear Mr. Swenson:

Referring to your letter of April 2, 1965, this office has completed the mineral review of the Navasota No. 2 Reservoir Project, Navasota River Watershed, Leon and Robertson Counties, Tex.

The proposed Navasota No. 2 Reservoir site on the Navasota River extends 27 miles upstream from the damsite. The damsite in Robertson and Leon Counties is approximately 7 miles west of Normangee, Tex. It is a multipurpose project to provide for flood control, water supply, and recreation benefits. The reservoir will have a potential total volume of 2,277,600 acre feet, comprising 1,935,600 acre feet for flood control at pool elevation of 341.0 feet, and 1,378,600 acre feet at normal pool elevation of 330.0 feet. The normal pool will provide a lake of 44,540 acres and the flood control pool will provide a lake of 58,180 acres.

The purpose of the study is to determine the effects on existing and potential mineral resource development in the Navasota No. 2 Reservoir area. It is not the purpose of this report to evaluate mineral properties or existing facilities. Other factors concerning the nature of petroleum operation problems in the lake, should petroleum be discovered, are discussed.

From the study of office maps and other information on hand, no productive oil and gas wells exist within the limits of the reservoir site. One pipeline traversing the Navasota Reservoir area will require relocation or protection in place. Deposits of sand and gravel and clay have been reported in the immediate area of the proposed Navasota No. 2 Reservoir.

Although no productive wells now exist in the lake site, present practices of the oil industry make it possible to drill wells and to produce oil and gas on inundated land by operating from elevated platforms. These elevated platforms will require a permanent derrick on the well and heavy barges for transporting equipment to and from the well. For wells drilled near shore or in shallow water, access may be had by a raised roadway. Directional drilling from shoreline locations may be practical, providing depth and location of the wells are suitable to obtain the required horizontal drift. These operating measures on inundated land would add to both the development cost and the producing cost.

The Bureau of Mines does not object to the possible construction, providing a detailed field examination is made by a qualified petroleum engineer during preconstruction planning for the purpose of recommending adequate protective measures for existing petroleum resources and developments in the Navasota No. 2 Reservoir area.

We were pleased to make the mineral review of the Navasota No. 2 Reservoir project.

Sincerely yours,

Robert S. Sanford

Robert S. Sanford
Area Director

REGION SIX
ARKANSAS
LOUISIANA
OKLAHOMA
TEXAS

U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS

Austin, Texas 78701

06-41

July 9, 1965

IN REPLY REFER TO:

Water Resources Development Project
Review of Reports on Brazos River and Tributaries,
Texas, Covering Navasota River Watershed

Col. F. P. Koisch
U. S. Army Engineer District, Ft. Worth
Corps of Engineers
100 West Vickery Boulevard
Fort Worth, Texas

Dear Sir:

We have reviewed your report dated July 1965 and offer the following comments:

On page 63, Item 116, it is noted that the State Highway Department has recommended that a highway crossing be considered in design of the Millican Dam since there appears to be definite possibility of connecting FM Highway 244 and State Highway 6 across this dam. If this crossing is to be certified as being needed and the increased project cost financed under Public Law No. 562, it will be necessary for the State Highway Department to follow the procedures prescribed in PPM 28-1. We have received no submission from the State as of this date.

We assume the cost of all highway relocation work as shown in Tables 4 and 5 will be borne by the Water Resource Project.

We are returning the draft copy (Senior Number 70) of your report as requested. We appreciate having the opportunity to review it.

Sincerely yours,

L. S. Coy
Division Engineer

Attachment

96-129 O-68-16

REGION SIX
ARKANSAS
LOUISIANA
OKLAHOMA
TEXAS

U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
P. O. BOX 12037
FORT WORTH 16, TEXAS

July 12, 1965

IN REPLY REFER TO:
06-00.1

Water Resources Development Project
Review of Reports on Brazos River and Tributaries,
Texas, Covering Navasota River Watershed

Col. F. P. Koisch
U. S. Army Engineer District, Ft. Worth
Corps of Engineers
100 West Vickery Boulevard
Fort Worth, Texas

Dear Colonel Koisch:

We are returning the draft copy (Serial Number 71) of the subject report furnished with our copy of your 6 July 1965 letter to Mr. Coy.

We are also forwarding Mr. Coy's July 9, 1965 letter and copy No. 70 of the report which you furnished him.

In order that coordinated replies from the Bureau of Public Roads may be presented, our division office replies are furnished through this office. This gives us an opportunity to review the division office copy of the report prior to its being returned to you. Therefore, in the interest of reducing printing costs, you may wish to discontinue sending this office draft copies of these reports.

We have no comments to offer regarding this report in addition to those furnished by Mr. Coy.

Sincerely yours,

Bill L. Andrews

Bill L. Andrews
Asst. Regional Engineer

Attachments

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
Southwest Region
Santa Fe, New Mexico 87501

IN REPLY REFER TO:

L7423

July 14, 1965

Colonel F. P. Koisch, CE
District Engineer, Fort Worth
P. O. Box 1600
Fort Worth, Texas 76101

Dear Col. Koisch:

The opportunity to review a draft copy of "Review of Reports on Brazos River and Tributaries, Texas, covering Navasota River Watershed," is appreciated.

Our interest in the Review of Reports is general, relating particularly to the recreational potential which would result from development of the Navasota No. 2 and Millican Reservoirs. As you noted in paragraph 113 and 114, the National Park Service at your request made a field reconnaissance of the proposals in 1960, our recreation report being presented in appendix V of your draft.

The draft copy is being returned in accordance with your request.

Sincerely yours,

Roger W. Allin
Assistant Regional Director
Cooperative Activities

Enclosure (Serial No. 67)

IN REPLY REFER TO.
SPA-RH

UNITED STATES
DEPARTMENT OF THE INTERIOR
SOUTHWESTERN POWER ADMINISTRATION

POST OFFICE DRAWER 1619
TULSA, OKLAHOMA 74101

July 27, 1965

Your reference:
SWFGB

District Engineer
U. S. Army Engineer District,
Fort Worth
Corps of Engineers
P. O. Box 1600
Ft. Worth, Texas 76101

Dear Sir:

Reference is made to your letter dated July 6, 1965, and the enclosed draft copy of your "Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed", dated July 1965.

The report states that preliminary estimates show that hydroelectric power is not economically attractive and that the specific costs of power produce a benefit-cost ratio of less than unity. There are no hydroelectric projects planned downstream of the Navasota watershed. Therefore, the interests of this Administration will not be affected by the recommendations of the District Engineer. The draft copy is returned as requested.

Sincerely yours,

Carl E. Roberts,
Chief, Division of Planning and
Resources

Enclosure

IN REPLY REFER TO:
Your File: SWFGB

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SOUTHWEST FIELD COMMITTEE, REGION SIX
Federal Building
300 East 8th Street
Austin, Texas 78701

July 28, 1965

District Engineer
U. S. Army Engineer District, Fort Worth
Corps of Engineers
P. O. Box 1600
Fort Worth, Texas 76101

Dear Sir:

Thank you for the opportunity to review a draft copy (Serial No. 87) of the Corps of Engineers "Review of Reports on Brazos River and Tributaries, Texas, Navasota River Watershed," dated July 1965, in accordance with Inter-Agency Agreement approved by the President on May 26, 1954.

The U. S. Geological Survey has a great interest in this report because it deals with the development of water resources. Changes in the Geological Survey's continuing basic water-resources studies will be necessary to meet project operation needs of the Corps of Engineers as well as to obtain future basic data for evaluating the quantity and quality of the water resources under the developed condition. The project will help control flooding on the lower Brazos River and will provide needed conservation storage for future water requirements in south Texas.

It is gratifying to note that extensive use was made of the historical streamflow data obtained by the U. S. Geological Survey in planning the project. The streamflow and water-quality studies made by Geological Survey on a continuous basis in the Navasota basin will not be terminated.

Water to be impounded by Millican Dam will inundate stream-gaging station No. 08-1110, Navasota River near Bryan, Tex. Additionally, when Navasota No. 2 dam is constructed, impounded water will inundate stream-gaging station No. 08-1105, Navasota River near Easterly, Tex.

The Geological Survey concurs in the project plan to provide for installation and maintenance of hydrologic equipment to determine the inflow, outflow, and reservoir contents of each reservoir. Funds provided for this purpose should be sufficient to not only cover the costs of relocating these gages, but also to provide for weir-type controls and improved hydrologic equipment necessary to obtain accurate records of streamflow and water-quality records that will be needed in water-management operations.

The station, Navasota River near Bryan, Tex., should be moved upstream so as to be above backwater from Millican Reservoir (possibly at the O.S.R. highway) and providing a record of inflow into Millican Reservoir. The station would also serve as the outflow station for Navasota No. 2 Reservoir when it is built.

The hydrologic equipment necessary for determining outflow from Millican Dam will require both a stage recorder and slope gage as this site will be in backwater, at times, from the Brazos River. We urge that funds be provided to install a concrete weir control at the outflow station to stabilize the channel at the gaging station so ordinary water releases and water-quality records may be accurately determined.

The Geological Survey, Water Resources Division, Texas District, will cooperate with the Corps of Engineers in making field reconnaissance and preparing cost estimates for the installation of the hydrologic instrument installations required. It is recommended that the operation of this station be operated as part of the cooperative network of the Geological Survey.

We wish to be kept informed as to the advancement of this project. Such information will assist this District in modifying or expanding water-resources study programs in this area as funds are made available to meet planning and operational needs of the Corps and others operating in the Brazos River basin.

The draft copy (serial No. 87) of the report is being returned under separate cover. Please furnish me a copy of the final report when it is available.

Very truly yours,

Trigg Twichell

Trigg Twichell
Contact Official for
Geological Survey

SPS:mlb
cc: Douglas R. Woodward, Washington, D. C.
S. K. Jackson, Area Hydrologist, Denver, Colo.
S. P. Sauer, Engr.-in-Chg., Austin Field Unit

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF OUTDOOR RECREATION
MID-CONTINENT REGION
BUILDING 56, DENVER FEDERAL CENTER
DENVER, COLORADO 80225

D6427TG

July 29, 1965

Colonel F. P. Koisch
District Engineer
U. S. Army Engineer District
P. O. Box 1600
Fort Worth, Texas 76101

Dear Colonel Koisch:

We have no comments on the draft of your "Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed," forwarded by your letter of July 6, 1965. By this statement, we do not imply that we approve or disapprove of the report or that we are not interested, but that we lack adequate resources to effectively review all reports currently being received.

We are returning your draft report (serial no. 88) as requested.

Sincerely yours,

W. W. Dresskell
Regional Director

Enclosure

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
REGIONAL OFFICE

PUBLIC HEALTH SERVICE

1114 Commerce Street
Dallas, Texas 75202

July 29, 1965

Colonel F. P. Koisch, District Engineer
U. S. Army Engineer District, Fort Worth
Corps of Engineers
P. O. Box 1600
Fort Worth, Texas 76101

Dear Colonel Koisch:

We have reviewed the "Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed," dated July 1965, as requested by your letter dated July 6, 1965.

Our appended report entitled "Water Supply and Water Quality Control Study, Navasota River Watershed, Lower Brazos River System, Texas," adequately states our views in regard to the storage of water for municipal and industrial supply, and the storage of dilution waters for pollution control. The reduction in flooding in the watershed that would result from construction of the reservoirs proposed would prove to be beneficial to the general public health of the region.

In addition, it is recommended:

1. That vector prevention and control measures be incorporated into the design or planning stage of the reservoir project.

2. That plans for reservoir clearing be concurred in by the Texas State Department of Health.

3. That consideration be given to the following measures in connection with development of recreational areas along the shores of the reservoir:

    a. Locating such areas, particularly those developed for overnight occupancy, along sections where the mosquito potentials are low.

    b. Providing for proper storage, collection, and disposal of refuse for the prevention of flies, wasps, rats, and wild rodents.

c. Providing for rodentproofed buildings at recreational areas where rodents may create public health hazards.

d. Providing for periodic removal of debris, rubbish, and other materials which may serve as harborage for rodents and other mammals.

e. Providing for removal of brush and weeds along paths, trails, and roadways for the prevention of tick infestations.

f. Providing for supplemental use of insecticides and rodenticides in situations where adequate vector control is not obtained through source reduction measures outlined above.

4. That postimpoundage vector control surveys be conducted to determine what additional measures are needed for adequate public health safeguards.

The above recommendations are concurred in by the Texas State Department of Health.

The opportunity to review this report is appreciated. We are returning the draft copy of the report (Serial number 72) as requested.

Sincerely yours,

Jerome H Svore

JEROME H. SVORE
Regional Program Director
Water Supply & Pollution Control

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
100 WEST VICKERY BOULEVARD
FORT WORTH 4, TEXAS

ADDRESS REPLY TO:
DISTRICT ENGINEER
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
P. O. BOX 1600
FORT WORTH, TEXAS
IN REPLY REFER TO
SWFGB

5 August 1965

Mr. Jerome H. Svore
Regional Program Director
Water Supply and Pollution Control
Public Health Service
1114 Commerce Street
Dallas, Texas 75202

Dear Mr. Svore:

In the absence of the District Engineer, Colonel Jack W. Fickessen, I am taking the liberty of acknowledging receipt of your letter dated 29 July 1965 furnishing the comments of your agency on "Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed," dated July 1965.

The additional recommendations contained in your letter regarding vector prevention and control measures, reservoir clearing, the development of recreational areas, and postimpoundage vector control surveys will be given further consideration during preconstruction planning of the proposed projects after they are authorized for construction.

Sincerely yours,

W. E. HOLLAND, JR.
Lt Col, CE
Deputy District Engineer

FEDERAL POWER COMMISSION
REGIONAL OFFICE

100 North University Drive
Fort Worth, Texas 76107
July 30, 1965

The District Engineer
U. S. Army Engineer District, Fort Worth
P. O. Box 1600
Fort Worth, Texas 76101

Dear Sir:

Reference is made to your letter (SWFGB) of July 6, 1965, furnishing a draft copy in final form of your "Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed" dated July 1965, for our review and comments.

The report recommends authorization of Millican and Navasota No. 2 reservoirs in lieu of the authorized Ferguson project, all on Navasota River, for purposes of flood control, water supply, recreation, and fish and wildlife. Our review of the report was directed towards the feasibility of including hydroelectric power features at Millican and Navasota No. 2 Reservoir projects as proposed for completion in 1975 and 2010 respectively. Our investigation determined that hydroelectric power development at the Millican project would be impractical because of low power heads, but that the Navasota No. 2 project would be favorable for providing hydro power. According to the hydrology presented in the Review Report, the required two-project yield of 475 cfs under 2010 flow conditions could be provided from about 700,000 acre-feet of storage at Navasota No. 2 with a reservoir yield of 235 cfs and with average and minimum power heads of 75 feet and 63 feet to support a 24,000 kw unit operating at a 5-percent load factor. The benefit-cost ratio for the specific power facilities based on current prices would be 0.9, a ratio which precludes the formation of a firm conclusion with regard to the hydroelectric power potential for 2010.

It is concluded that the installation of power features would not be justified at the Millican Project but that a final decision regarding power development at the Navasota No. 2 project should not be made at this time. Development of the proposed projects will not effect existing or potential hydro projects.

Your courtesy in contacting us is appreciated. Please note that these comments are prepared at field level and are not to be construed as an official opinion of the Federal Power Commission.

As requested in your letter, the copy of your report is being returned herewith.

Sincerely yours,

Lenard B. Young

Lenard B. Young
Regional Engineer

Enclosure No.4215:
As stated above

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
100 WEST VICKERY BOULEVARD
FORT WORTH 4, TEXAS

ADDRESS REPLY TO:
DISTRICT ENGINEER
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
P. O. BOX 1600
FORT WORTH, TEXAS
IN REPLY REFER TO

9 August 1965

SWFGP

Regional Engineer
Federal Power Commission
100 North University Drive
Fort Worth, Texas 76101

Dear Sir:

This is in reply to your letter of 30 July 1965 setting forth your comments on our Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed.

You comment to the effect that the Navasota No. 2 project would be favorable for providing hydro power. However, you further state that your investigation shows the benefit-cost ratio for the specific power facilities based on current prices would be 0.9, a ratio which precludes the formation of a firm conclusion with regard to the hydroelectric power potential for 2010.

We concur in your finding of the benefit-cost ratio being 0.9 when considering the specific power facilities only. However, it must be emphasized that this analysis shows the power potential in its best light, since it includes no cost for dam and reservoir.

The assignment of any portion of the costs for dam and reservoir would further reduce the benefit-cost ratio for the power function of the project. This fact further substantiates your views that the ratio of 0.9 for specific power facilities prevents any conclusion as to the feasibility of power in the year 2010.

As has been our practice in the past, we will examine the power potential of these projects further during the advance planning stage.

Sincerely yours,

JACK W. FICKESSEN
Colonel, CE
District Engineer

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
P. O. Box 648
Temple, Texas 76502

July 28, 1965

Colonel J. W. Fickessen
District Engineer
Corps of Engineers, U. S. Army
1100 West Vickery Blvd.
Box 1600
Fort Worth, Texas 76101

Dear Colonel Fickessen:

Thank you for the opportunity to review the report on Brazos River and Tributaries, Texas, covering the Navasota River Watershed.

It is noted that capacity provided for water conservation purposes includes amounts estimated to satisfy future municipal and industrial needs and potential requirements for irrigation. In connection with the later, it was pointed out that studies by the Bureau of Reclamation indicated that no large scale irrigation development is expected on the Navasota watershed under present economic conditions and legislation, but that large acreages of land suitable for irrigation are located downstream in the Brazos River flood plain. Consequently, it was felt that water requirements for irrigation needs should be included in a fully integrated water supply plan for the Lower Brazos River Basin.

The Soil Conservation Service is interested in the irrigation potential afforded by the proposed Millican Reservoir, since this Service will be requested to furnish technical assistance for on-farm irrigation systems when delivery canals from the reservoir are constructed.

No watershed projects have been approved for construction on upstream areas above the reservoirs recommended in this report. It is felt that needed land treatment and structural works of improvement installed on upstream watersheds indicated to be feasible for project development, and discussed on page 34 and elsewhere in this report, will be beneficial to the proposed reservoirs.

Page 34, paragraph 48 - This information is taken from the report of the United States Study Commission - Texas, dated March 1962. In the last sentence, the reference to Big Creek watershed lists benefits and cost which includes 8.6 miles of channel improvement in addition to the 10 floodwater retarding structures.

Page II-23 - It is stated that estimated present land treatment practices and existing small ponds have depleted the natural runoff from the watershed above Millican Reservoir by about 8 percent during recent years. This is not substantiated. The Study Commission Report shows the average annual 1941-1956 natural runoff at the Navasota dam site (1,330 square miles) to be 343,000 acre-feet. The 1958 condition runoff was estimated to average 338,000 acre-feet. This is about 1.5 percent.

Also, it is stated that estimated future Soil Conservation Service land treatment practices, small ponds, and retardation structures upstream from the Millican Reservoir would be fully effective by the year 2010, and would result in additional annual depletion of runoff varying from about 3 to 22 percent during recurrence of the critical drought period (1947-1957). The depletion factors were based on those established in conjunction with studies for the U. S. Study Commission. The Study Commission Report indicated that the natural runoff would be depleted by 3 to 22 percent. This was not an additional depletion to 1958 condition runoff. The average annual 1941-56, 2010 condition runoff, was estimated to be 322,000 acre-feet or 94 percent of natural.

If there are no objections, we are keeping draft copy No. 73, and are returning copies Nos. 74 and 75. We constantly have need for referring to such documents, even though they are in draft stage.

Sincerely yours,

H. N. Smith

H. N. Smith
State Conservationist

Attachments (2)

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
100 WEST VICKERY BOULEVARD
FORT WORTH 4, TEXAS

ADDRESS REPLY TO:
DISTRICT ENGINEER
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
P. O. BOX 1600
FORT WORTH, TEXAS
IN REPLY REFER TO

SWFGB

6 August 1965

Mr. H. N. Smith
State Conservationist
United States Department of Agriculture
Soil Conservation Service
P. O. Box 648
Temple, Texas 76502

Dear Mr. Smith:

Receipt is acknowledged of your letter of 28 July 1965 transmitting the comments of the Soil Conservation Service in regard to a field level review of our report "Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed."

The contents of page 34, paragraph 48, and page II-23 will be revised to agree with your comments.

Sincerely yours,

JACK W. FICKESSEN
Colonel, CE
District Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE

Branch of River Basin Studies
1104 T. & P. Building
Fort Worth, Texas 76102

July 12, 1965

District Engineer
Corps of Engineers, U. S. Army
P. O. Box 1600
Fort Worth, Texas 76102

Dear Sir:

We are returning the draft copy (Serial Number 79) of your "Review of Reports on Brazos River and Tributaries, Texas, covering Navasota River Watershed, dated July 1965.

As requested in your letter of July 6, 1965, our comments to your report will be made a part of the comments to be submitted by our Regional Office.

Sincerely yours,

John G. Degani

John G. Degani
Field Supervisor

Enclosure

96-129 O-68-17

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
POST OFFICE BOX 1306
ALBUQUERQUE, NEW MEXICO 87103

July 29, 1965

AIRMAIL

District Engineer
Corps of Engineers, U. S. Army
P.O. Box 1600
Fort Worth, Texas

Dear Sir:

This is in reply to your letter of July 6, 1965, which transmitted a copy of the Corps of Engineers' draft "Review of Reports on Brazos River and Tributaries, Texas, covering Navasota River Watershed," dated July 1965 for review and comment.

It is noted that this Bureau's report of April 2, 1965, is attached in Appendix V of the draft and that Appendix IV presents the Corps of Engineers' analysis for recreation and fish and wildlife enhancement for the project. This Bureau agrees that fishing and other recreational interests will be benefitted by the proposed project.

It is noted with interest that your report recognizes wildlife losses caused by the project and that the monetary value of the losses has been deducted from project benefits. However, we do not understand why the loss of 17,000 man-days of sport fishing occurring through displacement of lake and stream habitat was not similarly deducted from project benefits.

Based on an average use of the reservoirs of 6,000,000 visitor-days annually for all types of recreation, the Corps' analysis assumes that 1,782,000 man-days of fishing will be carried out annually. This Bureau, in its April 2, 1965, report, provided estimates of man-day use and monetary benefits for fishing expected in Millican and Navasota Reservoirs. Based on the capability of anticipated fish habitat, the report contained an estimate that the two reservoirs will be able to support an average of 240,000 man-days of fishing annually over the 100-year period of analysis.

Although it is agreed that the demand for water-based general recreation will be very great in the future, we cannot agree that fishing on Millican and Navasota Reservoirs will occur in a straight-line relationship with the demand for all types of outdoor recreation. Our conclusion in this regard is based on readily observable changes in fish habitat occurring in existing reservoirs which indicate that sport fishing cannot be maintained at high levels without costly intensive management of the habitat.

Most reservoirs in Texas are productive during the early years of impoundment and, during this period, sport fishing is good. Following this early period, sport fishing declines and nongame fishes become predominant. This phenomenon has been recorded in many parts of the country. Our Bureau is searching for answers to the problems of the decline in sport fish and fishing in warmwater reservoirs. Research programs concerned with these problems are being conducted in several parts of the country by this Bureau and various state fish and game agencies. The only solutions to these problems are, at present, expensive and very likely incompatible with other project purposes.

If the benefits for fishing are to be claimed for the project in the amount indicated in your report, then periodic rehabilitation of the fish habitat should become a project obligation. Such rehabilitation might be required as often as once every five to seven years with costs of about $3,000,000 each time the task is undertaken.

In project economic evaluation, we suggest use of this Bureau's estimates for fishing and hunting and recalculation of project economics based on those estimates.

It should be pointed out that this Bureau's report contained the recommendation that timber clearing within the reservoirs be kept to a minimum. Retention of timber within the reservoirs will lead to improved fishing and provide increased benefits to sport fishing. If project plans included reasonable assurances that timber clearing would be held to a minimum, then it is very possible that fishing benefits presented by this Bureau could be increased significantly.

Since non-Federal interests will be expected to fund a large proportion of specific costs allocated to recreation and fish and wildlife in compliance with the Federal Water Projects Recreation Act, we wonder whether the non-Federal interests have been made aware of their obligations in this regard.

We appreciate the opportunity extended to us to comment on the draft report. Under separate cover we are returning copy No. 78 of the draft.

Sincerely yours,

Carey H. Bennett

Carey H. Bennett, Chief
Division of Technical Services

Separate Cover:
Copy of report No. 78

cc:
Executive Director, Texas Parks and Wildlife Department, Austin, Texas
Field Supervisor, Division of River Basin Studies, Bureau of Sport Fisheries and Wildlife, Fort Worth, Texas

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
100 WEST VICKERY BOULEVARD
FORT WORTH 4, TEXAS

ADDRESS REPLY TO:
DISTRICT ENGINEER
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
P. O. BOX 1600
FORT WORTH, TEXAS
IN REPLY REFER TO

SWFGP

6 August 1965

Mr. John C. Gatlin
Regional Director
Bureau of Sport Fisheries and Wildlife
Fish and Wildlife Service
U. S. Department of the Interior
P. O. Box 1306
Albuquerque, New Mexico 87103

Dear Mr. Gatlin:

Reference is made to the recent letter from the Chief, Division of Technical Services, of your office, furnishing comments on our Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed.

In paragraph 3 of referenced letter, it states that it is not understood why the loss of 17,000 man-days of sport fishing occurring through displacement of lake and stream habitat was not similarly deducted from project benefits. For your information, this 17,000 man-days loss was inadvertently left out in the final summation of benefits for the report. It is estimated that the total monetary loss would be approximately $17,000 for the proposed plan, consisting of the Millican and Navasota No. 2 Reservoirs. However, adjustment of project benefits will not be made at this time, since it would have no effect on the economic justification of the plan.

In paragraph 4, the referenced letter does not question, but compares our estimate of 1,782,000 fishing visitors annually with the estimate of 240,000 man-days of fishing annually over the 100-year period of analysis in your report. First, it should be understood that our estimate is for fishing visitors and not man-days of fishing as you indicate. Visitation figures at Corps projects are based on the use of mechanical traffic counters, personal interview surveys, and at-site observations by project personnel. During the last three years, surveys have indicated that visitors to projects within the Fort Worth District have averaged 43 percent fishermen and 9 percent hunters. Therefore, the use in our report of 29.70 percent of the total visitation for the purpose of fishing and 0.30 percent of the total visitation for the purpose of hunting is considered conservative. Until some reasonable factor can be developed for conversion of fishing visitors to man-days of fishing, estimates of visitation and benefits by the Corps of Engineers and the Fish and Wildlife Service will continue to vary.

In paragraphs 5, 6, and 7 of referenced letter, it is indicated that in order for sport fishing to remain at high levels in existing and proposed reservoirs, costly intensive management of the habitat must be maintained. It further suggests that if benefits for fishing are to be claimed for the project in the amount indicated in our report, then a project cost of about $3,000,000 every five to seven years for rehabilitation of fish habitat should be included in our report. It is agreed that sport fishing may not be maintained at high levels without management of the habitat. However, data collected by this office have failed to show a decline in the number of fishermen at any of our existing reservoirs, most of which are at least ten years old.

Other comments in paragraphs 9 and 10 of referenced letter have been noted and will be given consideration. For instance, our clearing criteria always has zoned areas for fishing in reservoir construction, and the proposed Millican and Navasota No. 2 Reservoirs will be no exception.

A copy of the Fish and Wildlife Service's comments and this reply will be included in the report.

Sincerely yours,

JACK W. FICKESSEN
Colonel, CE
District Engineer

TEXAS WATER COMMISSION

COMMISSIONERS

JOE D. CARTER, CHAIRMAN
WILLIAM E. BERGER
O. F. DENT

SAM HOUSTON
STATE OFFICE BUILDING

AREA CODE 512
GREENWOOD 5-4514

P. O. BOX 12311
CAPITOL STATION
AUSTIN, TEXAS, 78711

JOHN J. VANDERTULIP
CHIEF ENGINEER

C. R. BASKIN
ASS'T. CHIEF ENGINEER

BURREL ROWE
CHIEF EXAMINER

AUDREY STRANDTMAN
SECRETARY

August 5, 1965

Colonel Frank P. Koisch, District Engineer
Corps of Engineers, U. S. Army
Fort Worth District
P. O. Box 1600
Fort Worth, Texas 76101

Dear Colonel Koisch:

Your letter of July 6, 1965 transmitted copies of your draft report titled "Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed" for review by the Texas Water Commission and other State agencies. Subsequently our agency transmitted copies of the report to the Texas Highway Department and the Texas Parks and Wildlife Department.

Comments prepared by the Texas Highway Department and by the Parks and Wildlife Department are enclosed with this letter.

The Texas Water Commission held a public hearing on your agency's previous report on the Navasota River Watershed in 1962. On August 2, 1962 the Commission entered an Order finding the proposed Millican project to be feasible. Section 5 of that Order states:

> "Section 5. Recommendations. The Texas Water Commission recommends:
> (a) That as a prerequisite to authorization of the project:
> (1) A review and revision of costs allocated to non-federal interests be made pursuant to the Federal Water Pollution Control Act of 1961, which provides for the inclusion of storage for water quality maintenance as desired Federal Project purpose. The benefits from inclusion of water quality maintenance would be widespread or national in scope, and the cost of such features should be non-reimbursable Federal costs.
> (2) A review and re-evaluation of project costs allocated to recreation and fish and wildlife purposes

be made. The benefits assigned to recreation and fish and wildlife as shown in the report are much smaller than that determined by the Commission's engineers.

(3) A re-examination be made of the project cost allocation in terms of water resource policies contained in Senate Document No. 97, 87th Congress, 2nd Session.

(b) That should the Congress determine to authorize the Millican Project, provision be made in such authorizing legislation for the possibility of stage development with the first phase or stage to consist of an impounding structure comparable to that designated in the report as "Optimum Plan."

Your July 1965 report has included a very complete analysis of each of the matters contained in the Commission's recommendations. During the period of your review Congressional consideration has been given to various aspects of water resources projects. The July 1965 report reflects consideration of these matters, including the proposed Federal Water Project Recreation Act of 1965.

The Corps of Engineers is to be commended for the very exhaustive analysis made of this complex water resources problem.

I am providing the members of the Water Commission with informational copies of my comments contained herein.

Sincerely yours,

John J. Vandertulip

John J. Vandertulip
Chief Engineer

Enclosures: Parks and Wildlife letter, July 15, 1965
Highway Department letter, August 2, 1965

COMMISSION

HERBERT C. PETRY, JR., CHAIRMAN
HAL WOODWARD
J. H. KULTGEN

TEXAS HIGHWAY DEPARTMENT

AUSTIN, TEXAS 78701

STATE HIGHWAY ENGINEER
D. C. GREER

August 2, 1965

IN REPLY REFER TO
FILE NO. D-5

Brazos, Grimes, Robertson and Leon Counties
Proposed Millican and Navasota No. 2 Reservoirs

RECEIVED
AUG 1965
TEXAS WATER COMMISSION
AUSTIN, TEXAS

Mr. John J. Vandertulip
Chief Engineer
Texas Water Commission
P. O. Box 12311, Capitol Station
Austin, Texas 78711

Dear Mr. Vandertulip:

We have reviewed the report prepared by the U. S. Corps of Engineers titled "Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed" as requested in your letter dated July 8, 1965.

Based on the information in the report, we believe that provisions have been made for the adjustment of all highways under the jurisdiction of this Department which will be affected by the construction of the two reservoirs. It appears that adequate cost estimates for such replacements are satisfactory based on current prices.

Your courtesy in making the report available for our information and review is appreciated.

Yours truly,

D. C. Greer
State Highway Engineer

By: Clyde F. Silvus

Clyde F. Silvus
Bridge Engineer

MLY:gk

TEXAS
PARKS AND WILDLIFE DEPARTMENT

COMMISSIONERS
WILL E. ODOM
CHAIRMAN, AUSTIN
A. W. MOURSUND
MEMBER, JOHNSON CITY
JAMES M. DELLINGER
MEMBER, CORPUS CHRISTI

J. WELDON WATSON
EXECUTIVE DIRECTOR

JOHN H. REAGAN BUILDING
AUSTIN, TEXAS 78701

July 15, 1965

Mr. John J. Vandertulip
Chief Engineer
Texas Water Commission
P. O. Box 12311
Capitol Station
Austin, Texas

Dear Mr. Vandertulip:

Reference is made to the "Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed", as prepared and assembled by the U. S. Army Corps of Engineers.

We have previously reviewed the wildlife and fisheries section and our letter of concurrence to it is contained as part of the report of the Bureau of Sport Fisheries and Wildlife in Appendix V. We have further reviewed the entire report and are in concurrence with its findings.

Sincerely yours,

J. Weldon Watson

J. Weldon Watson

JWW:TRL:pl

UNITED STATES
DEPARTMENT OF THE INTERIOR

BUREAU OF RECLAMATION

REGIONAL OFFICE - REGION 5
P. O. BOX 1609
AMARILLO, TEXAS 79105

IN REPLY
REFER TO: 5-740

August 16, 1965

Colonel F. P. Koisch, District Engineer
U.S. Army Engineer District, Fort Worth
Corps of Engineers
100 West Vickery Boulevard
Fort Worth, Texas

Dear Colonel Koisch:

Please refer to your letter of July 6, 1965, which transmitted to this office and to our Austin Development Office, for review and comment, your report entitled "Review of Reports on Brazos River and Tributaries, Texas, Covering Navasota River Watershed," dated July 1965.

This office and our Development Office at Austin have both reviewed the report and we do not have any comments.

Your courtesy in providing our offices an opportunity to comment on your report is appreciated. We will appreciate transmittal of copies of your final report to this office and our Austin Development Office. The draft copy, Serial No. 68, is being returned as requested.

Sincerely yours,

Acting Regional Director

Enclosure

BRAZOS RIVER AND TRIBUTARIES, TEXAS
(NAVASOTA RIVER WATERSHED)

INFORMATION CALLED FOR BY
SENATE RESOLUTION 148, 85TH CONGRESS
ADOPTED JANUARY 28, 1958

1. AUTHORITY.- The following information is furnished in response to Senate Resolution 148, 85th Congress, adopted January 28, 1958.

2. WATER PROBLEMS.- The principal water problems on the Navasota River watershed result from the frequent occurrence of floods and insufficient water supply. Major floods originating on the Navasota River watershed cause appreciable damages along the Navasota River and, in addition, augment considerably the flood conditions and damages along the main stem of the lower Brazos River. Periods of prolonged drought, upward trends in population, and expansion of industrial and municipal developments have made evident the increasing need for the conservation of surface runoff for all beneficial purposes in the lower Brazos River Basin.

3. FLOOD PROBLEMS.- A flood problem exists on the Navasota River within the investigated 83.4-mile reach between the mouth and the Navasota No. 2 Dam site where an agricultural area, devoted principally to production of beef and dairy products, is subject to frequent damage by floodflows originating on the Navasota River watershed. A serious flood problem also exists along the main stem of the lower Brazos River where damages to urban and highly developed agricultural areas are considerably increased during flood stages on the Brazos River by major floodflows discharging from the Navasota River.

4. WATER-SUPPLY PROBLEM.- At the public hearing, local interests stated the need for conservation of water for municipal, industrial, and agricultural purposes on the lower Brazos River Basin, including the Navasota River watershed. The organic quality of waters of the lower Brazos River Basin as measured by dissolved oxygen can be described as good. The mineral quality of the Brazos River, downstream of Whitney Reservoir is poor, due primarily to extensive natural brine pollution in the upper Brazos River Basin. The demand for municipal, industrial, and rural water requirements in the lower Brazos River, including the contiguous coastal area, is expected to increase from the present use of about 340 mgd to 1,326 mgd in year 2025 and 2,088 mgd in year 2075. The municipal and industrial water supply need on the Navasota River watershed is expected to increase from a present use of about 8 mgd to 83 mgd in 2025 and 168 mgd in 2075. The increases are mainly attributable to expected increases in population and industrial growth. Based on a comparison of supplies and demands, surface water storage on the Navasota River watershed

will be needed for the study area by year 1980. Full development of the water supply resources with other planned developments, will assist in meeting future needs to about year 2028.

5. RECOMMENDED PLAN OF IMPROVEMENT.- The District Engineer recommends that the authorized project for the Brazos River and Tributaries, Texas, be modified to provide for the authorization of a plan of stage development, including authorization of Millican and Navasota No. 2 Reservoirs (and appurtenant channel improvements and/or flowage easements on the Navasota River for flood release purposes), in lieu of the authorized Ferguson Reservoir project, for the purposes of flood control, water supply, and recreation and fish and wildlife enhancement. Pertinent data for the proposed plan is shown in table 1.

6. PROJECT COST AND ECONOMIC ANALYSES.- The recommended Millican and Navasota No. 2 Reservoirs, including appurtenant channel improvements and/or flood flowage easements downstream from the dams, would be constructed by the Federal government at a total estimated construction cost of $119,707,000, based on the January 1965 price level. The estimated annual charges are $4,888,700 of which $543,700 is for operation and maintenance and $4,345,000 is for interest and amortization. The annual charges for each reservoir unit are based on an interest rate of 3.125 percent, a 100-year amortization period, and an 8-year construction period. The estimates include allowance for contingencies and cost for engineering and overhead. Allowance for operation and maintenance including replacement of parts is based upon past experience for similar projects in this area. Only tangible benefits were used for the project evaluations.

7. BENEFITS AND BENEFIT-COST RATIO.- The first costs, annual charges, annual benefits, and benefit-cost ratio for 50-year and 100-year economic life are summarized in table 2.

8. PHYSICAL FEASIBILITY AND PROVISION FOR FUTURE NEEDS.- The selected plan of improvement referred to as Plan II throughout the report accomplishes the most desirable results of excess benefits over cost. By initiating a stage development plan with Millican Reservoir serving as the initial unit, 98 percent of the total flood control benefits available can be acquired in construction of the first unit. Millican Reservoir as the initial unit will provide $1,373,800 more excess benefits over cost than the best plan utilizing Navasota No. 2 Reservoir as the initial unit. Millican Reservoir will develop 63 percent of the water resources upstream from river mile 24.1 in comparison with 49 percent for the Navasota No. 2 site and can provide the maximum economical total development of water supply resources if the Navasota No. 2 site is never developed.

9. As the initial unit Millican Reservoir's flood control requirements was determined by analysis of all major Texas storms of record in both their natural and transposed positions. The selected capacity is sufficient to control the floods of record and the volume of flood-control storage provided approximates that required for 100-year flood control as based on a regional analysis of flood-control storage requirements. In determining the conservation storage capacity which should be provided in the reservoir, cognizance was taken of the requests of local interests which include the probable water requirements of downstream interests in addition to those in the local area. Yield-versus-storage relationships were established, and cost estimates were developed for several volumes of conservation storage. These studies disclosed that 680,200 acre-feet of conservation storage could be provided at reasonable cost and that this volume of storage was generally in accordance with the desires of those interested in developing the water resources within the State and in obtaining optimum development of water supply resources on the Navasota River watershed. Larger volumes of conservation storage could be provided in the project but the adopted amount of storage space meets the desires of responsible State agencies at this time. The storage allocations utilized in the proposed plan will serve both current and reasonably prospective flood control and water conservation needs. As the water supply requirement increased beyond the 300 cfs of dependable yield provided by Millican Reservoir, predetermined to be by 2010, then Navasota No. 2 Reservoir would be constructed, accompanied by a reallocation of storage in Millican Reservoir as shown in table 1. The two-reservoir-stage-development plan will provide adequate fish, wildlife and recreational facilities to meet the anticipated needs of the general public within the surrounding areas.

10. EXTENT OF INTEREST IN THE PROJECT.- The Brazos River Authority is the agency designated by the Texas Water Commission to negotiate with the Corps of Engineers in matters pertaining to water supply storage in the Corps projects in the Brazos River Basin. The Brazos River Authority submitted a resolution at the public hearing held on March 16, 1965, indicating approval of the proposed plan of improvement and expressed their willingness to assume the requirements of local cooperation for the water supply portion of the project. Objections to the location of reservoirs on the Navasota River have been expressed by local interests who live in the investigated reservoir areas. The major objections expressed by the opponents were in regard to the displacement or relocation of people who reside or own land within the proposed reservoir areas; the inundation of lands which they classify as the best and most highly developed portions of the watershed; the loss of game habitat with the resultant reductions in economic returns to the landowners, specifically in those areas which would be required for a project

at the Millican or the Ferguson site; the loss of tax revenue to school districts and county governments; and the development of projects on the Navasota River, from which the maximum benefits would be to landowners and water users on the lower Brazos River. Certain local interests who reside in the area to be inundated by Millican and Ferguson Reservoirs have expressed considerable opposition to these projects and have indicated a preference for the Navasota No. 2 site.

11. ALLOCATION OF COSTS.- The results of allocation of the costs of the recommended reservoir projects by the Separable Costs-Remaining Benefits method and by alternative methods listed in Senate Resolution 148, based on an assumed economic life of 100 years, are presented in table 3 and 4. The total costs allocated to water supply are the responsibility of local interests. The full local cooperation requirements for the recommended improvements provide that prior to construction local interests give assurances satisfactory to the Secretary of the Army that they will obtain all the necessary water rights and contribute the parts of the total first costs of the projects and the annual cost of operation, maintenance, and replacements allocated to water supply, and to recreation and fish and wildlife enhancement.

12. REPAYMENT ARRANGEMENTS.- Repayment arrangement for non-Federal interests are as follows:

a. Water supply.- The costs allocated to water supply are apportioned to non-Federal interest in accordance with the provisions of the Water Supply Act of 1958, Public Law 580, 85th Congress, as amended. Payment is not required with respect to storage for future water supply until such supply is first used except that payments must begin so as to permit paying out the cost allocated to water supply within the life of the project, but in no event to exceed 50 years after first use. Not more than 30 percent of the total estimated construction cost of each project can be allocated to anticipated future demands. No interest will be charged on the investment cost (construction cost plus interest during construction) allocated to future water supply until use is initiated, but the interest-free period shall not exceed 10 years.

b. Recreation and fish and wildlife.- In accordance with Public Law 89-72 (S. 1229, H.R. 5269), approved July 9, 1965, the non-Federal share of the separable costs of the project allocated to recreation and fish and wildlife enhancement shall be borne by non-Federal interests, under either or both of the following methods as may be determined appropriate by the head of the Federal agency having jurisdiction over the project: (1) payment, or provision of lands, interests therein, or facilities for the project; or (2) repayment, with interest at a rate comparable to that for other interest-bearing functions of Federal water resource projects, within fifty years of first use of project recreation or fish and wildlife enhancement facilities: Provided, That the source of repayment may be limited to entrance and user fees or charges collected at the project by non-Federal interests if the fee schedule and the portion of fees dedicated to repayment are established on a basis calculated to achieve repayment as aforesaid and are made subject to review and renegotiation at intervals of not more than five years.

13. ALTERNATIVE PROJECT CONSIDERATIONS.- Preliminary feasibility studies were made for a total of five potential reservoir sites (Millican, Ferguson No. 3, Iola, Bundic, and Navasota No. 2) located between river miles 24.1 and 83.4 on the Navasota River. Multiple-purpose project costs were developed at each of the sites for comparison purposes. Comparisons made of the excess benefits over costs for these sites resulted in the selection of the Millican, Ferguson No. 3, and Navasota No. 2 Reservoirs for detailed single-reservoir plan studies; and Millican and Navasota No. 2 Reservoirs for detailed two-reservoir stage-development plans. The basic report presents detailed comparisons of the investigated plans.

14. In the process of selecting the most desirable stage-development plan, equal consideration was given to the Millican Reservoir and the Navasota No. 2 Reservoir as the initial unit. The stage-development units were investigated with various combinations of water supply storages with a view to full development of the water supply resources upstream of the Millican Dam site. Plan II with Millican Reservoir (total controlled storage of 1,557,400 acre-feet) as the initial unit and Navasota No. 2 as the future unit (total controlled storage of 1,935,600 acre-feet) provided the greatest amount of excess benefits over cost. This plan exceeded the second-best plan (Plan V) with Millican Reservoir as the initial unit, by a total of $43,900 per year, and exceeded Plan VI, the most favorable plan with Navasota No. 2 Reservoir as the initial unit, by a total of $485,100 per year, as shown in table 5. The various combinations of Millican and Navasota No. 2 Reservoirs would provide the same total amount of annual benefits for recreation and fish and wildlife enhancement.

15. The economic and cost studies for the selected and alternative projects which are summarized in table 5 were made on the basis of an economic evaluation period 1975-2075, using a 3.125 percent interest rate. It was determined that an analysis on the basis of 50-year economic evaluation period 1975-2025 would not substantially change the relative economic merit of the selected and alternative plans.

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TABLE 1

PERTINENT DATA
NAVASOTA RIVER WATERSHED

Item	First Stage: Millican Reservoir	Second Stage: Navasota No. 2 Reservoir	Second Stage: Millican Reservoir
DAM			
Location, river mile	24.1	83.4	24.1
Drainage area, square miles	2,120	1,341	2,120
Type	Concrete and compacted earth fill	Concrete and compacted earth fill	Concrete and compacted earth fill
Length, feet	25,300	16,100	25,300
Height, feet	83	111	83
Freeboard, feet	12.1	7.6	7.4
Crown width, feet	30	30	30
SPILLWAY			
Type	Concrete ogee	Concrete ogee	Concrete ogee
Control	10 - 40'x30' tainter gates	9 - 40'x29' tainter gates	10 - 40'x30' tainter gates
Gross length, feet	472	424	472
Net length, feet	400	360	400
OUTLET WORKS			
Type	Gate controlled sluices	Gate controlled sluices	Gate controlled sluices
Number of sluices, conduits	2	2	2
Dimensions (width x height)	2' x 4'	2' x 4'	2' x 4'
Invert elevations, feet msl	180.0	256.0	180.0
Sluice or conduit control	2 - 2'x4' slide gates	2 - 2'x4' slide gates	2 - 2'x4' slide gates

RESERVOIR	First Stage Millican Elev. (ft-msl)	Area (acres)	Capacity (ac-ft)	Capacity (inches)	Navasota No. 2 Elev. (ft-msl)	Area (acres)	Capacity (ac-ft)	Capacity (inches)	Second Stage Millican Elev. (ft-msl)	Area (acres)	Capacity (ac-ft)	Capacity (inches)
Sediment storage	-	-	92,000	0.82	-	-	69,500	0.97	-	-	72,000	0.64
Top of conservation storage	219.0	42,400	754,400	6.74	330.0	44,540	1,378,600	19.28	228.0	55,500	1,193,500	10.66
Top of flood control storage	234.0	66,000	1,557,400	13.91	341.0	58,180	1,935,600	27.06	234.0	66,000	1,557,400	13.91
Maximum design water surface	237.9	73,800	1,830,000	16.34	346.4	69,440	2,277,600	31.85	242.6	83,300	2,199,100	19.63
Top of dam	250.0	-		-	354.0	-	-	-	250.0	-	-	-

Item	Navasota River Channel: First Stage	Navasota River Channel: Second Stage
IMPROVEMENTS		
River mile limits	9.5 - 22.4	67.9 - 82.9
Drainage area		
Head of improvement, sq. mi.	2,120	1,341
Channel improvements		
Existing length, mile	12.9	15.0
Improved length, mile	6.3	10.0
Bottom, width	60 - 100	90
Clearing		
Width, feet	225	200
Area, acres	280	280
Rights-of-way		
Land area, acres	315	315

TABLE 2

ANNUAL CHARGES, ANNUAL BENEFITS, AND BENEFIT-COST RATIO
50-YEAR AND 100-YEAR ECONOMIC LIFE
NAVASOTA RIVER WATERSHED

Item	Millican Reservoir	Navasota No. 2 Reservoir
BASED ON ECONOMIC LIFE OF 50 YEARS		
ECONOMIC EVALUATION PERIOD	1975-2025	2010-2060
FIRST COSTS	$57,942,000	$60,520,000
	57,258,000*	59,940,000*
AVERAGE ANNUAL COSTS		
Investment cost	2,563,000	2,683,200
Operation, maintenance, and replacement of parts	268,000	257,700
Total	2,831,000*	2,940,900*
AVERAGE ANNUAL BENEFITS		
Flood prevention	2,754,700	66,300
Water supply	1,320,000	1,908,400
Recreation	1,368,300	1,221,600
Total	5,443,000	3,196,300
RATIO OF BENEFITS TO COST	1.9	1.1
BASED ON ECONOMIC LIFE OF 100 YEARS		
ECONOMIC EVALUATION PERIOD	1975-2075	2010-2110
FIRST COSTS	58,620,000	61,087,000
	57,480,000*	60,413,000*
AVERAGE ANNUAL COSTS		
Investment cost	2,118,500	2,226,500
Operation, maintenance, and replacement of parts	286,000	257,700
Total	2,404,500*	2,484,200*
AVERAGE ANNUAL BENEFITS		
Flood prevention	3,111,500	156,700
Water supply	1,320,000	1,908,400
Recreation	2,216,900	1,582,900
Total	6,648,400	3,648,000
RATIO OF BENEFITS TO COST	2.8	1.5

*With future recreation facilities discounted to present worth at year 1975 for Millican Reservoir and at year 2010 for Navasota No. 2 Reservoir.

TABLE 3

ALLOCATION OF COSTS
MILLICAN RESERVOIR AS THE INITIAL UNIT
100-YEAR EVALUATION PERIOD 1975-2075
SELECTED PLAN OF STAGE DEVELOPMENT (PLAN II)
NAVASOTA RIVER WATERSHED

Item	Separable Cost-Remaining Benefits	Priority of Use	Incremental Cost
Allocations to flood control			
First cost	$27,009,900 (46.99%)	$22,750,000 (39.58%)	$47,870,000 (83.28%)
Annual cost of operation, maintenance, and replacement	58,600 (20.49%)	113,000 (39.58%)	103,000 (36.01%)
Allocations to water conservation			
First cost	19,215,500 (33.43%)	18,647,000 (32.44%)	5,690,000 (9.90%)
Annual cost of operation, maintenance, and replacement	33,200 (11.61%)	93,000 (32.44%)	5,000 (1.75%)
Allocations to recreation and fish and wildlife enhancement			
First cost	11,254,600 (19.58%)	16,083,000 (27.98%)	3,920,000 (9.82%)
Annual cost of operation, maintenance, and replacement	194,200 (67.90%)	80,000 (27.98%)	178,000 (62.24%)
Total project			
First cost	57,480,000*	57,480,000*	57,480,000*
Average annual operation, maintenance, and replacement	286,000	286,000	286,000

*With future recreation facilities discounted to present worth at year 1975.

TABLE 4

ALLOCATION OF COST
NAVASOTA NO. 2 RESERVOIR AS THE FUTURE UNIT
100-YEAR EVALUATION PERIOD 2010-2110
SELECTED PLAN OF STAGE DEVELOPMENT (PLAN II)
NAVASOTA RIVER WATERSHED

Item	Separable Cost-Remaining: Benefits	Priority of Use	Incremental Cost
Allocations to flood control			
First cost	$ 3,129,400 (5.18%)	$ 3,691,000 (6.11%)	$25,157,000 (41.64%)
Annual cost of operation, maintenance, and replacement	33,500 (13.00%)	15,800 (6.11%)	76,000 (29.49%)
Allocations to water conservation			
First cost	46,771,700 (77.42%)	42,936,000 (71.07%)	32,380,000 (53.60%)
Annual cost of operation, maintenance, and replacement	71,900 (27.90%)	183,100 (71.07%)	45,000 (17.46%)
Allocations to recreation and fish and wildlife enhancement			
First cost	10,511,900 (17.40%)	13,786,000 (22.82%)	2,876,000 (4.76%)
Annual cost of operation, maintenance, and replacement	152,300 (59.10%)	58,800 (22.82%)	136,700 (53.05%)
Total project			
First cost	60,413,000*	60,413,000*	60,413,000*
Average annual operation, maintenance, and replacement	257,700	257,700	257,700

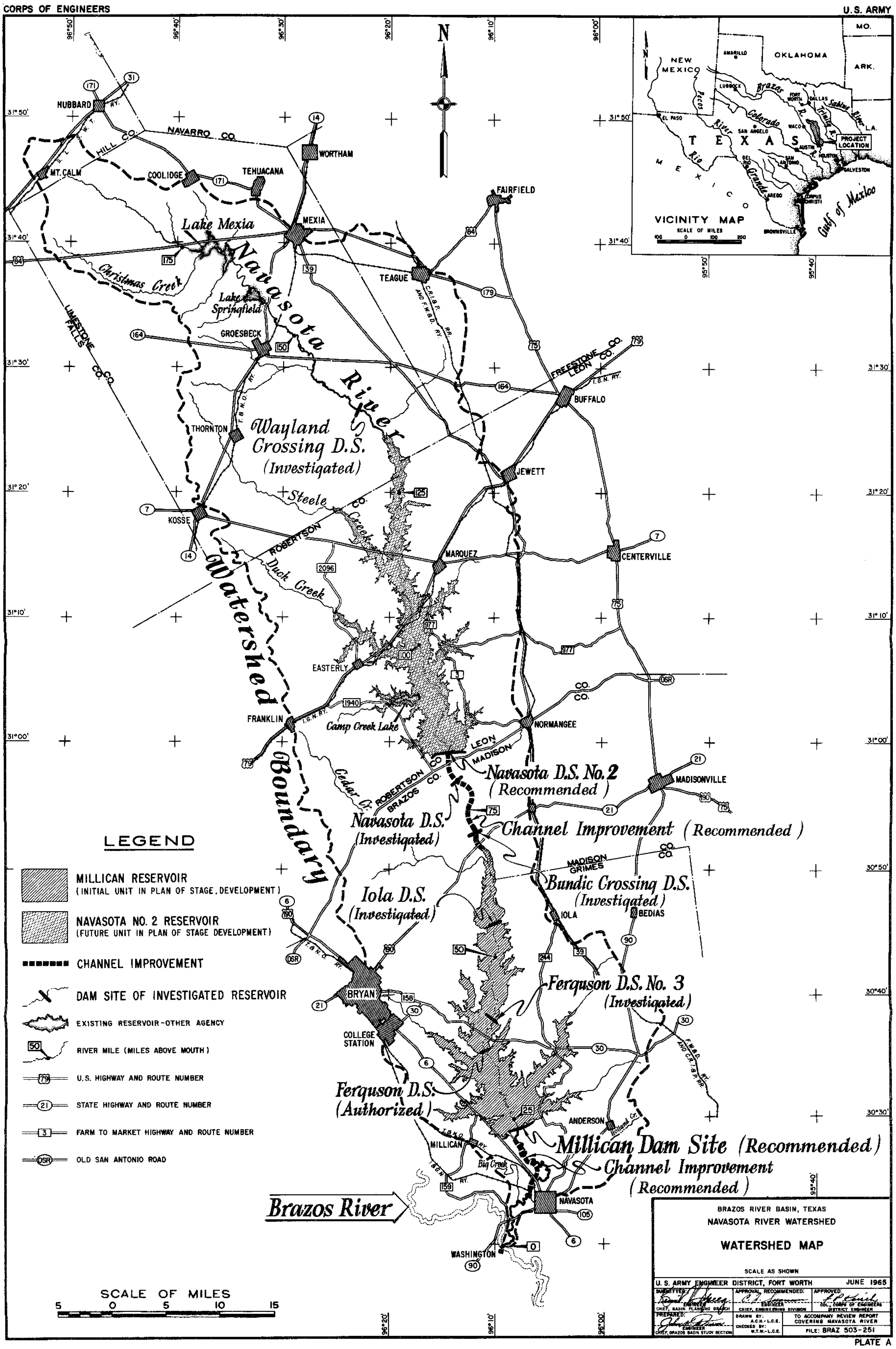
*With future recreation facilities discounted to present worth at year 2010.

TABLE 5

SUMMARY OF ECONOMIC AND COST ANALYSES
PLAN-COMPARISON STUDIES
ECONOMIC EVALUATION PERIOD 1975-2075
NAVASOTA RIVER WATERSHED

Plan	Storage FC (acre-feet)	Storage WC (acre-feet)	Dependable Yield cfs	Dependable Yield mgd	First Cost(1)	Annual Charges(2)	Annual Benefits(2)	Benefit-Cost Ratio	Excess Benefits over Cost
Millican as Initial Unit									
I (A-5)	786,400	2,408,300	480	310	$88,160,000	$3,652,200	$8,891,300	2.4	$5,239,100
V	906,000	2,443,400	475	307	80,009,000	3,291,300	8,936,300	2.7	5,645,000
II selected plan	910,300	2,441,200	475	307	78,057,000	3,241,900	8,930,800	2.8	5,688,900
X	907,300	2,560,400	470	304	84,886,000	3,492,400	8,910,500	2.6	5,418,100
IX	784,800	2,224,500	460	297	74,960,000	3,286,700	8,841,300	2.7	5,554,600
Navasota No. 2 as Initial Unit									
VII	904,500	2,648,200	470	304	83,016,000	3,469,300	8,624,700	2.5	5,155,400
VI	907,300	2,560,400	470	304	80,832,000	3,367,500	8,571,300	2.6	5,203,800
VIII	892,400	2,443,200	470	304	81,409,000	3,377,000	8,532,500	2.5	5,155,500
IV	910,300	2,441,200	475	307	86,681,000	3,610,400	8,524,100	2.4	4,913,700
III	906,000	2,443,400	475	307	91,020,000	3,763,700	8,510,900	2.3	4,747,200

(1) With future expenditures discounted to 1975 worth.
(2) Based on average annual equivalent values for the period 1975-2075.


CORPS OF ENGINEERS
U.S. ARMY
N
VICINITY MAP
SCALE OF MILES
NEW MEXICO
OKLAHOMA
MO.
ARK.
TEXAS
MEXICO
L.A.
PROJECT LOCATION
Gulf of Mexico
Brazos
Colorado
Pecos River
Rio Grande
Trinity R.
Sabine River
AMARILLO
LUBBOCK
FORT WORTH
DALLAS
WACO
EL PASO
SAN ANGELO
AUSTIN
HOUSTON
GALVESTON
SAN ANTONIO
DEL RIO
LAREDO
CORPUS CHRISTI
BROWNSVILLE
Lake Mexia
Lake Springfield
Navasota River
Watershed Boundary
Christmas Creek
Steele Creek
Duck Creek
Cedar Cr.
Big Creek
Holland Cr.
Camp Creek Lake
Wayland Crossing D.S. (Investigated)
Navasota D.S. No. 2 (Recommended)
Navasota D.S. (Investigated)
Channel Improvement (Recommended)
Iola D.S. (Investigated)
Bundic Crossing D.S. (Investigated)
Ferguson D.S. No. 3 (Investigated)
Ferguson D.S. (Authorized)
Millican Dam Site (Recommended)
Channel Improvement (Recommended)
Brazos River
HUBBARD
MT. CALM
COOLIDGE
TEHUACANA
WORTHAM
MEXIA
FAIRFIELD
TEAGUE
GROESBECK
THORNTON
KOSSE
BUFFALO
JEWETT
MARQUEZ
CENTERVILLE
EASTERLY
FRANKLIN
NORMANGEE
MADISONVILLE
IOLA
BEDIAS
BRYAN
COLLEGE STATION
ANDERSON
MILLICAN
NAVASOTA
WASHINGTON
HILL CO.
NAVARRO CO.
LIMESTONE CO.
FALLS CO.
FREESTONE CO.
LEON CO.
ROBERTSON CO.
MADISON CO.
BRAZOS CO.
GRIMES CO.
LEGEND
MILLICAN RESERVOIR (INITIAL UNIT IN PLAN OF STAGE DEVELOPMENT)
NAVASOTA NO. 2 RESERVOIR (FUTURE UNIT IN PLAN OF STAGE DEVELOPMENT)
CHANNEL IMPROVEMENT
DAM SITE OF INVESTIGATED RESERVOIR
EXISTING RESERVOIR-OTHER AGENCY
RIVER MILE (MILES ABOVE MOUTH)
U.S. HIGHWAY AND ROUTE NUMBER
STATE HIGHWAY AND ROUTE NUMBER
FARM TO MARKET HIGHWAY AND ROUTE NUMBER
OLD SAN ANTONIO ROAD
SCALE OF MILES
5 0 5 10 15
BRAZOS RIVER BASIN, TEXAS
NAVASOTA RIVER WATERSHED
WATERSHED MAP
SCALE AS SHOWN
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
JUNE 1965
TO ACCOMPANY REVIEW REPORT COVERING NAVASOTA RIVER
FILE: BRAZ 503-251
PLATE A

BRAZOS RIVER BASIN, TEXAS
NAVASOTA RIVER WATERSHED
BRAZOS RIVER BASIN
WATERSHED MAP

SCALE IN MILES
10 0 10 20 30 40 50

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1965

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
ENGINEER, CHIEF, BASIN PLANNING BRANCH	ENGINEER, CHIEF, ENGINEERING DIVISION	COL., CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ENGINEER, CHIEF, BRAZOS BASIN STUDY SECTION	DRAWN BY: M&F; CHECKED BY: WTW-LCK	TO ACCOMPANY REVIEW REPORT COVERING NAVASOTA RIVER; FILE: BRAZ 503-251

PLATE I