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LETTER

FROM

THE SECRETARY OF THE ARMY

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY, DATED APRIL 28, 1964, SUBMITTING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, ON AN INTERIM SURVEY OF HIGHLAND BAYOU, TEXAS, AUTHORIZED BY SECTION 204 OF THE FLOOD CONTROL ACT APPROVED JUNE 30, 1948



MAY 11, 1965.—Referred to the Committee on Public Works and ordered to be printed with four illustrations

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1965

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LETTER OF TRANSMITTAL

DEPARTMENT OF THE ARMY
WASHINGTON, D.C. 20310



IN REPLY REFER TO:

May 8, 1965

Honorable John W. McCormack
Speaker of the House of Representatives

Dear Mr. Speaker:

I am transmitting herewith a favorable report dated 28 April 1964, from the Chief of Engineers, Department of the Army, together with accompanying papers and illustrations, on an interim survey of Highland Bayou, Texas, authorized by Section 204 of the Flood Control Act approved 30 June 1948.

The views of the Governor of Texas, the Departments of the Interior and Agriculture, and the Public Health Service are set forth in the inclosed communications.

The Bureau of the Budget noted that the recommended plan of improvement would provide a greater degree of protection than an alternative plan which on the basis of the evaluation presented would provide the largest excess of benefits over costs. The Bureau recognized, on the basis of supplemental information furnished by the Chief of Engineers, that construction of the lower degree of protection could create a sense of security inconsistent with that level of protection, and probably would induce development beyond the protective capacity of such a project. On this basis the damage potential which might be expected if the lower level of protection were constructed could exceed that estimated in the report, resulting in greater residual flood damages and lower average annual benefits. The Bureau recognized, therefore, that the recommended plan which would provide the highest degree of protection should be considered the optimum protection plan, showing the greatest excess of annual benefits over annual charges. Revised average annual benefits are \$696,000 and the benefit-cost ratio is 3.6 on this basis.

The Bureau of the Budget advises that there is no objection to the submission of the proposed report to the Congress; however, it states that no commitment can be made at this time as to when any estimate of appropriation would be submitted for construction of the project modification, if authorized by the Congress, since this would be governed by the President's budgetary objectives as determined by the then prevailing fiscal situation. A copy of the letter from the Bureau of the Budget is inclosed.

Sincerely yours,



STEPHEN AILES

Secretary of the Army

1 Incl
Report

COMMENTS OF THE BUREAU OF THE BUDGET

EXECUTIVE OFFICE OF THE PRESIDENT

BUREAU OF THE BUDGET

WASHINGTON, D.C. 20503

April 26, 1965

Honorable Stephen Ailes
Secretary of the Army
Washington, D. C. 20310

Dear Mr. Secretary:

Mr. Alfred B. Fitt's letter of March 26, 1965, submitted the favorable report of the Chief of Engineers on an interim survey of Highland Bayou, Texas, authorized by the Flood Control Act approved June 30, 1948.

The Chief of Engineers recommends, subject to certain conditions of local cooperation, a plan for flood control by improving the channel of Highland Bayou and construction of a diversion dam to Highland Bayou with a diversion channel along the general course of Basford Bayou to Jones Bay. First cost is estimated at \$4,870,000, of which \$3,500,000 would be the Federal cost for construction and \$1,370,000 would be the non-Federal cost for lands, easements and rights-of-way and relocations.

The reporting officers investigated a number of alternatives and found that the one which, on the basis of the evaluation presented would provide the largest excess of benefits over costs, would be obtained from a plan protecting against a flood of 100-year frequency. First cost for this plan was estimated at \$3,930,000; annual charges \$163,000; annual benefits \$666,000. The benefit-cost ratio was estimated at 4.1.

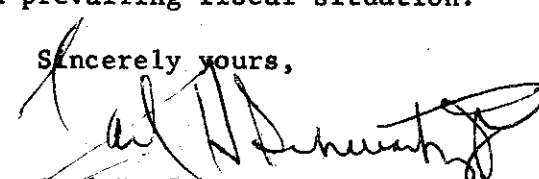
The above plan was not selected, however. Instead a plan protecting against a flood of 185-year frequency, at an increased first cost of \$940,000 was recommended. Estimated annual cost of the 185-year project is \$196,000; annual benefits \$671,000; the benefit-cost ratio is estimated at 3.4.

Supplemental information provided by the Chief of Engineers disclosed that the reason for selecting the 185-year protection plan was a belief that construction of a 100-year project would create a sense of security inconsistent with that level of protection, and probably would induce development beyond the protective capacity of such a project. The import of this is that the level of development and, therefore, the damage potential which can be expected if a project is constructed will exceed that estimated in the report, and if only a 100-year project is built the residual damage figure will be higher (and conversely, the average annual benefit lower) than shown in the report.

In recognition of this point the average annual benefit figures for both the 100 and 185-year projects have been modified. As a result it is now recognized that the 185-year project represents the optimum protection plan, showing the greatest excess of annual benefits, over annual charges. Revised average annual benefit and benefit-cost figures for the recommended project are \$696,000 and 3.6, respectively.

Accordingly, 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. However, no commitment can be made at this time as to when any estimate of appropriation would be submitted for construction of the project modification, 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.
Chief, Resources and
Civil Works Division

COMMENTS OF THE GOVERNOR OF TEXAS



JOHN CONNALLY
GOVERNOR OF TEXAS

April 23, 1964

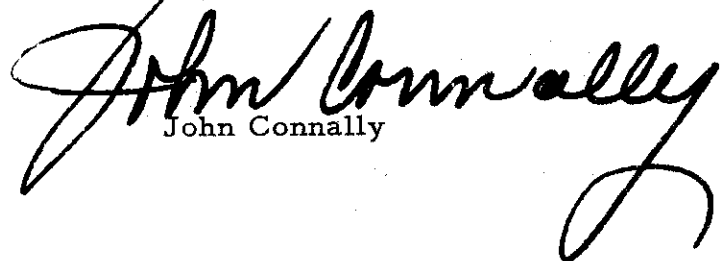
Lt. General Walter K. Wilson
Chief of Engineers
United States Corps of Engineers
Washington, D. C.

Dear General Wilson:

This is in regard to the Corps of Engineers flood control project on Highland Bayou. This work plan has been reviewed for me by the Texas Water Commission.

Based on the Commission's recommendation, I hereby approve the work plan in behalf of the State of Texas.

Sincerely,


John Connally

TEXAS WATER COMMISSION



AN ORDER approving the feasibility of the Highland Bayou Flood Control Project proposed in a U. S. Corps of Engineers Interim Survey Report on Highland Bayou, Texas.

BE IT ORDERED BY THE TEXAS WATER COMMISSION:

Section 1. Statement of Authority. Article 7472e, Vernon's Annotated Civil Statutes, provides that upon receipt of any engineering report submitted by a Federal Agency seeking the Governor's approval of a Federal Project, the Texas Water Commission shall study and make recommendations to the Governor as to the feasibility of the Federal Project. The Commission shall cause a public hearing to be held to receive the views of persons or groups who might be affected should the Federal Project be initiated and completed.

Section 2. Statement of Jurisdiction. (a) The Honorable John Connally has requested that the Texas Water Commission review the report of the Corps of Engineers, U. S. Army, entitled "Interim Survey Report of Highland Bayou, Texas", and to enter its order finding the project recommended therein to be feasible or not feasible. (b) In accordance with Article 7472e, and after due notice by publication, the Commission caused a public hearing to be held on April 1, 1964, at 10:00 o'clock a.m., in the offices of the Texas

Water Commission, 201 East 14th Street, Austin, Texas, on said report, at which time all those interested or who may be affected should the project recommended in said report be initiated and completed were requested to come forward and give testimony. Said hearing was continued from day to day until April 6, 1964.

Section 3. After fully considering all the evidence presented by persons and groups who may be affected should the project be initiated and completed, including the matters set forth in Section 4 of Article 7472e, the assurance of financial participation in the project by local interests, and the recommendations by the Chief Engineer of the Texas Water Commission, the Texas Water Commission finds that the project is feasible and the public interest will be served thereby.

Section 4. The Commission recommends:

(1) That the proposed project as recommended in said report by the U. S. Corps of Engineers relating to flood prevention in sections of LaMarque and Hitchcock, Texas, by enlargement and rectification of the channel of Highland Bayou with a diversion channel along the general course of Basford Bayou to Jones Bay be approved;

(2) That the Congress of the United States take action as expeditiously as possible to authorize and fund this urgently needed project to protect existing and future facilities in this important and rapidly developing area;

(3) That subsequent to Congressional approval and appropriation of funds, the matter should be reconsidered and re-evaluated giving consideration to possible alternate routes around Basford Bayou in

order to avoid undue interference with a project presently under development in that area;

(4) That ownership by the State of Texas of the waters involved be fully recognized by all interested parties and that lawful rights to the use of such waters, vested pursuant to State law, be respected, protected and preserved.

Section 5. It is further ordered that a certified copy of this order be transmitted to the Governor.

Section 6. This order shall take effect on the 6th day of April, 1964, the date of its passage, and it is so ordered.

SIGNED IN THE PRESENCE OF THE
TEXAS WATER COMMISSION

/s/ Joe D. Carter
Joe D. Carter, Chairman

ATTEST:

/s/ Audrey Strandtman
Audrey Strandtman, Secretary

STATE OF TEXAS §
§
COUNTY OF TRAVIS §

I, Audrey Strandtman, Secretary of the Texas Water Commission, do hereby certify that the foregoing and attached is a true and correct copy of an order of said Commission, the original of which is filed in the permanent records of said Commission.

Given under my hand and the seal of the Texas Water Commission, this the 7 day of April, A. D., 1964.



Audrey Strandtman, Secretary

COMMENTS OF THE DEPARTMENT OF THE INTERIOR



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

March 25, 1964

Dear General Wilson:

This is in reply to your letter of January 3, 1964, requesting our comments on reports on Highland Bayou, Texas.

Your report recommends flood control improvements, particularly to the cities of La Marque and Hitchcock, Texas at an estimated cost of \$4,870,000 for construction. The proposed improvements would not affect any existing or proposed Reclamation projects and neither would fish and wildlife resources be affected.

There is a possibility that the area involved contains archeological values which should be salvaged prior to construction. The Regional Director, Southwest Regional Office, National Park Service, P. O. Box 1728, Santa Fe, New Mexico, 87501, should be kept advised as to progress on this project. He may then program and initiate such surveys, salvage, and preservation of historical and archeological evidence as may exist. This is in accordance with provisions of the Act of June 27, 1960 (74 Stat. 220).

We appreciate the opportunity of presenting our views.

Sincerely yours,

A handwritten signature in cursive script that reads "Robert W. Nelson".

Deputy Assistant Secretary of the Interior

Lt. General Walter K. Wilson, Jr.
Chief of Engineers
Department of the Army
Washington 25, D. C.

COMMENTS OF THE DEPARTMENT OF AGRICULTURE



DEPARTMENT OF AGRICULTURE
WASHINGTON 25, D.C.

April 17, 1964

Honorable Stephen Ailes
Secretary of the Army

Dear Mr. Secretary:

This is in reply to the Chief of Engineers' letter of January 3, 1964, transmitting for our review and comment his proposed interim survey report on the Highland Bayou, Texas.

The report recommends the improvement of Highland Bayou for flood control by improving the channel of Highland Bayou and construction of a diversion dam on Highland Bayou with a diversion channel along the general course of Basford Bayou to Jones Bay. The cost of the improvement is estimated at \$4,870,000, of which \$3,500,000 would be the Federal cost for construction, and \$1,370,000 would be the non-Federal cost for lands, easements, rights of way, and relocation of structures. The benefit-cost ratio set forth in the report is 3.4 to 1.

The report states that both the existing and projected development in the Highland Bayou flood plain is urban in character and represents a high type of residential and commercial development.

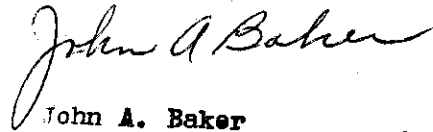
There are no National Forest lands or interests within the project area and effects of the project upon non-Federal woodland would not be of major significance.

Drainage investigations by technicians of this Department in cooperation with the U. S. Study Commission, Texas, indicated that drainage problems exist in a large portion of the Highland Bayou watershed. Major outlets were found to be inadequate in some of the areas needing drainage. The works of improvement proposed in the report should alleviate the drainage problems to some degree by providing major outlets and to this extent would be beneficial to the minor agricultural interests in the project area.

This department has no existing or planned projects which would be adversely affected by the proposed Highland Bayou project.

Thank you for providing this report for our review.

Sincerely yours,

A handwritten signature in cursive script that reads "John A. Baker". The signature is written in dark ink and is positioned above the typed name.

John A. Baker
Assistant Secretary

COMMENTS OF THE PUBLIC HEALTH SERVICE



DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

PUBLIC HEALTH SERVICE

WASHINGTON 25, D. C.

BUREAU OF STATE SERVICES

Refer to:

April 2, 1964

Lieutenant General Walter K. Wilson, Jr.
Chief of Engineers
Department of the Army
Washington 25, D. C.

Dear General Wilson:

This is in reply to your letter of January 3, 1964, requesting comments on the U. S. Army Engineers' Report on Highland Bayou, Texas.

This project is not expected to have any adverse effects on water supply, water pollution control, or vector control. The reduction of flooding in the built-up areas should be beneficial to the general public health environment.

The opportunity to review this report is appreciated. We stand ready to supply further consultation on your request.

Sincerely yours,

Keith S. Krause
Chief, Technical Services Branch
Division of Water Supply and
Pollution Control

HIGHLAND BAYOU, TEXAS

REPORT OF THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY



IN REPLY REFER TO

ENGCW-PD

HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON 25, D.C.

28 April 1964

SUBJECT: Highland Bayou, Texas

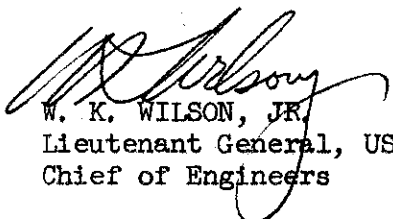
TO: THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my report on Highland Bayou, Texas, in partial response to an item in Section 204 of the Flood Control Act, approved 30 June 1948, for a survey of streams flowing through Brazoria-Galveston Soil Conservation District, Texas. My report includes the reports of the District and Division Engineers and the Board of Engineers for Rivers and Harbors.

2. The reporting officers recommend the improvement of Highland Bayou, Texas, for flood control by improving the channel of Highland Bayou, and construction of a diversion dam in Highland Bayou with a diversion channel along the general course of Basford Bayou to Jones Bay. The cost of the improvement is estimated at \$4,870,000, of which \$3,500,000 would be the Federal cost for construction, and \$1,370,000 would be the non-Federal cost for lands, easements, rights-of-way, and relocations of structures and utilities. Annual charges are estimated at \$196,000, including \$37,000 for non-Federal operation and maintenance. The annual benefits are estimated at \$671,000. The benefit-cost ratio is 3.4.

3. The Board of Engineers for Rivers and Harbors concurs generally in the findings of the reporting officers and recommends the improvement subject to certain local cooperation.

4. I concur in the recommendations of the Board.


W. K. WILSON, JR.
Lieutenant General, USA
Chief of Engineers

REPORT OF THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS

ENGBR(5 Aug 63) 2nd Ind
SUBJECT: Highland Bayou, Texas

Board of Engineers for Rivers and Harbors, Washington, D. C. 20315
21 November 1963

TO: Chief of Engineers, Department of the Army

1. Highland Bayou drains 38 square miles in Galveston County, Texas, along the western shore of Galveston Bay. The land surface slopes gently from a maximum elevation of 30 feet to sea level in the coastal marsh at its mouth. Portions of the cities of La Marque and Hitchcock are within the flood plain of the bayou. The watershed development is basically residential and commercial although considerable portions presently are used for agricultural purposes. The projected residential and commercial growth of the area indicates that the agricultural lands will change to urban development within the next few years.
2. Floods result from intense local thunderstorms of short duration, general storms which extend over a period of several days, and torrential rainfall associated with hurricanes and other tropical disturbances. Damaging floods have occurred six times since 1940. The floods of March 1957 and June 1960 caused damages estimated at \$200,000 each; and damages from a standard project flood are estimated at \$3.2 million. Average annual flood damages under existing conditions are estimated at \$313,000.
3. Local interests desire channel improvements and diversion of runoff from the upper watershed for major drainage and flood control. They have expressed willingness to cooperate in the improvements.
4. The District Engineer finds that the major flood problems arise from inadequate channel capacity to contain floods originating within the watershed. In several reaches, improvements along the banks of the bayou preclude extensive enlargement or rectification without excessive cost. Several plans to divert flow from the upper reaches of Highland Bayou into other streams were considered. The District Engineer reports that the most practicable and economically desirable plan of improvement would provide for enlargement and rectification of Highland Bayou, and for the diversion of all flows from the upper watershed through a diversion channel along the general course of Basford Bayou to Jones Bay. Exclusive of preauthorization study costs of \$16,000, he estimates the first cost of the proposed improvements at \$4,870,000, of which \$3,500,000 would be the Federal

cost for construction and \$1,370,000 would be the non-Federal cost for lands, easements, rights-of-way, and relocations of structures and utilities. Annual charges are estimated at \$196,000. Average annual benefits from reduction of flood damage to current and future developments are estimated at \$671,000. The benefit-cost ratio is 3.4 based on a 100-year period of analysis and an interest rate of 3 percent. The District Engineer recommends channel improvement of Highland Bayou and a diversion dam and a diversion channel following generally along Basford Bayou to Jones Bay as described in his report, subject to certain conditions of local cooperation. The Division Engineer concurs.

5. The Division Engineer issued a public notice informing interested parties of his recommendations and giving them an opportunity to furnish additional information to the Board. No communications have been received.

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

6. Views.--The Board of Engineers for Rivers and Harbors concurs in general in the views and recommendations of the reporting officers. The work proposed is needed and economically feasible, and the local cooperation is appropriate. The Board notes that non-Federal work costs are a substantial part of total costs, and are considered appropriate.

7. Recommendations.--The Board recommends improvement of Highland Bayou at Hitchcock and La Marque, Texas, for local flood protection by provision of channel improvement along Highland Bayou and diversion of Highland Bayou flows generally along Basford Bayou to Jones Bay at an estimated cost to the United States of \$3,500,000 for construction; all generally in accordance with the plan of the District Engineer and with such modifications thereof as in the discretion of the Chief of Engineers may be advisable: Provided that local interests furnish assurances satisfactory to the Secretary of the Army that they will:

a. Provide without cost to the United States all lands, easements, rights-of-way, and spoil-disposal areas necessary for construction of the project;

b. Provide without cost to the United States, all relocations and alterations of bridges, except railroad bridges, and of all buildings, structures, pipelines, sewers, utilities, and any other alterations of existing improvements which may be required for construction of the project;

c. Hold and save the United States free from damages due to the construction works;

d. Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army;

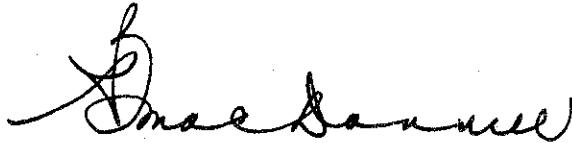
e. Provide and maintain all lateral channels and drains that may be necessary for proper functioning of the project;

f. Prevent any encroachment on the flood-carrying capacities of improved channels; and

g. At least annually, notify all interested parties that the project will provide protection from upstream flooding up to the standard project flood but will not provide protection from hurricane or storm tide flooding;

and provided further that no construction be started until the effect on the proposed works of hurricane protection now under study has been determined.

FOR THE BOARD:

A handwritten signature in cursive script, appearing to read "R. G. MacDONNELL".

R. G. MacDONNELL
Major General, USA
Chairman

REPORT OF THE DISTRICT ENGINEER

INTERIM SURVEY REPORT ON HIGHLAND BAYOU, TEXAS

SYLLABUS

This report comprises the results of an investigation of the flood problems along Highland Bayou which flows through La Marque and Hitchcock, Texas. It was found that:

a. Flooding of Highland Bayou causes extensive damages in sections of both La Marque and Hitchcock. Damages from occurrence of a standard project flood are estimated at \$3,188,000 and average annual damages from flooding of the stream under existing conditions are estimated at \$313,000.

b. Enlargement and rectification of the natural channel of Highland Bayou and diversion of flows from the upper part of the watershed through a diversion channel following generally along Basford Bayou to Jones Bay, as proposed in the plan of improvement of this report would eliminate all damages from floods as large as the standard project flood and would materially reduce damages from larger floods. Average annual benefits during the life of the project are estimated at \$671,000 and the proposed improvements would be justified with a benefits to costs ratio of 3.4.

Accordingly, it is recommended that a Federal project be authorized for providing flood protection to sections of La Marque and Hitchcock, Texas, by enlargement and rectification of the channel of Highland Bayou and construction of a diversion dam in Highland Bayou with a diversion channel along the general course of Basford Bayou to Jones Bay, generally as described in this report. The estimated first cost to the United States of the recommended new work is \$3,500,000. The recommendation is subject to certain provisions of local cooperation.

U. S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
GALVESTON, TEXAS

August 5, 1963

SUBJECT: Interim Survey Report on Highland Bayou, Texas, Brazoria-Galveston
Soil Conservation District

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

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

INTRODUCTION

1. Scope.- This investigation comprises a study of survey scope to determine the advisability of flood control improvements in the Highland Bayou watershed. Detailed field surveys and office studies were made to determine the most practicable plan of improvement. The detailed field investigations consisted of surveys for delination of the flood plain; surveys to determine the size and depth of the existing stream channel and details of bridges, culverts, utilities and other structures crossing the channel; borings to determine subsurface conditions for proposed channel improvements; and an economic survey to determine the damage resulting from floods.

2. During the course of the investigation, the District Engineer made a reconnaissance of the watershed and held conferences with local interests to discuss the plan of improvement being considered and the probable requirements of local cooperation.

3. Arrangement of report.- The following sections of this report contain the results, conclusions and recommendations of the Galveston District Engineer, based upon analysis of detailed technical data and investigations reported upon in the following appendixes to this report:

- Appendix I - Hydrology and Hydraulics
- Appendix II - Economic Evaluation

Appendix III - Engineering and Cost Data

Appendix IV - Comments by other Agencies

4. History of investigations.- Under the authority quoted in paragraph 5, a Preliminary Examination of the Streams Flowing Through the Brazoria-Galveston Soil Conservation District, Texas was submitted on February 15, 1950. The examination was made to consider the advisability of improving the streams in the Brazoria-Galveston SCD for navigation, flood control, drainage, and related purposes. The report recommended that a survey of the streams flowing through the district be made to determine the most feasible plan for flood control, major drainage and related purposes, the cost of the improvements, and the extent and advisability of undertaking construction of improvements with Federal funds. In the preliminary examination, Highland Bayou was determined to be a stream of Federal interest.

5. Authority for this investigation.- Authority for this interim report on Brazoria-Galveston Soil Conservation District, Highland Bayou, is contained in an item in Section 204 of the Flood Control Act, approved June 30, 1948, which is quoted as follows:

"Sec. 204. The Secretary of the Army is hereby authorized and directed to cause preliminary examinations and surveys for flood control and allied purposes, including channel and major drainage improvements, and floods aggravated by or due to wind or tidal effects to be made under the direction of the Chief of Engineers, in drainage areas *** which include the following-named localities, ***;

Streams flowing through the Brazoria-Galveston Soil Conservation District, *** Texas, with a view to improvement in the interest of navigation, flood control, and related purposes, including channel and major drainage improvements; ***."

6. On February 26, 1962, the Chief of Engineers approved preparation of an interim report on Highland Bayou, Texas, in the interest of flood control and major drainage.

7. Public hearing.- At a public hearing held at Hitchcock, Texas, on November 21, 1961, local interests presented statements and briefs relative to severe flooding by Highland Bayou and requested flood control improvements. The hearing was attended by 131 persons, including Federal, County, and local officials, representatives of business interests and other interested persons.

8. Improvements desired.- At the public hearing, the Galveston County Commissioners' Court requested that improvements be made for flood control in the Highland Bayou watershed. In support of their request, local interests state:

a. The area drained by Highland Bayou has experienced enormous residential and commercial growth, which has greatly increased runoff into the bayou.

b. The topography of the adjacent lands is such that lateral drainage systems become inoperative due to backwater when the bayou becomes bank full.

c. In recent years, extensive damage to residential and commercial property has resulted from backwater during and following frequent heavy rainfalls.

d. No specific requests for improvements for navigation, major drainage for agriculture or related improvements were made by local interests. There are no present or foreseeable future needs for improvements in these fields and such improvements are not considered further in this report.

9. In its brief, the Galveston County Commissioners' Court recommended that adequate channel capacity be provided by rectification of the Highland Bayou channel and by construction of a diversion channel from the upper portion of the watershed, southward to Karankawa Bayou. Other interested local parties generally concurred with this proposed solution to the flood control problems.

WATERSHED DESCRIPTION

10. General location and size.- Highland Bayou rises near Arcadia, in Galveston County, Texas, and flows into Jones Bay, an arm of West (Galveston) Bay. The watershed, with an area of about 38 square miles, lies entirely within Galveston County. It is about 14 miles long and varies in width from about 0.3 mile at its lower end to a maximum of about 5 miles near its midpoint. The location and extent of the watershed are shown on plate 1.

11. Physical characteristics of the watershed.- The land surface of the Highland Bayou watershed slopes gently in a southeasterly direction from a maximum elevation of about 30 feet to about sea level in the coastal marsh at its mouth. The only significant irregularities in the slope are the valley cut by the bayou and drainage ditches which have been excavated in adjacent areas. Because of the relatively flat terrain, the watershed divides are not well defined. All elevations in this report refer to U. S. Coast and Geodetic Survey mean sea level datum.

CLIMATOLOGY

12. Climatological data.- Highland Bayou watershed lies in a humid region with warm summers and mild winters. The proximity of this watershed to the Gulf of Mexico, the prevalence of southerly winds, and the absence of marked geographic relief features result in high relative humidity and uniformity in climate. Freezing temperatures are infrequent and of short duration. Data from the U. S. Weather Bureau station at Galveston, Texas, which is about 11 miles southeast from the Highland Bayou watershed, indicates that the mean annual temperature is 70.1 degrees Fahrenheit. Temperatures at this station have ranged from a summer maximum of 101 degrees to a winter minimum of 8 degrees. January, the coldest month, has an average minimum temperature of 39 degrees, and August, the warmest month, has an average maximum temperature of 88.0 degrees.

13. The prevailing winds are from the south or southeast during all but the winter months when high pressure air masses approaching from the north causes the winds to shift and come from that direction.

14. Precipitation.- Based on records, of the U. S. Weather Bureau station at Galveston, the mean annual precipitation is 45.19 inches. The annual precipitation has ranged from a maximum of 78.39 inches in 1900 to a minimum of 21.40 inches in 1948. The maximum precipitation recorded at Galveston for a 24-hour period during each month of the year is shown in the following tabulation:

MAXIMUM RECORDED 24-HOUR RAINFALL
AT GALVESTON, TEXAS
FOR EACH MONTH OF THE YEAR
1880 THROUGH 1960

<u>Month & Year</u>	<u>Rainfall in inches</u>
January 1923	5.38
February 1952	6.55
March 1944	4.58
April 1904	9.23
May 1916	6.13
June 1925	10.27
July 1900	14.35
August 1915	9.05
September 1900	10.00
October 1901	14.00
November 1940	9.01
December 1884	4.50

15. The area is subject to intense local thunderstorms of short duration, general storms which extend over a period of several days, and to torrential rainfall associated with hurricane and other tropical disturbances. The maximum 24-hour rainfall recorded at the Galveston station was 14.35 inches in July 1900. However, unofficial records from non-recording gages of various types, operated by residents on the Highland Bayou watershed, have indicated total rainfall of from 10 to 20 inches for rainstorms occurring in 1957 and 1960.

16. Runoff.- There are no stream gages on Highland Bayou. Normal stream flow is from slight to intermittent. Urban development on the watershed in recent years has increased the amount of roof and paved areas. Because of the probability of almost complete urban development of the watershed during the life of the project, a low infiltration index of 0.05 inch per hour with initial loss of 1.00 inch was adopted for hydrologic studies.

17. Flood history.- Based on available records and information furnished by local interests, damaging floods occurred on Highland Bayou in 1940, 1945, 1957, 1959, 1960, and 1961. No records of discharges for these floods are available. The probability of damaging floods on Highland and Basford Bayous following within a short time after the occurrence of severe damage from tidal flooding was investigated. Under this circumstance, it is likely that little additional damage would result from the stream flooding, since it is probable that much of the tidal flood damage would not have been repaired. The Galveston Weather Bureau records indicate no instance, within a 80-year period of record, whereby rainfall exceeding 3 inches in 24 hours has occurred within a 30-day period following passage of a hurricane. Accordingly, no allowance or reduction in benefits has been made because of this possibility.

18. Flood frequencies.- Flood frequency studies were based on an analysis and frequency study of rainfall records at Galveston, Texas, covering a 80-year period from 1880 through 1960. Peak discharge rates for floods were computed from the 24-hour rainfall values by the Snyder Synthetic Unit Hydrograph Method.

19. Standard project flood.- Computations of a standard project flood for the Highland Bayou watershed were made. A standard project rainfall totaling 25.84 inches over a four-day period was estimated for the 38 square mile watershed, with a maximum 24-hour rainfall of 21.28 inches occurring on the first day. Based on this rainfall, the peak discharge of the standard project flood with a diversion channel through Basford Bayou was estimated at 10,700 cubic feet per second at the mouth of Highland Bayou and 12,400 cubic feet per second at the mouth of Basford Bayou.

20. Other floods investigated.- Flows from floods of lesser intensity than the standard project flood were estimated in a manner similar to that used for the standard project flood. Storms having a frequency of occurrence of once in about 50 years and 100 years were estimated. These storms were estimated to have peak discharges at the mouth of Highland Bayou of about 8,000 cubic feet per second and 9,600 cubic feet per second, respectively, and Basford Bayou of about 9,100 cubic feet per second and 11,100 cubic feet per second, respectively.

21. Existing improvements.- Galveston County Drainage Districts No. 1 and No. 2, created in 1908 and 1910, respectively, by Acts of the Texas Legislature, are responsible for constructing and maintaining lateral ditches for proper drainage and preventing flooding conditions within their territorial limits. The entire Highland Bayou watershed lies within these two districts. The drainage districts have rectified portions of the upper reaches of Highland Bayou and have constructed and rectified laterals flowing into the bayou. Laterals and ditches emptying into the bayou above F.M. Road 2004 were constructed in 1941 and 1942 when Camp Wallace military reservation was being built. Maintenance of these ditches has not been continued since abandonment of the camp in about 1946.

EXTENT AND CHARACTER OF FLOODED AREAS

22. Area subject to flooding.- The flood plain of the standard project flood on Highland Bayou totals about 20,000 acres and includes portions of the cities of La Marque and Hitchcock, Texas. Development within the flood plain includes commercial and residential properties, streets and bridges, utilities, and a cemetery. The flood plain is crossed by one interstate highway, one state highway, two farm-market highways and several thoroughfares providing access to industrial plants and commercial developments in adjacent areas. Flooding of these transportation routes causes extensive rerouting and delays to traffic. Based on the expected growth rate for the area, it is estimated that 8,000 acres of the remaining undeveloped land above seven foot elevation within the flood plain will be substantially developed in future years. This development would further increase the flood damage potential.

23. The flood plain was investigated in detail and inspections were made of all property subject to flood damage. The value of all existing physical property in the flood plain of the standard project flood was estimated in August 1963 to be \$11,139,000. A breakdown of this value by principal classes of property is given in table A. By the year 2060, when the expected growth will have occupied about 50 percent of the flood plain, the total value of all physical property therein, based on 1963 price levels, will be \$55,695,000.

TABLE A

VALUE OF PHYSICAL PROPERTY IN THE FLOOD PLAIN OF THE STANDARD PROJECT FLOOD, EXISTING CONDITIONS (August 1963 price level)

Type of property	Value
Residential	\$10,296,000
Commercial	195,000
Municipal	596,000
Utilities	52,000
	<u>\$11,139,000</u>

24. Flood damages.- The flood damage data obtained through the field economic survey formed the basis for estimating the average annual damages. The damages that would result from occurrence of a standard project flood under the present flood plain development are estimated at \$3,188,000. Based on estimates of damages at various elevations of flooding, stage-damage relationships were developed. Rainfall records, field surveys, computations of runoff and discharge and historical flood information furnished by local interests were used to establish a relationship between peak discharge stages and frequency of occurrence which is expressed as the estimated number of times the various stages would be equaled or exceeded in 100 years. Damage-frequency curves were constructed by plotting damage-frequency coordinates, which were determined from the mutual stage relationships of the stage-damage curves and the stage-frequency curves. The average annual damages were then computed from the damage-frequency curves. The average annual damages under existing conditions were computed to be \$313,000. Details of these damages are shown in the Economic Evaluation Appendix.

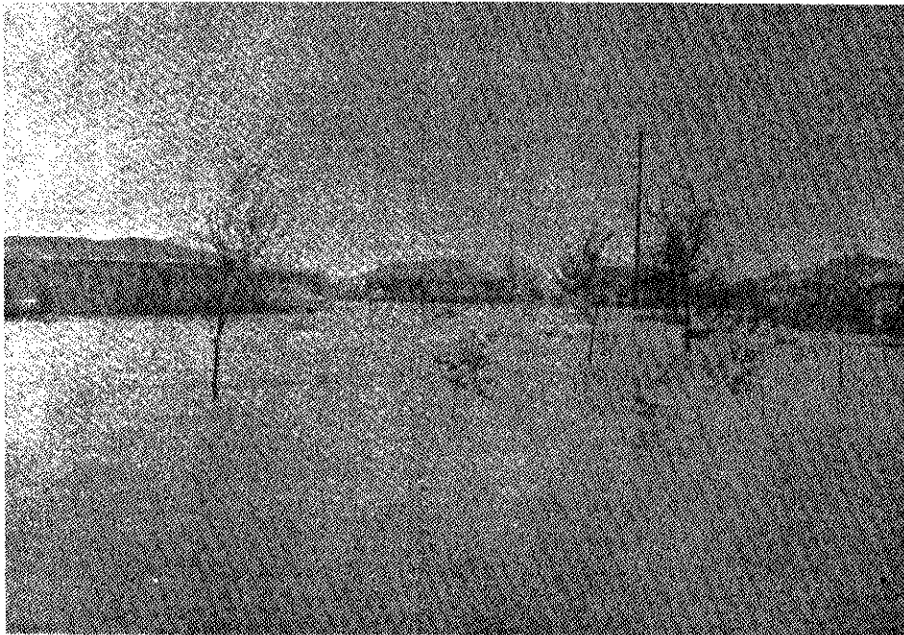


FIGURE 1

GREENWOOD SUBDIVISION, FLOOD OF JUNE 1961

ECONOMIC DEVELOPMENT

25. Early development.- Historically, the mainland portion of Galveston County, north of Galveston Island, did not share appreciably in the rapid growth and development of the city of Galveston, during the 19th and early part of the 20th century. During much of this period, Galveston was the principal seaport and, to a large extent, the financial center of the state. Although Houston, about 50 miles to the north, enjoyed considerable growth during this period, the area between the two cities remained largely undeveloped, except for a few small settlements along the three railroads, which were built to connect the cities. The principal use of the land during this time was for grazing and truck farming.

26. Following the devastating hurricane of 1900, Galveston constructed a massive concrete seawall along the Gulf shore and carried out an extensive grade raising program for much of the city, as it then existed. During the first third of the 20th century, Galveston continued to expand until it had occupied virtually all of the protected and raised area on the eastern part of the island. During this period, also, a number of important oil and gas fields were discovered in the area between Galveston and Houston and a small concentration of petroleum refineries had begun to develop around Texas City. By about 1935-40, Galveston had very little remaining area suitable for residential construction and land prices were rising rapidly due to the shortage.

27. Recent development of mainland area.- In 1937, a modern new highway bridge was built across West Bay from Galveston Island to the mainland and many additional highway improvements have been constructed throughout the mainland area since that time. Starting slowly and increasing rapidly in the years of World War II and the period following, a migration of population to the mainland area has been very apparent. The population of Galveston has remained relatively static, while that of the area between Galveston and Houston has grown spectacularly. Texas City, La Marque, and Hitchcock in Galveston County, Alvin in Brazoria County, and Dickinson and several communities in Harris County have all enjoyed rapid growth since World War II. A substantial industrial development of petroleum refining and petrochemical manufacturing in the Texas City area has accompanied the residential growth. This trend is continuing as evidenced by several recent expansions of existing industrial plants and construction of a large new chemical plant on Chocolate Bayou, a few miles southwest of Hitchcock.

28. Character of physical development.- Although the entire mainland area between Galveston and Houston is developing rapidly in all urban characteristics, Hitchcock and the area in the flood plain of Highland Bayou are almost entirely residential and commercial. The commercial development comprises the normal concentration of shops, stores, service establishments and small businesses which usually accompany residential development. The residences, however, are of comparatively

high value and the area presents a general picture of attractive, well-maintained homes, largely owner-occupied. In the coastal area, generally, residential development along a sizable stream or watercourse is quite attractive to prospective purchasers. The normal fringe of timber along such streams provide desirable homesites with considerable aesthetic appeal. The stream itself affords a valuable recreation facility and easy access to adjacent bay areas for small boats. Usually, the highest types of residential development will tend to concentrate along and near the streams and Highland Bayou furnishes a good example of this tendency.

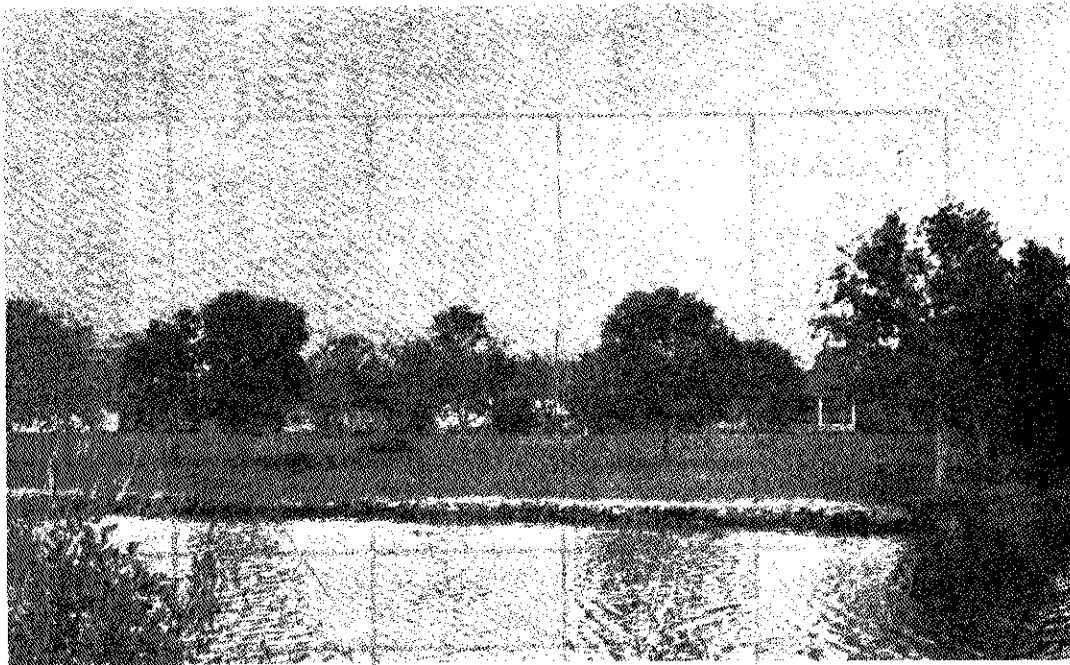


FIGURE 2

HIGHLAND BAYOU - PERTHUIS FARM SUBDIVISION

EXISTING RESIDENTIAL DEVELOPMENT

29. Although many of the lowest areas would be attractive because of nearness to the stream, developers tend to avoid such areas because of frequent flooding from even minor floods. It is in the areas of infrequent flooding from large floods that much of the flood damage problem develops. Many people locate in these areas without being aware of the problem. Others, although recognizing the problem, trust that their period of occupancy will occur in the probable lengthy period between floods. For these reasons, it is a foregone conclusion that the very largest floods will cause major damages and much suffering and hardship for the people involved.

30. Base study area.- The base study area selected for the study of Highland Bayou comprises about 302 square miles located in the mainland portion of Galveston County and includes the adjacent cities of Texas City, La Marque and Hitchcock. These three cities had a total population of 51,250 in 1960. The population of the rural areas and unincorporated communities in the base study area was 19,925. The growth of population of the base study area compared with that of Galveston and the state of Texas is shown on figure 3.

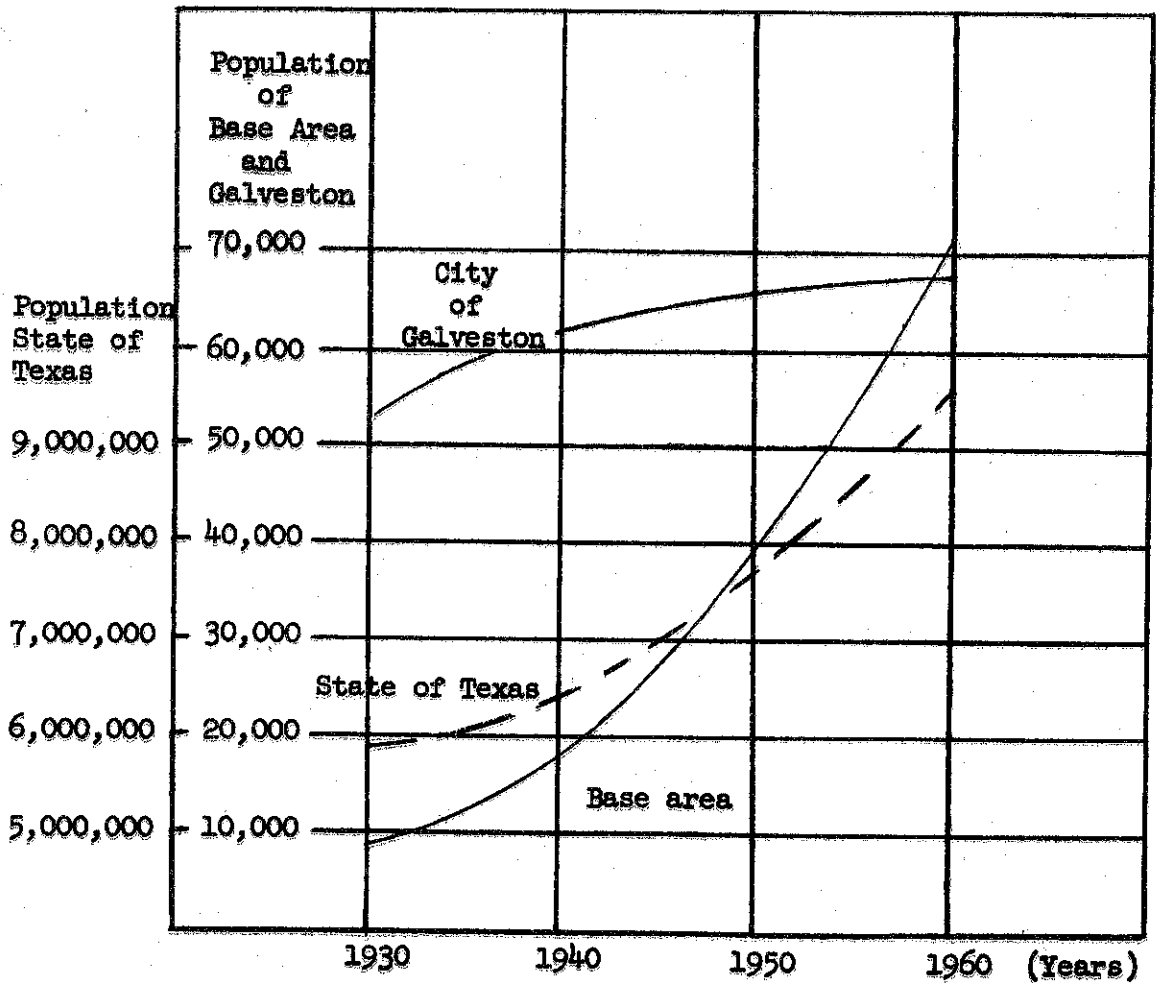


FIGURE 3

POPULATION GROWTH

31. Employment.- Texas City offers the major industrial employment for the Texas City-La Marque-Hitchcock complex with about 7,000 persons employed at the three petroleum refineries, four petrochemical plants, one rare metals smelter, and several smaller industrial plants. The annual payroll of these plants totals about 50 million dollars. Other important sources of employment are found in retailing and service establishments, marine shipping, service and repair, fishing and oystering, and agricultural pursuits. Many residents of the area commute to jobs in the nearby cities of Galveston, Pasadena and Houston.

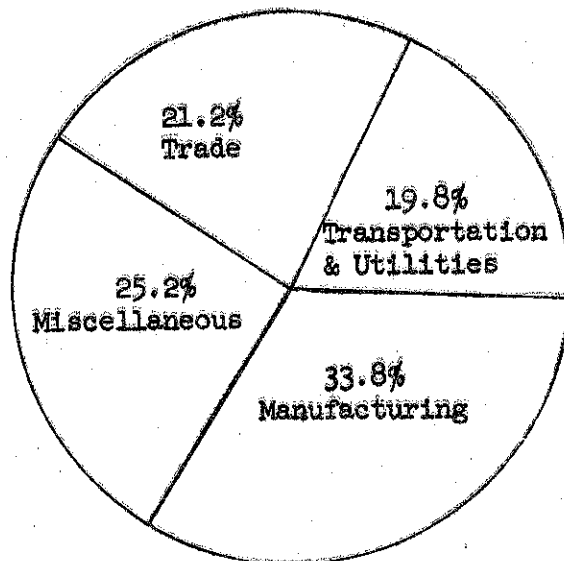


FIGURE 4

DISTRIBUTION OF EMPLOYMENT-GALVESTON COUNTY 1959

32. Consumer spendable income.- The estimated spendable income of Texas City households in 1961 averaged over \$6,900, which was about the same as reported for Galveston County. This is considerably higher than reported for the neighboring Chambers and Brazoria Counties, which were estimated at \$4,712 and \$5,182, respectively.

33. Analysis of trends shown by basic economic indicators.- As part of the economic base study, a compilation of statistical data was made for several factors which, in general, should indicate trends of growth and development for communities developing primarily as residential. Analyses were made for population, bank deposits, building

permits and rendered municipal tax values in the base study area. For several reasons, however, it was found that no conclusions could be drawn from the past records of bank deposits, building permits or municipal tax values. The large growth in residential development of the mainland area of Galveston County has occurred in a relatively short, recent period. During this time, the cities of Hitchcock and La Marque were incorporated. La Marque and the older city of Texas City have added substantially to their originally incorporated areas, with several annexations during the period. Both La Marque and Texas City include considerable amounts of industrial development within their city limits. The mainland banks are depositories for the large industries in the area and, periodically, serve as depositories for Galveston County funds. Building permits are not required in Hitchcock and have been required in La Marque only since 1954. Each of these indicators shows large variations from time to time that do not follow the known pattern of comparatively steady growth of residential development that has occurred in the Hitchcock and La Marque vicinities. If it were practicable to remove the statistical effects of industrial influence and other anomalies in the records of bank deposits, building permits and tax valuations caused by the various influences described above, it is believed that the trends of these indicators would closely parallel that of population. Accordingly, the statistics on population were given considerably greater weight in the prediction of future growth and development for the area.

34. Other influencing factors on future growth.- The industries associated with petroleum refining and petrochemical processing and manufacturing in the Texas City vicinity have continued to modernize and expand plant facilities in recent years. There is every indication that these plants will continue to grow and develop for the foreseeable future. Employment in the plants probably will grow, although at somewhat smaller rates, because of increasing automation in plant operations. It is expected that new petrochemical plants and associated industries will locate in the general vicinity of the existing plants. The Monsanto Chemical Co. has recently completed a new plant on Chocolate Bayou in Brazoria County, about 17 miles southwest of Hitchcock. This plant is integrated with the older and larger plant of the same company at Texas City. Its construction illustrates the tendency to locate such plants in the general vicinity of existing plants, because of interdependence of products or processing requirements. The National Aeronautical and Space Administration is now constructing its Manned Spacecraft Center on Clear Creek in Harris County, about 15 miles northeast of Hitchcock. Although the full impact of this facility cannot be accurately predicted at this time, it is certain that many industrial, technological and service installations will be developed in the general vicinity. All of the surrounding area, including Hitchcock, will be stimulated by this development.

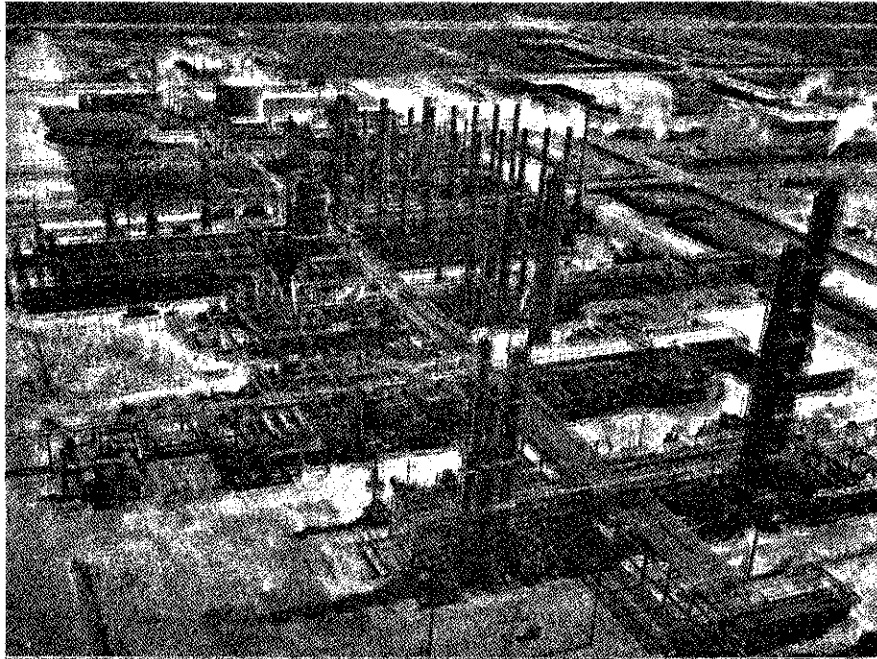
35. Projected growth in vicinity of Highland Bayou.- It is believed that the pattern of future development along Highland Bayou will conform to the present pattern and will remain largely urban, residential and commercial. The degree of development is expected to parallel closely the growth in population. In the Economic Base Study of the service area of the Trinity River Basin, made in 1962 for a comprehensive survey report on the Trinity River and Tributaries, Texas, it was shown that, during the period 1960-2070, the population of the United States may be expected to increase at an average annual rate of 1.4 percent and the population of Texas at an average annual rate of 1.6 percent. Based on the rapid growth of recent years and the influencing factors discussed above, it might reasonably be expected that Hitchcock, La Marque and vicinity will grow at a faster rate than either the nation or the state as a whole. Although this could be demonstrated, it would be based on a short period of statistical data. Accordingly, for this investigation the projected growth rate for the state as a whole has been adopted for the Hitchcock-La Marque locality. This is believed to be very conservative.

36. Land use.- The total land area in the Highland Bayou flood plain is about 20,000 acres, of which the existing residential and commercial developments occupy about 2,000 acres. Assuming the population density per acre to remain about the same as now, the projected population increase would require about 8,000 additional acres within the next 100 years. This additional development would occupy about one-half of the entire flood plain. About 8,000 acres of the remainder lies below 7 feet elevation. This land is subject to the threat of flooding from hurricane tides at relatively frequent intervals and probably would remain undeveloped unless the threat of hurricane tidal flooding were removed. Flood control improvements on Highland Bayou would have little or no effect on the development of this land.

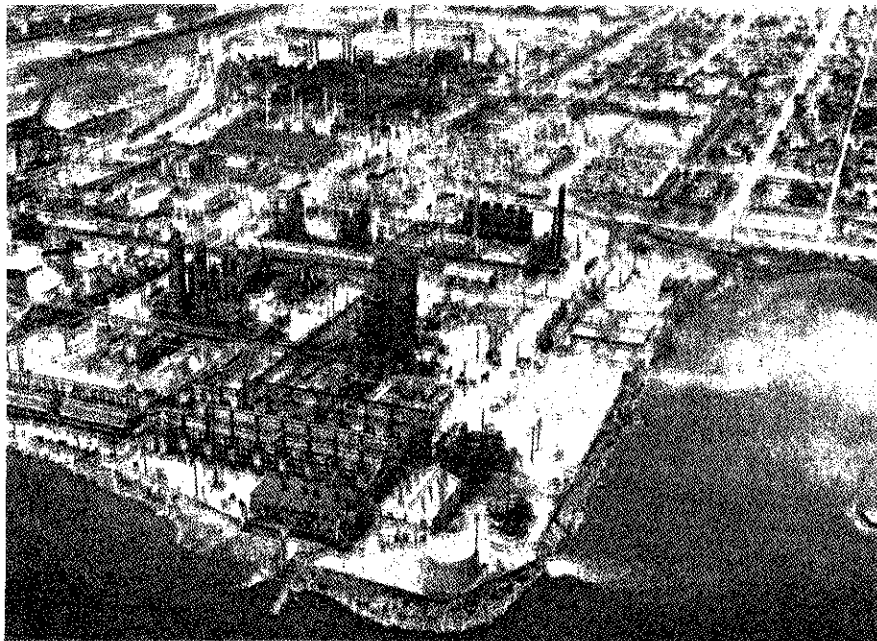
IN TEXAS
STATE

2

PLAIN WITHIN THE DEVELOPMENT



**MONSANTO CHEMICAL CO. PLANT ON CHOCOLATE BAYOU IN
BRAZORIA COUNTY, TEXAS**



**MONSANTO CHEMICAL CO. PLANT AT
TEXAS CITY, TEXAS**

FIGURE 5

EXISTING PETROLEUM REFINING PLANTS

FLOOD PROBLEMS AND SOLUTIONS CONSIDERED

37. Flood problems.- The principal flood problem along Highland Bayou results from residential and commercial developments in the flood plain through parts of the cities of Hitchcock and La Marque. Flooding of these areas results principally from inadequate capacity of the existing channel to contain floods originating on the watershed. The bayou is crossed by bridges and pipelines which restrict the passage of floodwaters and materially increase flood stages. Although at the present time considerable portions of the Highland Bayou watershed are used for agricultural purposes, principally grazing, no appreciable losses are being experienced because of inadequate drainage of the agricultural lands. It is expected that these lands will change from agricultural to urban development within the next few years. Accordingly, no problems from agricultural drainage have been considered in this investigation.

38. Solutions considered.- The relatively flat terrain and the high degree of development in the Highland Bayou watershed precludes the use of storage or detention reservoirs as a practicable means of flood control within the watershed. Through several reaches of the bayou, improvements along the banks preclude extensive enlargement or rectification of the main channel without incurring excessive costs. Several small, coastal streams meander through the low-lying, flat land to the south of Hitchcock and La Marque Bay and empty directly, or through other watercourses, into West (Galveston) Bay. There is little or no development along these streams that would preclude channel improvement. Accordingly, several plans were developed to divert flows from the upper reaches of Highland Bayou into one of the smaller streams to the south. This type of diversion would minimize the problem of providing adequate flow capacity in the middle and lower reaches of Highland Bayou.

PROJECT FORMULATION

39. Plans considered.- Four general plans were given engineering and economic consideration for reducing flood damages in the Highland Bayou flood plain. The four plans are described as follows:

a. Rectifying and enlarging the natural channel of Highland Bayou.

b. Diverting all runoff from above Highland Bayou stream mile 9.50 through Willow and Halls Bayou to West (Galveston) Bay and improving Highland Bayou as necessary below point of diversion.

c. Diverting all runoff from above Highland Bayou stream mile 9.50 through Karankawa Bayou and Karankawa Lake to West (Galveston) Bay and improving Highland Bayou as necessary below point of diversion.

d. Diverting all runoff from above Highland Bayou stream mile 8.65 through Basford Bayou to West (Galveston) Bay and improving Highland Bayou as necessary below point of diversion.

40. Comparison of plans.- For economic comparison of the four plans on a common scale, designs and cost estimates were made for improvements along each route that would contain the standard project flood without damage to existing and prospective property development in the flood plain. The plan with the smallest estimated cost was found to be diversion through Basford Bayou, or the plan described in sub-paragraph d. above. This plan has the additional advantage of requiring the least disruption and relocation of existing improvements and probably would have been favored, even had it not proven to be the most economical. The economic comparison of the four plans investigated is summarized as follows:

	<u>Annual benefits</u>	<u>Annual charges</u>	<u>Excess benefits over costs</u>	<u>Benefits to costs ratio</u>
a. Improvement of Highland Bayou only	\$637,000	\$250,000	\$387,000	2.5
b. Diversion through Willow & Halls Bayous	637,000	261,000	376,000	2.4
c. Diversion through Karankawa Bayou	637,000	236,000	401,000	2.7
d. Diversion through Basford Bayou	671,000	196,000	475,000	3.4

41. Maximization of benefits.- After determining that diversion through Basford Bayou would afford the most favorable general plan, investigations were made to determine the optimum scale of improvement from an economic standpoint. Benefits and costs, on an annual basis, were estimated for improvements along this route that would afford protection from several floods of lesser magnitude than a standard project flood. A curve was constructed by plotting the excess benefits over costs for each plan against the expected frequency interval in years for the largest flood which could be contained without damage by the improvements proposed by that plan. It was found that the benefits would be maximized, or the largest excess of benefits over costs would be obtained from a plan affording protection from the largest flood that might be expected to occur with a frequency interval of once in about 100 years.

42. Selection of plan.- It was found, also, that the plan affording protection from the standard project flood was only slightly less favorable from an economic standpoint than the one affording protection from a 100-year flood. The estimated annual charges would be increased by \$33,000 and the estimated annual benefits by \$5,000. On the basis of total estimated benefits and costs, the standard project flood protection would have a benefits to costs ratio of 3.4, compared with 4.1 for the plan affording protection from the 100-year flood. Both the existing and projected development in the Highland Bayou flood plain is fully urban in character and represents a high type of residential and commercial development. Even though 100-year protection shows the maximum excess of monetary benefits of cost, it should be recognized that a plan so limited would tend to give a false sense of security against much larger floods. This could lead to development of the area at a much more rapid rate than that indicated by the projections, which assume no flood protection to be in effect. If this should happen after a 100-year project had been constructed and, subsequently, a flood of greater magnitude did occur, it is virtually certain that the resulting damages would be much higher than the present stage-damage relationship indicates. Further, experience has shown that the heaviest damages and greatest degree of hardship and suffering, with occasional loss of lives, have occurred in similar developed areas when the very largest floods overtax the capacities of partial flood protection systems. The long intervals between maximum floods encourage extensive development of the fringe areas, with disastrous results when such floods do occur. It is believed that, for the small additional cost required, protection from the standard project flood is fully warranted. Accordingly, the plan affording this degree of protection has been selected as the plan of improvement.

PLAN OF IMPROVEMENT

43. The plan of improvement for Highland Bayou provides, in general for constructing a diversion dam in Highland Bayou to divert all flow from above stream mile 8.65 into Basford Bayou and for improving the channels of Highland and Basford Bayous as necessary to contain the standard project flood without damage. The Highland Bayou channel would be enlarged and rectified from its mouth to a point near the diversion dam and from the diversion dam upstream to mile 11.83. The diversion channel would extend about 7.53 miles from the diversion dam on Highland Bayou, following generally along the route of Basford Bayou to its mouth at Jones Bay, an arm of West (Galveston) Bay.

44. The proposed improved channels would be trapezoidal in cross section, and unlined. The banks would be sodded and side slopes would range from 1 vertical on 2-1/2 to 3 horizontal. Bottom widths of the improved Highland Bayou channel below the diversion dam would vary from about 240 feet at the mouth to 10 feet near the dam. Above the dam the channel bottom width would range from about 90 feet to 45 feet in the upper reaches. Bottom widths of the Basford Bayou diversion channel would vary from about 145 feet at the mouth to 90 feet at the Highland Bayou diversion dam. The diversion dam would be constructed from material excavated for channel improvements. The dam would have a crown width of 20 feet and crown elevation of 15 feet, about 3 feet higher than the standard project flood water surface. Both upstream and downstream side slopes would be 1 on 3. The crown and slopes would be sodded for erosion protection.

45. The general plan of improvement is shown on plate 2. Pertinent data on design criteria for channel sizes are shown in appendix I. Details of the principal features of the plan are shown in appendix III. Profiles and typical cross sections of the proposed improved channels are shown on plate 3.

46. Construction of the plan of improvement would require alteration of one railroad bridge and construction of one new railroad bridge. Alteration of 3 road or highway bridges and construction of 7 new road or highway bridges would be required. One abandoned road bridge would be removed. Twenty-three pipelines ranging in size from 2 inches to 30 inches in diameter would require alteration.

47. Excavated material from the lower reaches of Highland Bayou and the Basford Bayou diversion channel would be disposed of on marsh lands adjacent to the channels. In the middle and upper reaches of the bayous, some of the excavated material can be utilized for filling and leveling low-lying areas. Disposal areas for the balance can be obtained within reasonable haul distances from the channels. Construction of the proposed

improvements would require about 305 acres of rights-of-way for construction, 110 acres for berms or work area and about 249 acres of spoil disposal areas for disposal of excavated materials.

48. The proposed improved channels have been designed, generally to carry the flow from a standard project flood, as described in appendix I, with a minimum freeboard of one foot above the design water surface and with a water surface elevation of 3.3 feet above mean sea level in Jones Bay at the mouth of Highland Bayou. Along most of the improved channels, the water surface would be below the bank line; however, in the lower reaches through the low marsh area adjacent to the bay, the water surface would conform to tidal levels and frequently would not be confined to the channel.

ECONOMIC EVALUATION OF PROJECT

49. General.- The economic evaluation of the proposed project for flood control along Highland Bayou included several comparisons of estimated benefits and costs to insure that: (a) the best plan had been developed, (b) the proper scale of development had been selected and (c) construction of the proposed improvements was fully justified from an economic standpoint. The various factors entering into these determinations are discussed in paragraphs 39 through 42.

50. Estimates of first cost of plan of improvement.- Detailed estimates of first cost for constructing the proposed plan of improvement for affording flood protection for areas adjacent to Highland Bayou are summarized in the following table B. The estimates are based on August 1963 price levels. The division of first costs is based on the requirements of local cooperation set forth in paragraph 58.

TABLE B

ESTIMATES OF FIRST COST
IMPROVEMENT OF HIGHLAND BAYOU

Item	Cost
<u>Federal first cost</u>	
Relocations (RR bridges)	\$ 123,000
Channels	<u>2,818,000</u>
Subtotals	2,941,000
Engineering and design	281,000
Supervision and administration	278,000
Total Federal first cost	3,500,000
<u>Non-Federal first cost</u>	
Lands and damages	623,000
Relocations (utilities and bridges)	<u>747,000</u>
Total Non-Federal first cost	1,370,000
Total estimated first cost	<u>4,870,000</u>

51. Estimate of annual charges.- Detailed estimates of investments and annual charges for the plan of improvement are summarized in the following table C.

TABLE C
ESTIMATES OF INVESTMENT AND ANNUAL CHARGES
HIGHLAND BAYOU

Item	Total
Investment:	
Federal first cost	\$ 3,500,000
Interest during construction	<u>105,000</u>
Federal investment	3,605,000
Non-Federal first cost	1,370,000
Interest during construction	<u>41,000</u>
Non-Federal investment	1,411,000
Total investment	5,016,000
Annual charges:	
Federal	
Interest and amortization	114,000
Maintenance and operation	<u>None</u>
Subtotal, Federal	114,000
Non-Federal	
Interest and amortization	45,000
Maintenance and operation	<u>37,000</u>
Subtotal, Non-Federal	82,000
Total annual charges	196,000

52. Benefits.- The benefits which would be derived from the proposed flood control improvement would consist of prevention of flood damages to existing property and to additional future development within the flood plain that can be expected in the absence of the project.

53. Prevention of damages.- The average annual damages from flooding of Highland Bayou, under existing conditions of protection and development in Hitchcock and La Marque, are estimated at \$313,000.

This estimate includes the primary physical damages to property from flood inundation and the non-physical losses incurred, including loss of wages, interruption to traffic and costs related to recovering from flood emergencies. The proposed project would prevent most of these damages in the area to be protected. The difference in the damages that are experienced under existing conditions and the damages that would still be experienced after construction of the proposed improvements is a benefit that would accrue and is estimated at \$312,000 annually. The estimated benefits from the prevention of damages would be increased by the prevention of damages to additional properties that will be constructed in the flood plain. The benefits from the prevention of damages to future developments, which would be constructed in the absence of the project, based on a 100-year period of economic analysis, and expressed in terms of annual equivalent benefits, is estimated at \$359,000.

54. About 8,000 acres of the lowest portion of the watershed, below seven foot elevation, has practically no existing development subject to flood damages. This area is flooded at comparatively frequent intervals by high tides associated with tropical disturbances. A number of small houses are located in this area but are raised on pile foundations above flood levels. No benefits for prevention of flood damages to property in this area, either existing or future, were estimated for the improvements proposed in this report.

55. Summary of benefits.- The total annual benefits that would accrue from the proposed flood protection improvements proposed in this report, including the benefits attributable to the normal future growth and development, are estimated at \$671,000.

56. Comparison of benefits and costs.- The estimated average annual benefits, annual charges, and ratio of benefits to charges for the proposed improvement to Highland and Basford Bayous, based on August 1963 price levels, are given below:

Average annual benefits	\$671,000
Annual charges	196,000
Ratio of benefits to charges	3.4

APPORTIONMENT OF COSTS

57. Apportionment of costs among interests.- The apportionment of first costs of the proposed improvements between the Federal Government and the local interests would be in accordance with Federal law applicable to local flood protection projects and with the proposed requirements of local cooperation set forth in paragraph 58. Under these requirements, the first costs of all lands, easements and rights-of-way necessary for construction of the project would be borne by local interests. The cost of all necessary relocations and alterations of structures, including buildings, pipelines, sewers, utilities, and bridges, except railroad bridges, would be borne by local interests. All first costs for construction of the proposed improvements and all preauthorization survey costs would be borne by the Federal Government. All costs of maintenance and operation of the proposed improvements would be borne by local interests. The proposed apportionment of the estimated first cost and annual maintenance cost of the proposed improvements is shown in table D.

TABLE D

APPORTIONMENT OF FIRST COST AND ANNUAL MAINTENANCE

Item	Federal	Non-Federal	Total
First cost			
Construction	\$ 3,363,000	None	\$ 3,363,000
Lands	14,000	\$ 623,000	637,000
Relocations	123,000	747,000	870,000
Total first cost	3,500,000	1,370,000	4,870,000
Annual cost and maintenance and operation			
	None	37,000	37,000

LOCAL COOPERATION

58. Proposed local cooperation.- The improvement of Highland Bayou proposed herein would be a local flood protection project subject to the requirements of local cooperation generally specified by law for such projects. It is proposed that local interests shall be required to participate in the project as follows:

a. Provide without cost to the United States all lands, easements and rights-of-way and spoil disposal areas necessary for construction, maintenance and operation of the project;

b. Provide without cost to the United States, all relocations and alterations of bridges, except railroad bridges, and of all buildings, structures, pipelines, sewers, utilities and any other alterations of existing improvements which may be required for construction of the project;

c. Provide and maintain all lateral channels and drains that may be necessary for proper functioning of the project;

d. Hold and save the United States free from damages due to the construction works;

e. Prevent any encroachment on the flood carrying capacities of the improved channels;

f. Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army, and

g. At least annually, notify all interested parties that the project will provide protection from upstream flooding up to the Standard Project Flood but will not provide protection from hurricane or storm tide flooding.

COORDINATION WITH OTHER AGENCIES

59. Initiation of studies.- Copies of the notice of public hearing, held in Hitchcock, Texas, on November 21, 1961, were sent to all known Federal, State and local agencies that were believed to have a possible interest in flood control improvements for Highland Bayou.

60. The Bureau of Sport Fisheries and Wildlife of the United States Fish and Wildlife Service and the Texas Game and Fish Commission were advised by letters of the proposed improvements and the views and comments of those agencies were requested.

61. The Bureau of Sport Fisheries and Wildlife.- The Acting Southwest Regional Director, in a letter report dated May 17, 1963, stated that the proposed improvements would neither affect adversely nor offer opportunities for enhancement of the relatively minor fish and wildlife resources of the area.

62. The Texas Game and Fish Commission.- The Director, Program Planning, of the Texas Game and Fish Commission in a letter dated May 6, 1963, concurs with the report of the Bureau of Sport Fisheries and Wildlife.

63. Public Health Service.- The Regional Director, Water Supply and Pollution Control, of the Public Health Service in a letter dated July 18, 1963 stated that the proposed improvements would create a better environment for good public health.

64. Department of Agriculture.- The State Conservationist of the United States Department of Agriculture, Soil Conservation Service, in a letter dated July 29, 1963, stated that the plan of improvement in this report would not adversely affect any existing or planned projects of the Soil Conservation Service.

65. Bureau of Mines.- The Acting Area Director, Area IV, Bureau of Mines, Department of Interior, in a letter dated August 30, 1963, stated that the plan of improvement in this report would have no adverse effect on mineral resources in the area.

DISCUSSION

66. This report comprises the results of an investigation of the flood problems along Highland Bayou flowing through Hitchcock and La Marque, Galveston County, Texas. Highland Bayou has a total drainage area of about 40 square miles and Basford Bayou has a drainage area of about 20 square miles and both empty into Jones Bay, an arm of West (Galveston) Bay. At the present time about 10 percent of the flood plain is developed for residential and commercial use. This pattern of development is well established and is expected to continue throughout the flood plain. It is expected that development will occupy all but the lowest areas of the flood plain during the life of the project. It is estimated that occurrence of a standard project flood would cause damages of about \$3,188,000 under existing conditions. Average annual damages under existing conditions are estimated at \$313,000.

67. Local interests desire flood control improvements to alleviate damages in Hitchcock and La Marque caused by periodic flooding of Highland Bayou, and have suggested diversion of flows from the upper portion of Highland Bayou watershed as a means of providing the desired flood control. The route for diversion suggested by local interests would generally follow Karankawa Bayou and empty into Karankawa Bay.

68. The investigation developed that improvement of the Highland Bayou channel and diversion of flows from the upper watershed offered the most practicable means of flood control for the area. Various plans for a diversion channel were studied during the investigation and diversion along a route generally following Basford Bayou to Jones Bay was found to be the most economical. An analysis to determine the optimum degree of protection that should be provided indicated that full protection from the largest flood that would have a recurrence interval of once in about 100 years would provide the maximum excess of benefits over costs; however, as discussed in paragraph 42, it was concluded that since the area involved is fully urban and protection from the standard project flood would require only slightly greater costs, protection from the standard project flood should be provided. The plan, which is a modification of the plan proposed by local interests, generally, would provide for enlargement and rectification of the existing Highland Bayou channel and for diversion of flows above mile 8.65 through a diversion channel following generally along the route of Basford Bayou to Jones Bay. A number of bridges, pipelines and other structures, which now obstruct flows in the bayous, would be relocated or altered as necessary.

69. The total first cost of the proposed improvements is estimated at \$4,870,000, of which \$3,500,000 would be Federal cost and \$1,370,000 would be non-Federal, in accordance with the apportionment of costs described in paragraph 57. The total annual charges are estimated at \$196,000. The proposed improvements would prevent practically all of the flood damages caused by runoff from heavy rainfall on the watershed,

except that occurring coincident with abnormally high tides caused by tropical disturbances. Total average annual benefits from the proposed improvements are estimated at \$671,000. The benefits to costs ratio is estimated at 3.4.

70. The requirements of local cooperation are described in paragraph 58. The Galveston County Commissioners' Court has indicated its willingness to meet the requirements of local cooperation.

71. The proposed improvement of the Highland Bayou channel and diversion of flows from the upper watershed provides the most practicable means of flood control for the area and is consistent with the overall comprehensive development of hurricane-flood protection for the Texas City-La Marque-Hitchcock area. A survey investigation is in progress to determine the advisability of extending the authorized hurricane flood protection project for Texas City and vicinity to provide hurricane flood protection for the La Marque-Hitchcock area. The area under study includes the Highland Bayou-Basford Bayou watersheds but the study has not reached the point that economic justification for a definite plan of improvement can be established. If the hurricane flood protection project proves to be feasible, it is possible that interior drainage might be simplified and a more economical overall project developed by diverting a portion of the Highland Bayou flows to the west of the hurricane flood protection structures rather than through Basford Bayou. This possibility was investigated in a preliminary manner during this study. With the limited topographic data available and the incomplete conclusions concerning the hurricane flood protection, it was determined that the Basford Bayou route for diversion is the most favorable at this time. It is planned, however, to make additional studies of the interior drainage problem with respect to Highland Bayou when development of the hurricane flood protection plan has reached a more conclusive stage. If it is found that the best overall plan would include diversion of a portion of Highland Bayou flow to the west of the hurricane flood protection structures and if such a plan is found to be economically justified, appropriate modification of the Highland Bayou project would be recommended in that report. The necessary design changes would be effected during preconstruction planning of the Highland Bayou Project.

72. Additional information called for by Senate Resolution 148, 85th Congress, adopted January 28, 1958, is contained in an attachment to this report.

CONCLUSIONS

73. Based upon findings of this investigation, it is concluded that:

a. A serious flood problem exists on Highland Bayou where existing residential and commercial areas of Hitchcock and La Marque, Texas, are subject to extensive damages from flooding of the bayou.

b. Enlargement and rectification of the existing channel of Highland Bayou and construction of a diversion channel generally following Basford Bayou to Jones Bay, as described in the plan of improvement proposed in this report, would provide a high degree of protection to the parts of the cities of Hitchcock and La Marque that are located in the flood plain of Highland Bayou. Damages from floods larger than a standard project flood would be substantially reduced.

c. The improvements proposed herein would have estimated total annual charges of \$196,000, annual benefits of \$671,000 and a benefits to costs ratio of 3.4, based on August 1963 price levels.

d. The total first cost of the improvements proposed herein is estimated at \$4,870,000, of which the Federal share would be \$3,500,000. The non-Federal share would be \$1,370,000. The total annual cost of maintenance and operation, estimated at \$37,000 would be borne by the local interests.

RECOMMENDATIONS

74. Accordingly, it is recommended that a Federal project be authorized to provide flood protection to Hitchcock and La Marque, Texas, by improvement of the channel of Highland Bayou, construction of a diversion dam and a diversion channel following generally along Basford Bayou to Jones Bay, generally as described in the plan of improvement section of this report, and with such modifications thereof as in the discretion of the Chief of Engineers may be advisable, at an estimated total first cost to the United States of \$3,500,000 for new work, and subject to the condition that the local interests agree to:

a. Provide without cost to the United States all lands, easements and rights-of-way and spoil disposal areas necessary for construction, maintenance and operation of the project;

b. Provide without cost to the United States, all relocations and alterations of bridges, except railroad bridges, and of all buildings, structures, pipelines, sewers, utilities and any other alterations of existing improvements which may be required for construction of the project;

c. Provide and maintain all lateral channels and drains that may be necessary for proper functioning of the project;

d. Hold and save the United States free from damages due to the construction works;

e. Prevent any encroachment on the flood carrying capacities of the improved channels;

f. Maintain and operate all works after completion in accordance with regulations prescribed by the Secretary of the Army, and

g. At least annually, notify all interested parties that the project will provide protection from upstream flooding up to the Standard Project Flood but will not provide protection from hurricane or storm tide flooding.

- 3 Incls
1. Plates
2. Appendixes I thru IV
3. Attachment

JAMES S. MAXWELL
Colonel, CE
District Engineer

[First endorsement]

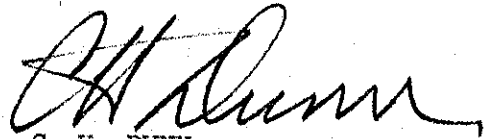
SWDGW-4

SUBJECT: Interim Survey Report on Highland Bayou, Texas, Brazoria-Galveston Soil Conservation District

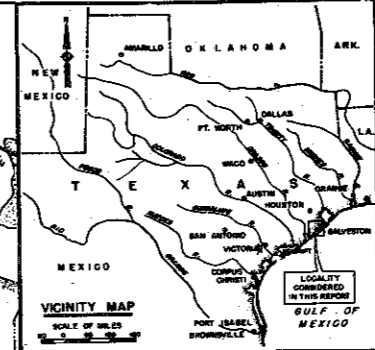
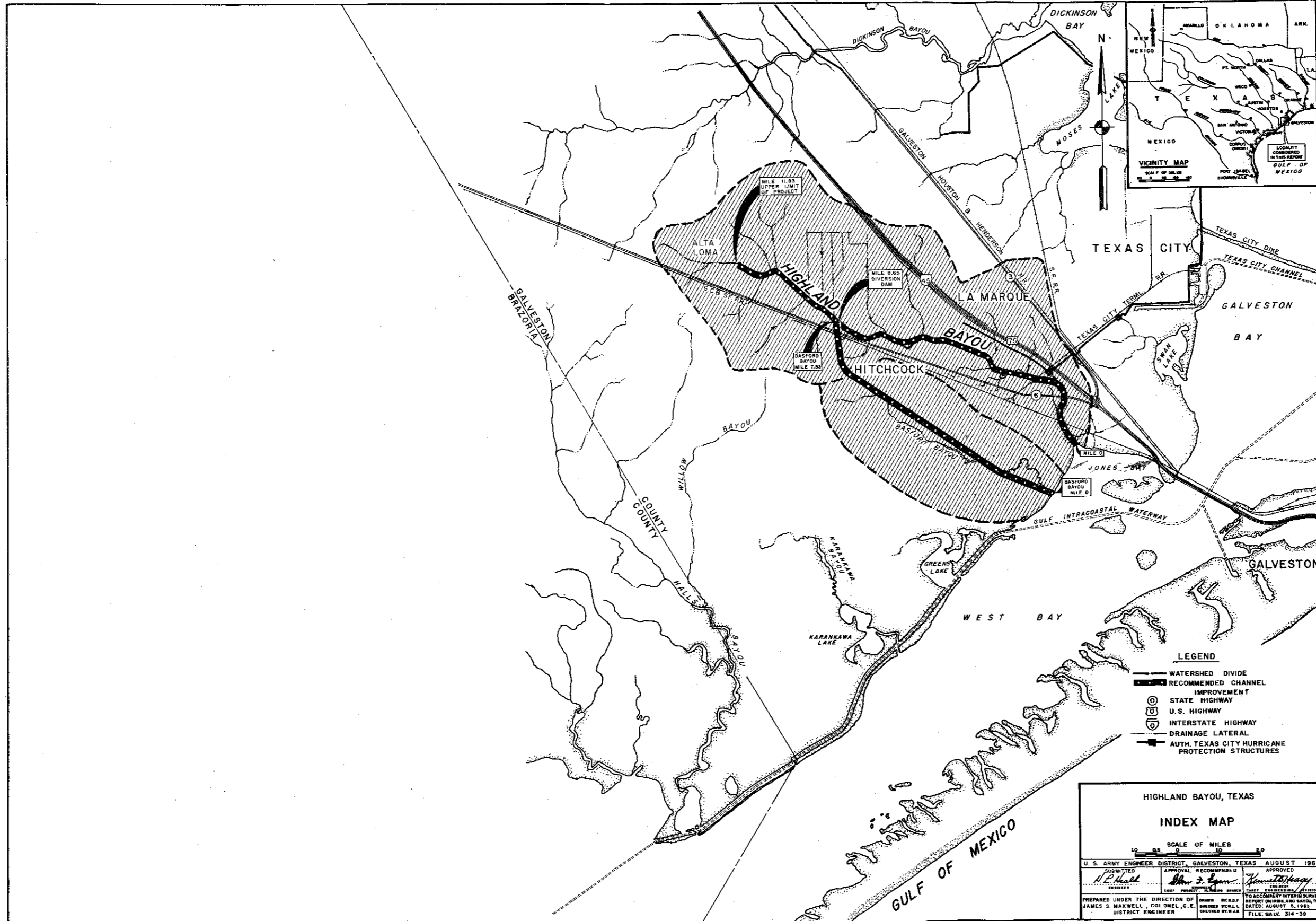
United States Army Engineer Division, Southwestern, Dallas, Texas
September 26, 1963

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

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



C. H. DUNN
Brigadier General, USA
Division Engineer



LEGEND

- WATERSHED DIVIDE
- RECOMMENDED CHANNEL IMPROVEMENT
- ⊙ STATE HIGHWAY
- ⊠ U.S. HIGHWAY
- ⊕ INTERSTATE HIGHWAY
- DRAINAGE LATERAL
- AUTH. TEXAS CITY HURRICANE PROTECTION STRUCTURES

HIGHLAND BAYOU, TEXAS

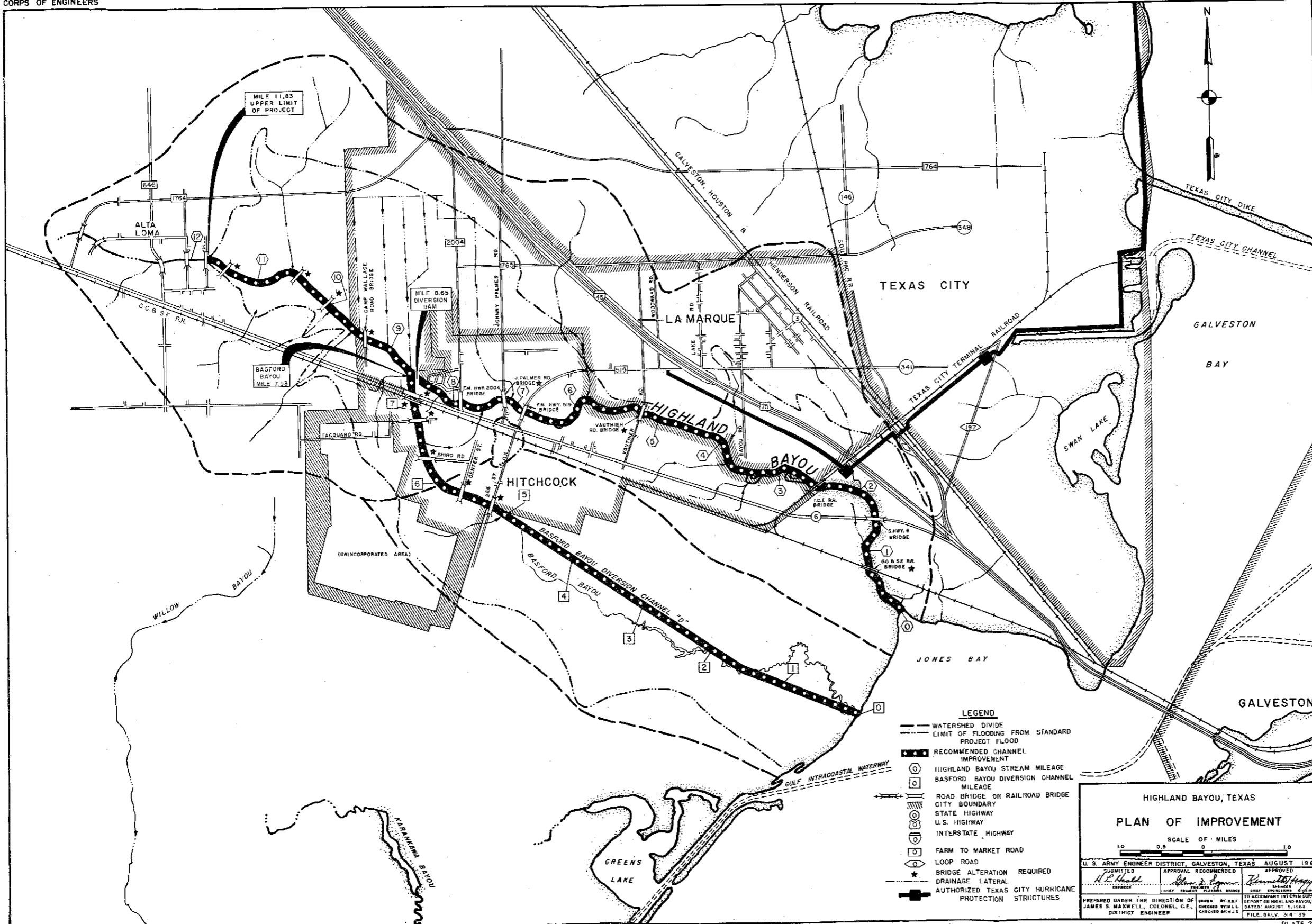
INDEX MAP

SCALE OF MILES
0 10 20

U. S. ARMY ENGINEER DISTRICT, GALVESTON, TEXAS		AUGUST 1963
SUBMITTED <i>H.P. Hall</i> ENGINEER	APPROVAL RECOMMENDED <i>Wm. J. Egan</i> ENGINEER	APPROVED <i>James S. Maxwell</i> DISTRICT ENGINEER
PREPARED UNDER THE DIRECTION OF JAMES S. MAXWELL, COLONEL, C.E. DISTRICT ENGINEER		TO ACCOMPANY INTERIM SURVEY REPORT ON HIGHLAND BAYOU, TEXAS DATED: AUGUST 9, 1963. FILE: GALV. 314-39

47-541 O-65 (Face p. 36) No. 1







INTERIM SURVEY REPORT
ON
HIGHLAND BAYOU, TEXAS

APPENDIX I
HYDROLOGY AND HYDRAULICS

INTERIM SURVEY REPORT
ON
HIGHLAND BAYOU, TEXAS

APPENDIX I
HYDROLOGY AND HYDRAULICS

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(Not printed)

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- 2 Discharge-drainage area relationship-Highland Bayou
above Diversion Ditch "D" and Basford Bayou
- 3 Discharge-mileage chart-Highland Bayou below Diversion
Ditch "D"
- 4 Discharge-mileage chart-Highland Bayou above Diversion
Ditch "D" and Basford Bayou
- 5 Discharge-drainage area relationship-Highland Bayou
below Diversion Ditch "D"

INTERIM SURVEY REPORT
ON
HIGHLAND BAYOU, TEXAS

APPENDIX I

HYDROLOGY AND HYDRAULICS

1. General.- This appendix presents information concerning the hydrology and hydraulic conditions of the Highland Bayou watershed pertinent to the planning of a proposed flood control project in the vicinity of Hitchcock and La Marque, Texas. Data in this appendix relates particularly to rainfall and runoff from the watershed, discharge flows in the bayou under present conditions, and the hydraulic design of the channels necessary to provide adequate flood protection for developments in the watershed.

2. Climate.- The Highland Bayou watershed lies in a relatively humid and temperate climatic region. Summers are long and hot, but are tempered somewhat by winds from the Gulf of Mexico. Winters are generally mild and snowfall is infrequent. Records of the U. S. Weather Bureau station at Galveston, Texas, which is about 11 miles southeast of the Highland Bayou watershed, indicate that the mean annual temperature is 70.1 degrees Fahrenheit. Temperatures at Galveston have ranged from a summer maximum of 101 degrees to a winter minimum of 8 degrees. January, the coldest month, has an average daily minimum temperature of 49.2 degrees and August, the warmest, has an average maximum of 88.0 degrees. These data are indicative of climatological conditions over the Highland Bayou watershed.

3. During most of the year the prevailing winds are from the south and southeast. Practically all north winds occur over periods of a few days duration during the winter months. Data relating to precipitation and wind movements obtained from records of the U. S. Weather Bureau station at Galveston are given in table A and B.

TABLE A

PRECIPITATION AT GALVESTON, TEXAS
(Period of record - 80 years)

Month	Normal monthly Rainfall (Inches)	Maximum monthly (Inches)	Year	Minimum monthly (Inches)	Year	Maximum in 24-hours (Inches)	Year
January	4.09	10.39	1899	0.02	1909	5.38	1923
February	2.88	8.29	1881	0.09	1954	6.55	1952
March	3.10	9.39	1926	0.016	1953	4.58	1944
April	3.09	11.04	1904	0.01	1887	9.23	1904
May	3.20	10.50	1929	T	1899	6.13	1916
June	3.35	15.49	1919	T	1907	10.27	1925
July	4.80	18.74	1900	T	1924	14.35	1900
August	3.55	19.08	1915	0.00	1902	9.05	1915
September	5.44	26.01	1885	0.04	1924(1)	10.00	1900
October	3.59	17.78	1871	T	1952	14.00	1901
November	3.84	16.18	1940	0.03	1903	9.01	1940
December	4.26	10.28	1887	0.23	1889	4.50	1884
Year	45.19	26.01	1885 (Sep.)	0.00	1902 (Aug.)	14.35	1900 (July)

NOTES: Normal values are based on the period 1921 - 1950

(1) Also occurred on earlier dates.

T Trace

TABLE B

WIND VELOCITY AT GALVESTON, TEXAS
WIND MOVEMENT IN MILES PER HOUR

Month	Wind					Year
	Mean hourly speed (m.p.h.)(2)	Prevailing direction(1)(4)	Speed :m.p.h.:	Fastest recorded mile Direction(1)(2)		
January	11.4	SE	53	S		1915
February	11.6	SE	60	N		1927
March	11.7	SE	50	SE		1952
April	11.9	SE	56	N		1952(3)
May	11.4	SE	60	W		1953
June	10.5	S	62	SE		1921
July	9.6	S	68	NW		1943
August	9.3	S	91	E		1915
September	10.0	SE	87(5)	NE		1900
October	10.3	SE	66	SE		1949
November	11.0	SE	54	N		1950
December	11.2	N	50	NW		1954
Year	10.8	SE	91	E		1915 (Aug)

- (1) Direction from which wind is blowing.
- (2) Length of record 84 years.
- (3) Also occurred on earlier dates.
- (4) Record not continuous, length 40 years.
- (5) Estimated by U. S. Weather Bureau.

4. Precipitation.- Rainfall data were obtained from records of the U. S. Weather Bureau first order station at Galveston, and cover the period from April 1880 to December 1960. The annual rainfall recorded at Galveston ranges from a maximum of 78.39 inches in 1900 to a minimum of 21.40 inches in 1948. The average monthly rainfall is 3.77 inches. The monthly distribution of rainfall averages range from a maximum of 5.44 inches (144 percent of mean) for September to a minimum of 2.88 inches (76 percent of mean) for February. The mean monthly distribution of rainfall and the percentage of the mean for each month to the mean of all months in the year at Galveston are shown in table C.

TABLE C
NORMAL MONTHLY DISTRIBUTION OF PRECIPITATION
AT GALVESTON

Month	Precipitation in inches	Percent of mean
January	4.09	108
February	2.88	76
March	3.10	82
April	3.09	82
May	3.20	85
June	3.35	89
July	4.80	128
August	3.55	94
September	5.44	144
October	3.59	95
November	3.84	102
December	4.26	113
Mean	3.77	100

NOTE: Normal values are based on the period 1921 - 1950

5. Rainfall intensities for short periods.- Rainfall intensities or the maximum recorded precipitation for selected short periods varying from 1 to 72 hours are shown in table D.

TABLE D

MAXIMUM PRECIPITATION FOR SHORT PERIODS

Selected periods (in hours)	:	Maximum precipitation (in inches)
1	:	5.31
2	:	7.58
3	:	8.78
6	:	11.79
12	:	12.75
24	:	14.35
72	:	16.04

6. Rainfall intensity-frequency data.- A statistical analysis was made of the rainfall data from the Galveston Weather Bureau station for the years 1892 to 1947. In this analysis all recorded rainfall amounts greater than one inch were tabulated in increments of 0.1 inch for 1, 2, 3, 6, 12 and 24 hour periods. For each increment, the mean of all the rainfall amounts in that increment was plotted against the frequency of occurrence interval in years, obtained by dividing the total years of the record period by the total number of occurrences in that increment. For the one-hour period, this gives directly the rainfall intensity in inches per hour vs. frequency in years. For each of the other duration periods, the mean rainfall for each increment was divided by the duration period in hours and plotted as rainfall intensity in inches per hour against the frequency of occurrence interval as described above. The results for the selected duration periods were plotted and smooth curves were drawn for each period. These curves were then read to determine the rainfall rate and frequency to be expected for a given duration period. The results of this analysis were compared with the rainfall intensity-duration-frequency curves given in the U. S. Weather Bureau, Technical Paper No. 25 for the years 1903 to 1951 and the rainfall intensities resulting from the analysis of the Galveston records were found to be slightly higher. Since the Galveston records covered a longer period, it was decided to use the results of this analysis. The results of these analyzed data are given in table E.

7. Adequacy of frequency determinations.- In determining the profile for project design conditions a tide level of 3.3 feet above mean sea level was used to determine the stages of natural flows in the bayou. In the absence of tropical disturbances, the 3.3-foot tide is estimated to have an occurrence of once a year and is about the highest level of tidal levels induced by normal meteorological conditions not associated with tropical disturbances. It is recognized that rainfall will occur with tides either higher or lower than 3.3 feet and stages of flow in Highland and Basford Bayous will be affected accordingly. The benefits which have been estimated for the improvements considered in this report are on the conservative side, since no benefits have been claimed for reduction in damages produced by rainfall occurring with tide stages greater than 3.3 feet. The improvements would, however, effect reduction in stream stages from rainfall occurring with tide stages somewhat higher. Similarly, somewhat greater reductions in stream stages would be effected during tide stages lower than 3.3 feet, but no additional benefits have been evaluated for this circumstance. The possibility of reduced benefits because of the occurrence of heavy rainfall within a short period subsequent to severe tidal flooding, wherein the tidal flooding damage had not been repaired, was investigated. A study of hurricane and rainfall records at Galveston for the period from 1886 to 1962 indicates that there has been no instance within the 77-year period, whereby rainfall exceeding 3.00 inches in 24-hours has occurred within a 30-day period following a hurricane. It is believed that no allowance or reduction in benefits need be made because of this possibility.

TABLE E
 RAINFALL INTENSITY-FREQUENCY DATA
 GALVESTON, TEXAS

Frequency of occurrence (years)	Rainfall in inches						
	1-hour	2-hours	3-hours	6-hours	12-hours	24-hours	
1	1.73	2.37	2.76	3.33	3.85	4.27	
2	2.13	2.96	3.50	4.44	5.18	5.66	
3	2.40	3.35	3.99	5.20	6.11	6.67	
5	2.78	3.89	4.65	6.27	7.28	8.09	
8	3.18	4.44	5.31	7.35	8.47	9.46	
10	3.38	4.74	5.66	7.89	9.07	10.13	
15	3.78	5.32	6.30	8.85	10.08	11.33	
20	4.08	5.76	6.78	9.54	10.80	12.14	
30	4.53	6.44	7.54	10.50	11.72	13.18	
40	4.89	6.96	8.10	11.10	12.24	13.75	
50	5.19	7.38	8.58	11.58	12.60	14.21	
100						17.00	
SPF						21.28	

TABLE F

STANDARD PROJECT STORM INDEX RATIOS AND CRITICAL ARRANGEMENT
FOR DRAINAGE AREAS OF VARIOUS IMPROVEMENT PLANS FOR HIGHLAND BAYOU

Time	Highland Bayou		Highland Bayou above Below Diversion		Highland Bayou above Diversion Ditch		Highland Bayou above Diversion Ditch		Highland Bayou Below Diversion		Highland Bayou above Diversion Ditch							
	SPF index R.F. 19" Area = 38.15 sq.mi.	SPF index R.F. 19" Area = 26.98 sq.mi.	SPF index R.F. 19" Area = 18.59 sq.mi.	SPF index R.F. 19" Area = 12.89 sq.mi.	SPF index R.F. 19" Area = 19.64 sq.mi.	SPF index R.F. 19" Area = 27.95 sq.mi.	SPF index R.F. 19" Area = 38.15 sq.mi.	SPF index R.F. 19" Area = 26.98 sq.mi.	SPF index R.F. 19" Area = 18.59 sq.mi.	SPF index R.F. 19" Area = 12.89 sq.mi.	SPF index R.F. 19" Area = 19.64 sq.mi.	SPF index R.F. 19" Area = 27.95 sq.mi.						
	ratio:(inches)	Change:	ratio:(inches)	Change:	ratio:(inches)	Change:	ratio:(inches)	Change:	ratio:(inches)	Change:	ratio:(inches)	Change:						
1st 24 hours	1.12	21.28	21.28	1.14	21.66	21.66	1.155	22.00	22.00	1.17	22.20	22.20	1.15	21.90	21.90	1.135	21.60	21.60
2nd 24 hours	1.28	24.32		1.30	24.70		1.31	24.89		1.32	25.08		1.30	24.70		1.29	24.51	
3rd 24 hours	1.33	25.27		1.34	25.46		1.37	26.03		1.38	26.22		1.36	25.84		1.35	25.65	
4th 24 hours	1.36	25.84		1.38	26.22		1.40	26.60		1.41	26.79		1.39	26.41		1.375	26.13	
<u>CRITICAL ARRANGEMENT OF 1st 24 HOUR RAINFALL</u>																		
1st 6 hours	9.80	2.09		9.80	2.12		9.80	2.16		9.80	2.18		9.80	2.15		9.80	2.12	
2nd 6 hours	20.30	4.32		20.30	4.40		20.30	4.46		20.30	4.51		20.30	4.44		20.30	4.38	
3rd 6 hours	56.80	12.08		56.80	12.30		56.80	12.50		56.80	12.60		56.80	12.44		56.80	12.27	
4th 6 hours	13.10	2.79		13.10	2.84		13.10	2.88		13.10	2.91		13.10	2.87		13.10	2.83	

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8. Standard project storm.- The standard project storm for the Highland Bayou watershed was determined in accordance with procedures described in Engineering Manual EM 1110-2-1411 (Civil Engineers Bulletin 52-8, dated 26 March 1952), entitled, "Standard Project Storm Determinations." The SPS index rainfall was determined to be 19 inches for a 200 square mile area. SPF index ratios of the areas, for the several different channels considered in this study are shown in table F. The critical arrangement of rainfall by 6-hour periods to produce the maximum runoff from each area is also shown in table F.

9. The first 24-hour rainfall period was divided into four 6-hour periods which were arranged critically in accordance with the procedure illustrated by plate 10, Engineering Manual EM 1110-2-1411 (Civil Engineers Bulletin 58-2, dated 26 March 1952). The percentages of the 24-hour rainfall estimated for each 6-hour period were determined also as shown on this plate. An infiltration index of 0.05 inches per hour, with an initial loss of 1.00 inch, was applied to determine the excess of rainfall over runoff.

10. Other storms investigated.- The effects of rainfall from rainstorms of 50-year and 100-year frequencies were investigated for project formulation purposes. Runoff from these storms was estimated in the same manner as for the standard project storm.

11. Design unit hydrographs.- Unit hydrographs were constructed in accordance with Engineering Manual 1110-2-1405, "Flood Hydrograph Analyses and Computations," dated 31 August 1959. As no observed unit hydrographs were available, coefficients for the Highland Bayou drainage area were selected on the basis of studies made on the Buffalo Bayou watershed at Houston, Texas, which are considered conservative for this watershed. Coefficients were tentatively selected for appropriate subdivisions of the drainage areas and the synthetic unit hydrograph peak discharges and lags were computed. The peak discharges were then plotted in relation to the drainage areas and smooth curves were drawn through points corresponding to the principal drainage area subdivision. Synthetic unit hydrograph coefficients were then estimated on the basis of discharge values selected from the curves. The adopted coefficients and resulting unit hydrographs are tabulated in table G, the results of this study are shown on exhibit 1 of this appendix.

TABLE G
UNIT HYDROGRAPHS
HIGHLAND BAYOU WATERSHED

Time in hours	Highland Bayou above mouth	Highland Bayou above Diversion Ditch "D" and Bearford Bayou	Highland Bayou above Diversion Ditch "B" and Willow Bayou	Highland Bayou-below Diversion Ditch "B" & "C"	Highland Bayou-below Diversion Ditch "D"	Highland Bayou above Diversion Ditch "C" and Karankawa Bayou	Highland Bayou above Diversion dam @ mile 8.91	Highland Bayou-below Diversion Ditch "D" @ mile 6.00
	D.A. = 38.15 sq.mi. Ct = 3.0 640C _p = 300 t _{PR} = 12.2 hrs. q _{PR} = 24.9 cfs/s.m.	D.A. = 27.95 sq.mi. Ct = 3.0 640C _p = 300 t _{PR} = 12.1 hrs. q _{PR} = 24.8 cfs/s.m.	D.A. = 18.59 sq.mi. Ct = 3.0 640C _p = 300 t _{PR} = 12.0 hrs. q _{PR} = 25.0 cfs/s.m.	D.A. = 26.98 sq.mi. Ct = 3.0 640C _p = 300 t _{PR} = 10.7 hrs. q _{PR} = 28.6 cfs/s.m.	D.A. = 19.64 sq.mi. Ct = 3.0 640C _p = 300 t _{PR} = 9.5 hrs. q _{PR} = 31.4 cfs/s.m.	D.A. = 12.89 sq.mi. Ct = 3.0 640C _p = 300 t _{PR} = 9.6 hrs. q _{PR} = 31.3 cfs/s.m.	D.A. = 15.99 sq.mi. Ct = 3.0 640C _p = 300 t _{PR} = 6.7 hrs. q _{PR} = 44.8 cfs/s.m.	D.A. = 7.45 sq. mi. Ct = 3.0 640C _p = 300 t _{PR} = 4.6 hrs. q _{PR} = 65.5 cfs/s.m.
	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
0	0	0	0	0	0	0	0	0
2	185	140	90	125	200	160	130	310
4	400	340	191	385	385	264	310	486
6	608	500	292	700	540	370	376	400
8	765	618	395	765	598	401	400	320
10	882	675	448	771	617	403	395	255
12	950	693	465	765	612	380	470	200
14	935	690	460	738	585	341	400	155
16	895	658	450	680	509	305	350	115
18	835	620	422	620	412	268	300	80
20	770	555	380	548	350	235	270	50
22	695	490	340	485	300	205	245	23
24	605	435	307	420	240	175	200	0
26	550	382	270	360	200	148	175	
28	480	347	235	305	168	122	142	
30	425	305	208	252	140	105	110	
32	372	262	182	205	118	81	80	
34	327	235	157	165	99	62	55	
36	280	205	135	130	80	50	25	
38	240	175	115	100	65	37	0	
40	210	148	97	70	50	24		
42	180	124	82	50	35	14		
44	155	104	70	35	22	8		
46	132	85	58	20	11	4		
48	115	70	45	10	0	0		
50	98	53	37	0				
52	80	40	29					
54	61	30	20					
56	42	20	12					
58	22	10	5					
60	0	0	0					

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12. The following formulas from EM 1110-2-1405 were used in the construction of the unit hydrographs:

$$t_p = C_t (LL_{ca})^{0.3}$$

$$t_r = \frac{t_p}{5.5}$$

$$q_p = \frac{640C_p}{t_p}$$

$$t_{pR} = t_p + 0.25 (t_R - t_r)$$

$$q_{pR} = \frac{640C_p}{t_{pR}}$$

$$q_{pR} = \frac{q_p t_p}{t_{pR}}$$

Where:

t_p = lag time from midpoint of unit rainfall duration, t_r , to peak of unit hydrograph, in hours.

t_r = unit rainfall duration equal to $\frac{t_p}{5.5}$ in hours.

t_R = unit rainfall duration other than standard unit, t_r , adopted in specific study, in hours.

t_{pR} = lag time from midpoint of unit rainfall duration, t_R , to peak of unit hydrograph, in hours.

q_p = peak rate of discharge of unit hydrograph for unit rainfall duration, t_r , in c.f.s./sq.mi.

q_{pR} = peak rate of discharge of unit hydrograph for unit rainfall duration, t_R , in c.f.s./sq.mi.

Q_p = peak rate of discharge of unit hydrograph in c.f.s.

A = drainage area in sq. mi.

L_{ca} = river mileage from the station to center of gravity of the drainage area.

C_t & $640C_p$ = coefficients depending upon units and drainage basin characteristics.

13. Standard project flood - hydrographs.- Standard project flood hydrograph for the Highland Bayou watershed at certain locations were constructed by applying the 24-hour S.P.S. rainfall excess to the unit hydrographs shown in table G. For the recommended improvement by diversion of the upper part of Highland Bayou through Diversion Ditch D and Basford Bayou, the relationship between the discharges and the drainage area are shown by the curves on exhibits 2 through 5 of this appendix. Exhibits 2 and 4 show the relationships for Highland Bayou above Diversion Ditch D and Basford Bayou, exhibits 3 and 5 show the relationships for Highland Bayou below Diversion Ditch D.

14. Plans investigated.- The hydraulic analysis of flooding problems on Highland Bayou shows that the principal deficiency in the natural channel is inadequate capacity to contain heavy concentrations of runoff from the watershed through the middle and lower reaches of the stream. Studies were made of several combinations of improvement of the existing channel and diversion of flows from the upper watershed into adjacent coastal streams. The first plan investigated (Plan A) would provide for improvement of the Highland Bayou channel only from its mouth at mile 0.00 to mile 14.36. Analysis of this plan indicated that to contain the S.P.F. discharge of 16,654 c.f.s. within banks, the existing channel would require deepening and widening to provide base width ranging from 410 feet at the mouth to 10 feet in the upper reaches. The second plan (Plan B) would provide for diversion of all flows from the Highland Bayou watershed above mile 9.50 through a diversion channel to the upper reach of Willow Bayou and improvement of Willow Bayou to Halls Bayou. This plan would also provide for improvement of the natural channel of Highland Bayou from its mouth to the point of diversion at mile 9.50. The third plan (Plan C) would provide also for diversion of the upper Highland Bayou flows at mile 9.50. The diversion would be to Karankawa Bayou, however, instead of the Willow Bayou. Karankawa Bayou would be improved to its mouth at Karankawa Lake. Highland Bayou, below the point of diversion, would be improved as in plan B. The fourth plan (Plan D) would provide for diversion of all flows in Highland Bayou above mile 8.65 to Basford Bayou. With improvement of Basford Bayou by enlargement and rectification to its mouth. Highland Bayou would also be improved by enlargement and rectification from the point of diversion to its mouth. Table H shows the maximum S.P.F. discharge in c.f.s. and the size of improved channel required to contain the S.P.F. discharges within banks through the several reaches comprising the combinations of stream improvement in the four plans described above.

TABLE B

SEPT DISCHARGES AND SIZES OF IMPROVED CHANNELS
PROPOSED UNDER VARIOUS PLANS INVESTIGATED
FOR IMPROVEMENT OF HIGHLAND BAYOU

Plan A (Diversion)				Plan B (Diversion)				Plan C (Diversion)				Plan D (Diversion)				Plan E (Diversion)			
Highland Bayou only				Highland Bayou above Highland Bayou				Highland Bayou above Highland Bayou				Highland Bayou above Highland Bayou				Highland Bayou above Highland Bayou			
Width	Depth	Area	Volume	Width	Depth	Area	Volume	Width	Depth	Area	Volume	Width	Depth	Area	Volume	Width	Depth	Area	Volume
(ft.)	(ft.)	(sq. ft.)	(cu. ft.)	(ft.)	(ft.)	(sq. ft.)	(cu. ft.)	(ft.)	(ft.)	(sq. ft.)	(cu. ft.)	(ft.)	(ft.)	(sq. ft.)	(cu. ft.)	(ft.)	(ft.)	(sq. ft.)	(cu. ft.)
10	2.16	16	0	13.001	10	4.40	0	13.001	10	4.40	0	10	10	100	0	10	10	100	0
10	2.16	16	4.33	13.721	10	4.40	17	13.721	10	4.40	17	10	10	100	17	10	10	100	17
10	5.31	298	4.01	13.845	10	4.40	93	13.845	10	4.40	93	10	10	100	93	10	10	100	93
10	5.31	298	4.41	14.100	10	4.40	278	14.100	10	4.40	278	10	10	100	278	10	10	100	278
15	5.64	600	2.15	12.019	10	4.40	877	12.019	10	4.40	877	10	10	100	877	10	10	100	877
15	5.64	600	2.15	11.640	10	4.40	877	11.640	10	4.40	877	10	10	100	877	10	10	100	877
15	5.71	1,050	1.41	11.239	10	4.40	1,153	11.239	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	10.850	10	4.40	1,153	10.850	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	10.462	10	4.40	1,153	10.462	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	10.074	10	4.40	1,153	10.074	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	9.686	10	4.40	1,153	9.686	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	9.298	10	4.40	1,153	9.298	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	8.910	10	4.40	1,153	8.910	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	8.522	10	4.40	1,153	8.522	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	8.134	10	4.40	1,153	8.134	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	7.746	10	4.40	1,153	7.746	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	7.358	10	4.40	1,153	7.358	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	6.970	10	4.40	1,153	6.970	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	6.582	10	4.40	1,153	6.582	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	6.194	10	4.40	1,153	6.194	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	5.806	10	4.40	1,153	5.806	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	5.418	10	4.40	1,153	5.418	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	5.030	10	4.40	1,153	5.030	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	4.642	10	4.40	1,153	4.642	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	4.254	10	4.40	1,153	4.254	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	3.866	10	4.40	1,153	3.866	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	3.478	10	4.40	1,153	3.478	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	3.090	10	4.40	1,153	3.090	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	2.702	10	4.40	1,153	2.702	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	2.314	10	4.40	1,153	2.314	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	1.926	10	4.40	1,153	1.926	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	1.538	10	4.40	1,153	1.538	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	1.150	10	4.40	1,153	1.150	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	0.762	10	4.40	1,153	0.762	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	0.374	10	4.40	1,153	0.374	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153
15	5.71	1,050	1.41	0	10	4.40	1,153	0	10	4.40	1,153	10	10	100	1,153	10	10	100	1,153

NOTE: Widths shown are bottom widths and do not include channel side slopes. Depths shown are feet, mean sea level.

15. Diversion dam.- The diversion dams, proposed under plans B, C & D, would be of compacted earth and would extend completely across the natural channel of Highland Bayou, so as to divert all flows above the dam. The Highland Bayou watershed is relatively small and most rains that produce runoff will do so from the entire watershed. Highland Bayou below either of the proposed diversion dams, as well as the diversion channels, would be effected by the normal tidal flows, which will keep the water in both channels in motion. Thus, there should be no problems of stagnation in either channel and no opening through the diversion dam is considered necessary to provide flushing action in the channel below the dam.

16. Laterals.- An investigation was made of the existing laterals within the Highland Bayou watershed. It was found that, generally, sufficient laterals of adequate size have been constructed for proper drainage of the presently developed areas within the watershed. However, maintenance of a number of the laterals has been inadequate for proper functioning of the drainage system. A number of lateral drainage channels are obstructed by growths of weeds and brush and by silted reaches. Unless these channels were restored to their design operating capacity, a number of areas within the watershed would continue to experience flooding after construction of the main outlet improvements proposed herein. It is believed that any recommendation for main outlet improvement should be conditioned upon the furnishing of assurances by local interests that they will restore and maintain the lateral drainage system to its proper operating capacity.

17. Freeboard requirements.- Flow capacities of the proposed improved channels have been selected to provide, generally, a minimum freeboard of one foot above the computed flood water surface along most of the improved channel. In the low marsh reaches near the stream mouths and through a few small localized depressions in the general bank lines, one foot freeboard would not be provided by the natural banks. In the low marsh reaches, bank overflow does no damage of consequence. Through the localized depressions, it would not be economical to lower the water surface further to provide the minimum clearance. It is proposed that, where practicable, these depressions be filled with excavated material to maintain the necessary freeboard.

18. Structure clearance.- A minimum clearance of one foot between the design water surface and aerial structures crossing the channel, including pipelines, sewers and low steel of bridges, will be provided.

19. Starting elevations.- A study of coincident occurrence of rainfall and tide levels for the Galveston Vicinity was made in connection with hydrologic and hydraulic analyses of the Texas City Hurricane-Flood Protection Project. This study indicated for normal tides, excluding those effected by hurricanes and tropical disturbance, a tide elevation of 3.3 feet above mean sea level could be expected to occur coincident with rainfall about once each year. This study is concerned with damages caused by fresh water flooding and not that caused by high tides. This tidal elevation was adopted for drainage analyses of the Texas City Hurricane-Flood Protection Project and is considered equally valid for the Highland Bayou vicinity. Accordingly, this elevation was adopted for the starting elevation for backwater computation for Highland Bayou.

20. Backwater computations.- The backwater computations were made using the energy gradient method.

$H_a = D + V^2/2g$ = the specific energy height of energy grade line above the flow line.

Where, D = depth of flow in feet.

V = velocity, in feet per second.

$V^2/2g$ = velocity head, in feet.

g = gravitational constant.

The difference in elevation of the energy gradient line between the two sections represents the total loss between those sections. This total loss consists of friction loss and turbulence loss. The friction loss is given by Manning's formula:

$$Q = \frac{1.486}{n} A r^{2/3} S^{1/2}$$

$$S^{1/2} = \frac{Qn}{1.486 A r^{2/3}}$$

$$S = \left[\frac{Qn}{1.486 A r^{2/3}} \right]^2 = \frac{H_f}{L}$$

$$H_f = \left[\frac{Qn}{1.486 A r^{2/3}} \right]^2 L$$

Where,

Q = discharge in c.f.s.

n = coefficient of roughness.

A = cross sectional area in square feet.

r = hydraulic radius,

S = slope of water surface in feet per foot.

H_f = friction head loss in feet.

L = distance between sections in feet.

Turbulence losses in transition sections were assumed to be proportional to the change in velocity head, H_v .

$$\text{Transition loss} = K_t \Delta H_v$$

K_t = 0.2 for velocity increasing upstream, 0.1 for velocity decreasing upstream.

$$H_v = \frac{V_1^2}{2g} - \frac{V_2^2}{2g} \quad \text{where,}$$

V_1 = velocity at one end of transition section

V_2 = velocity at other end of transition section

$$\text{Total loss between sections were applicable} = L \left[\frac{Q_n}{1.486 Ar^{2/3}} \right]^2 + K_t \Delta H_v$$

21. In evaluating the effects of the proposed improvements, the reduction of flood stages in the bayou channel was considered with respect to corresponding reductions of water levels throughout the flood plain. The improved channels would contain within banks all flood flows of storms up to and including the standard project storm, except in the lower reaches. The reduction of the water level that would be effected, within the design flood plain, except for the lower reaches, then, would depend upon the efficiency of the drainage facilities in carrying runoff to the bayou. Maintenance of the existing laterals and construction of new laterals, as additional lands are developed, would be required throughout the flood plain. Construction and maintenance of adequate lateral channels is a responsibility of local interests, but should be provided for with adequate assurances of local cooperation in any overall improvement project adopted.

INTERIM SURVEY REPORT
ON
HIGHLAND BAYOU, TEXAS

APPENDIX II
ECONOMIC EVALUATION

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APPENDIX II

ECONOMIC EVALUATION

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APPENDIX II

ECONOMIC EVALUATION

1. General.- This appendix presents the economics of the proposed flood protection project for Highland Bayou. The economic study is presented in five sections, as follows: (a) extent and character of the flooded areas, (b) property values, (c) flood damages, (d) benefits, and (e) project formulation. The section on the extent and character of the flooded area describes the flood plain and the type of improvements in the flood plain. The sections on property values and flood damages contain an estimate of the value of physical property in the flood plain, estimates of the flood damages that would be sustained by this property, and estimates of the average annual flood damages that occur to existing property in the flood plain and damages that would occur to projected future developments in the flood plain. The section on benefits describes and presents estimates of the benefits that are expected to accrue from the plan of improvement recommended in this report. The section on project formulation describes and compares the economic analyses made for the various plans investigated and presents the basis of selection for the plan of improvement recommended in this report.

2. The estimates of values, damages, and benefits are based on data obtained from field surveys conducted by the Corps of Engineers, and information submitted by local interests at the public hearing. Aerial mosaics and quadrangle sheets were used for delineating the flood plain and for gathering data on property values and flood damages. The area subject to flooding that was investigated in detail is shown on plate 2 of this report.

EXTENT AND CHARACTER OF THE FLOODED AREA

3. Highland Bayou extends approximately 14 miles inland from West Bay to its headwaters in the vicinity of Arcadia, where the natural ground elevation is about 30 feet above mean sea level. Starting at the head of the bayou, the triangular shaped flood plain becomes gradually wider downstream and covers about 31 square miles. Near the town of Hitchcock, the flood waters from Highland Bayou watershed spread over into the Basford Bayou watershed. The flood plain continues to widen until it reaches a maximum width of about 5 miles at the marshline near the coast. Most of the older section of Hitchcock lies on an island of higher ground about 0.4 mile wide and 0.6 mile long in the center of the flood plain. Except for a fringe of trees located along the banks of the bayou, the undeveloped parts of the flood plain are mostly prairie, which has been used for farming or grazing in the past. About 10 percent of the flood plain has been developed for residential and commercial uses and the remainder is now being used for grazing and rice farming. There is no industrial development in the flood plain at the present time.

PROPERTY VALUE

4. Existing development.- The majority of the residences in the flood plain were built during the last 15 years, as the population of Hitchcock increased from about 1,100 in 1950 to 5,200 in 1960. About two-thirds of the homes are of wood frame construction on elevated piers and the remainder are either wood frame or brick veneer built on slab foundations. The homes range in value from \$10,000 to \$20,000 with the average value per home, including both real and personal property, being about \$14,500. Most of the homes are well maintained. The commercial properties include the normal businesses for servicing residential developments, i.e., grocery stores, service stations, beauty salons, hardware, appliance stores, etc.

5. Estimated value of property in flood plain.- The value of all the existing physical property in the flood plain of the standard project flood was estimated in August 1963 to be \$11,139,000. The values of all classes of properties were estimated on the basis of market value, which was determined by consulting realtors and investors and examining tax assessors' valuations. Table A presents the estimates of values, classified by use, of existing property for the area within the flood plain.

TABLE A

VALUE OF PHYSICAL PROPERTY IN THE FLOOD PLAIN
OF THE STANDARD PROJECT FLOOD, EXISTING CONDITIONS
(August 1963 price level)

<u>Type of property</u>	<u>Value</u>
Residential	\$10,296,000
Commercial	195,000
Municipal and roads	596,000
Utilities	<u>52,000</u>
Total	11,139,000

FLOOD DAMAGES

6. Classes of damages.- Damage estimates are based on data obtained through field surveys and physical inspection of all properties in the flood plain of the standard project flood. The flood damage estimates were made after considering a number of factors, such as the type of loss, the kind and value of structure or improvement, depth of inundation and location. Separate estimates were made for the various types of physical property classified by use as residential, commercial, municipal, utilities and for various types of nonphysical losses.

7. Primary damages in the area were estimated as the tangible losses that would occur through: (1) physical damage to structures, machinery, stock, and cost of cleaning and repairs; and (2) nonphysical losses, including net loss of wages, interruption to traffic and communications, cost of rescue work and policing, cost of combating insects and disease, and cost of relief and care of flood victims.

8. Secondary damages such as loss of production, additional transportation cost, or loss of wages outside the area of influence of the project were not evaluated. Intangible losses including loss of life and adverse effects related to public health, security and national defense also were not evaluated.

9. Flood damages. - Estimates were made of damages that would occur from inundation under existing conditions of development. Inundation from the standard project flood would affect approximately 600 buildings. Damages to roads were estimated on the basis of experienced losses to similar types of roads in other areas. Primary flood damages have been estimated for the various stages of flooding. For more precise definition as to location, the area of flooding was divided into three reaches, in which separate estimates of damages were made. The three reaches are: Reach 1 - mouth of Highland Bayou to stream mile 5.5; Reach 2 - stream mile 5.5 to mile 7.2 (John Palmer Road); and Reach 3 - mile 7.2 to the head of the bayou. For illustration of method, a stage-damage curve for Reach 3 is shown on exhibit 1 of this appendix.

10. Damages from experienced floods. - Prior to 1940, development was sparse in the Highland Bayou flood plain and records of damages from floods are not available. The first known instance of substantial damage occurred in 1940, when Camp Wallace was under construction as a military facility. A rainfall of approximately 9 inches over a few hours time caused serious flooding, with the camp area being inundated with about 2 feet of water. After completion of construction and occupancy, Camp Wallace experienced similar inundation from rainfall in 1945. The amounts of damages from these floods are not known. After World War II and the industrial expansion at Texas City, construction of a number of new residential subdivisions were started in the Hitchcock vicinity. No flooding problems were experienced during the comparatively dry years of the early 1950's. Since 1957, the Highland Bayou area has experienced four serious floods caused by heavy rains and/or hurricanes. On July 24-25, 1959, hurricane "Debra" struck the upper Texas coast with moderately high tides accompanied by very heavy rainfall. Damages from inundation from rainfall runoff in the Highland Bayou watershed were estimated at \$300,000. A tidal surge of about 13.0 feet above mean sea level, during hurricane "Carla" in September 1961, produced estimated damages of about \$2,350,000. Records from the Galveston Weather Bureau showed that 15.32 inches of rainfall were recorded for the four-day period of the hurricane, and other field information indicated that the precipitation in the Hitchcock area was at least equal to or in excess of this amount for the same period. However, field studies indicated that most of the flood damages in the Hitchcock area resulted from the tidal surge of the hurricane rather than from rainfall. Runoff from heavy local rainstorms in March 1957, and June 1960, produced floods on

Highland Bayou and caused damages estimated about \$200,000 each. The rainfall on the Highland Bayou watershed during these storms is not known. At the Galveston Weather Bureau Station, about 11 miles southeast, the March 1957 storm produced rainfall of 2.96 inches in 16 hours and 2.96 inches in 24 hours. Records of the June 1960 storm show rainfall at Galveston totaling 1.52 inches in 24 hours and 2.15 inches in 60 hours. However, the rainfall on the Highland Bayou watershed is known to have been much greater during both storms. Various types of bucket and other nonrecording gages operated by local residents indicated total rainfall of from 10 to 20 inches at numerous places in the watershed for both rainstorms.

11. Damages from the standard project flood and other floods.- Damages that would occur from the standard project flood under the present state of development are estimated at about \$3,188,000, of which \$2,869,000 would be incurred by residential property. Damages were also estimated, under existing conditions of development, for floods resulting from the heaviest rainfall that would be expected to occur on the Highland Bayou watershed with frequencies of once in 100 years and once in 50 years. Damages from the 100-year flood are estimated at \$2,320,000 and, from the 50-year flood, are estimated at \$1,946,000.

12. Average annual damages under existing conditions.- Estimates of average annual damages were computed by correlating the stage-damage relationship with the flood stage-frequency relationship to establish the damage-frequency relationship. The average annual damages are determined from the area under the damage-frequency curve. Examples of these curves are shown for Reach 3 as exhibits 1, 2, and 3, respectively, to this appendix. The total average annual damages for existing conditions and state of development for the three reaches are estimated at \$312,600. Stage-frequency relationships developed for use in this report are based on rainfall frequencies coincident with tide stages of 3.3 feet or less, mean sea level, in Jones Bay.

13. Residual damages.- The several investigated improvement plans would afford protection to the Highland Bayou watershed from floods of various magnitudes, including the 50-year flood, the 100-year flood, and the standard project flood. Under each plan, some remaining, or residual, damages would still occur with the proposed improvements in operation. The residual damages would be experienced from floods greater than the largest flood which could be contained without damage by the improvements designed and proposed for each plan; however, the total damages from such floods would be reduced by the proposed improvements. The residual damages for improvements providing various degrees of protection along the alignment of the recommended plan for Reach 3 are shown graphically on exhibit 3 of this appendix. The average annual residual damages for the recommended plan are estimated at \$1,100, and are computed to include damages from upstream flooding and not from tidal action.

BENEFITS

14. General.- The principal benefits from flood control improvements on Highland Bayou would be derived from the prevention of flood damages, both to existing property and to that which will be developed in the flood plain in the future. Minor benefits from improved facilities for recreational boating and various intangible benefits would also accrue. These benefits, however, have not been evaluated. Benefits and costs were estimated for each of the several plans investigated during the study. The method of selecting the plan of improvement that represents optimum development and as recommended in this report is discussed in paragraph 24 on project formulation. The benefits discussed in the following paragraphs are those estimated for the recommended project. The benefits for the other plans investigated were estimated in the same manner.

15. Benefits from damages prevented for existing property.- The annual benefits that would accrue from prevention of flood damages to existing property by the plan of improvement presented in this report would be the average annual flood damages that occur to existing property within the flood plain less the residual damages that would still occur with the proposed improvements in operation. The estimated damages result only from upstream flooding and not from any tidal action. The average annual flood damages that occur to existing property under present conditions are estimated at \$312,600, and the residual damages estimated for the recommended plan are \$1,100. The average annual damage prevention benefits for existing development that would be effected by the plan of improvement are estimated at \$311,500.

16. Benefits from damages prevented for future growth and development.- The growth and development of the Highland Bayou area will be in consonance with the overall growth and development of the mainland portion of Galveston County. As discussed in the economic base study in exhibit 4 of this appendix, projection of the trends shown by several basic economic indicators shows that the uniform rate of growth of the population for growth of industrial and residential developments may be expected to continue throughout the foreseeable future in the Galveston County mainland area. The Highland Bayou area is centrally located with respect to the probable areas of future industrial development. Its geographic and topographic advantages have resulted in a rapid residential development of areas on both sides of the bayou in recent years and this trend is expected to continue. Accordingly, the character of future development within the Highland Bayou flood plain has been assumed to be principally residential and commercial similar to that now existing. Projection of the basic economic indicators as developed in the economic base study, shown in exhibit 4 of this appendix, shows that a projected growth rate of 1.6 percent annual increase may be expected for the foreseeable future. Accordingly, the development of property in the Highland Bayou area would be expected to expand by about 400 percent above the existing development within the 100-year period used for economic analysis of the project. The total land area in the flood plain is about 20,000 acres, of which 2,000 acres are occupied by existing residential and commercial developments. Of the remaining undeveloped

land, about 10,000 acres would be suited for similar development under existing conditions, of which about 8,000 acres are expected to be developed within the 100-year period of the project life and about 2,000 acres will remain undeveloped. The remaining 8,000 acres are low-lying land below 7 foot elevation and would not be suited to development unless protection from hurricane tidal flooding were provided. This projected development would occupy the entire flood plain, with the exception of approximately 10,000 acres, which would remain undeveloped. Flood control improvements on Highland Bayou would have little effect on the development in the area below 7-foot elevation. The future development of residential and commercial property that would occur within the flood plain, without the proposed flood control improvements, would be subject to the same degree of flood damages experienced by the present developments under existing conditions. The annual damages prevented to future developments for each year in the future were estimated as an appropriate percent (determined by the accumulated growth factor at that time) of the average annual damages prevented for existing properties under improved conditions. The future damages prevented were reduced to an annual average equivalent value by compound interest methods prescribed by Engineering Manual 1120-2-118, using an interest rate of 3.0 percent and a 100-year period of analysis. The equivalent average annual benefits for the damages prevented by the recommended plan of improvement for the prospective growth and development are \$359,400.

17. Enhancement.- The lands susceptible to enhancement in value within the project area are considered to be coastal marshlands. These lands will continue to be vulnerable to inundation from hurricane tides at comparatively frequent intervals after improvements proposed in this report are completed. It is considered that until such time that these lowlands can be protected from flooding by hurricane tides, there will be no appreciable development that would upgrade the use of or enhance the value of these lands. Therefore, no benefits from enhancement of lands have been credited to the project as proposed in this report.

18. Recreation benefits.- The proposed plan of improvement for Highland Bayou includes rectification and enlargement of the natural channel of Highland Bayou and a diversion channel to West (Galveston) Bay by way of Basford Bayou. The Bayou Vista subdivision is being developed near the mouth of Highland Bayou. The houses in this subdivision are being constructed on timber pile foundations with floor elevations raised above estimated hurricane flood elevations. Interlacing canals have been constructed to provide water frontage to all lots and access to the bays through a main channel for small boats. About 150 houses have been completed and plans call for 500 additional homes. A similar subdivision is in the planning stage for Basford Bayou. Although access to the subdivision channels would be improved by improvement of the main channels, the pattern and extent of recreational boating in the area will not be measurably altered. The small boats have relatively shallow drafts and can navigate

the natural channels without difficulty. It is not likely that the amount of traffic would increase because of the proposed project, and recreational benefits are considered to be negligible.

19. Although Highland and Basford Bayous would provide access from West(Galveston)Bay for small boats seeking refuge from tropical disturbances, the low-lying banks of the bayous would not afford adequate protection from sizeable storms, accordingly no benefits pertaining to a harbor of refuge have been evaluated.

20. Intangible benefits.- In addition to the tangible benefits which have been evaluated, certain benefits of an intangible nature would be realized. The intangible benefits include the elimination of loss of life from large floods, improved sanitary conditions, and reduction in fire hazards during floods. Such benefits cannot readily be expressed in monetary terms and have not been evaluated for this report.

21. Summary of benefits.- The total average annual benefits for the recommended plan of improvement, evaluated on the basis of August 1963 prices, are summarized as follows:

a. Flood damages prevented to existing developments	\$311,500
b. Flood damages prevented to future developments (average annual equivalent value)	<u>359,400</u>
Total average annual benefits	670,900

22. Comparison of benefits and costs.- The estimated annual charges for the recommended plan of improvement are presented in detail in appendix III of this report. The annual charges include the estimated costs for operating and maintaining the proposed project. The average annual benefits were estimated as described in the foregoing paragraphs. The estimated total average annual benefits are \$670,900, the annual charges \$196,000, and the benefit-cost ratio is 3.4.

PROJECT FORMULATION

23. Plans considered.- In determining the most feasible plan for reducing flood damages in the Highland Bayou flood plain, four general plans were given engineering and economic consideration. The four plans considered are described as follows:

- a. Rectifying and enlarging the natural channel of Highland Bayou.

- b. Diverting runoff from upper 11.2 square miles of Highland Bayou watershed through Willow and Halls Bayou to West(Galveston) Bay and rectifying and enlarging the natural channel of Highland Bayou as necessary below point of diversion.
- c. Diverting runoff from upper 11.2 square miles of Highland Bayou watershed through Karankawa Bayou and Karankawa Lake to West(Galveston)Bay and rectifying and enlarging the natural channel of Highland Bayou as necessary below point of diversion.
- d. Diverting runoff from upper 18.6 square miles of Highland Bayou watershed through Basford Bayou to West(Galveston)Bay and rectifying and enlarging natural channel of Highland Bayou as necessary below point of diversion.

24. Selection of plans.- For economic comparison of the several plans on a common scale, improvements were designed for each route to contain the standard project flood without damage to existing and prospective property developments in the flood plain. Although the excavation costs were lowest in the plan for improvement of Highland Bayou only (para. 23a above), the costs for rights-of-way and relocations for this plan were considerably greater than for the other plans. Necessary channel widening under this plan would require removal of a number of expensive residences in both the Perthuis Farms and Greenwood Subdivisions. Excavation costs were comparatively large for both the diversion plan through Willow and Halls Bayou (para. 23b above) and through Karankawa Bayou (para. 23c above). The most economical plan was found to be the diversion through Basford Bayou (para. 23d above). This plan has the additional advantage of requiring a minimum of disruption and relocation of existing improvements and probably would have been selected, even if it had not proven to be the most economical route. Benefits and annual charges were estimated for the improvements proposed under each of the plans and each plan was found to have a favorable benefits-costs ratio. The plan for diversion through Basford Bayou, however, was found to be the most favorable, having both the largest annual benefits and the smallest annual charges. The estimated annual benefits, annual charges, excess benefits over costs, and benefits to costs ratio for each of the plans investigated are summarized as follows:

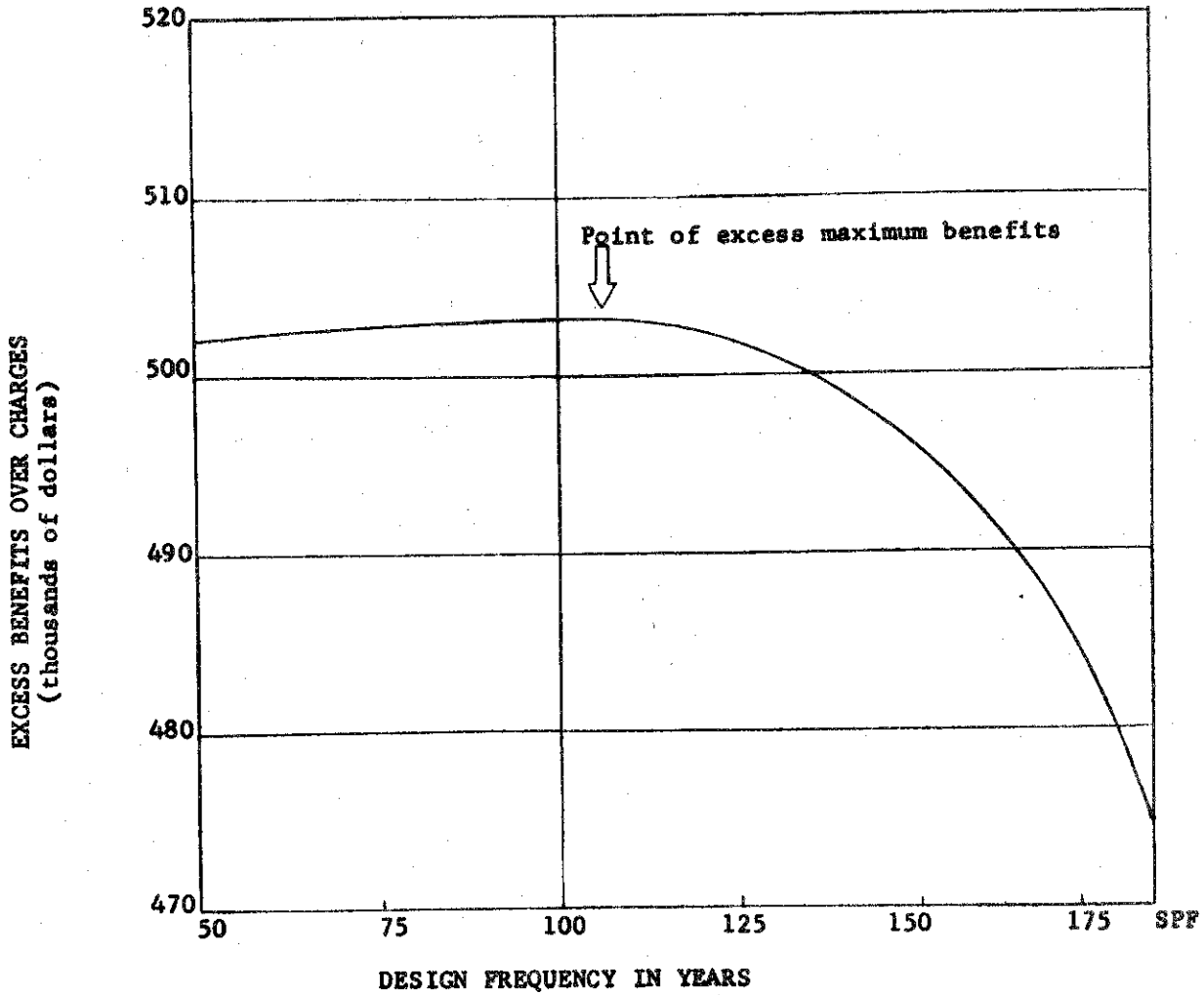
	<u>Annual</u> <u>benefits</u>	<u>Annual</u> <u>charges</u>	<u>Excess</u> <u>benefits</u> <u>over costs</u>	<u>B/C</u> <u>ratio</u>
a. Improvement of Highland Bayou only	\$636,900	\$250,000	\$386,900	2.5
b. Diversion through Willow and Halls Bayous	636,900	261,000	375,900	2.4
c. Diversion through Karankawa Bayou	636,900	236,000	400,900	2.7
d. Diversion through Basford Bayou	670,900	196,000	474,900	3.4

25. Scale of development.- After determining the most favorable general plan for reducing flood damages in the Highland Bayou flood plain, investigations were made to determine the optimum scale of development from an economic standpoint. Improvements were designed to provide protection from floods of several magnitudes, ranging from a frequency of occurrence of once in about 50 years to a standard project flood. Preliminary designs were made of improvements to provide channel capacities sufficient to pass, without damage, floods having peak discharges at the mouth of Highland Bayou of 8,100 c.f.s. (50-year frequency), 9,600 c.f.s. (100-year frequency), and the standard project flood, estimated at 10,700 c.f.s. Estimates of first cost and annual charges were made for each of the plans as shown in appendix III. Estimates of benefits were computed for each plan in accordance with methods described in paragraphs 15 through 21 of this appendix. The estimated benefits, annual charges, excess benefits over costs, and benefit to-cost ratio for each of the three plans are as follows:

	<u>Annual benefits</u>	<u>Annual charges</u>	<u>Excess benefits over costs</u>	<u>B/C ratio</u>
a. 50-year design	\$640,000	\$138,000	\$502,000	4.6
b. 100-year design	666,000	163,000	503,000	4.1
c. SPF design	670,900	196,000	474,900	3.4

26. Maximization of benefits.- Net benefits are maximized if the scale of development is extended to the point where the benefits added by the last increment of improvement are at least equal to the cost of adding that increment. Curves were constructed by plotting the estimated annual benefits, annual charges, and excess benefits over charges for each of the plans considered against the expected frequency interval in years for the largest flood, against which protection would be provided under the respective plan. Inspection of the curve shows that the plan with the maximum excess of benefits over the charges would be in the vicinity of one that would provide protection from the largest flood that might be expected to occur at about 100-year intervals. Near this point the total benefits exceed total costs by the maximum amount as shown in figure 1.

FIGURE I
MAXIMIZATION OF BENEFITS CURVE



28. Selection of design.- Although the maximum excess of benefits over costs would be realized from improvements affording protection from damages from the largest flood expected to occur within periods of about 100 years, extension of the scale of improvement to provide protection from flooding by the standard project flood would be only slightly less favorable from the standpoint of economics. The additional improvement required to afford protection

from the standard project flood would increase the estimated annual charges by about \$33,000 and would increase the estimated annual benefits by \$5,000. Thus, on an incremental basis, the additional improvement would have a benefits to costs ratio of 0.2. On a basis of estimated total benefits and annual charges, improvements affording protection from the 100-year flood would have an estimated benefits to costs ratio of 4.1, compared with 3.4 estimated for the improvements affording protection from the standard project flood.

29. Both the existing development in the Highland Bayou flood plain and that projected for the future are urban in character. Generally in the coastal area, residential development along and adjacent to a sizeable stream of water-course is quite attractive to prospective purchasers. Usually, the fringe of timber along such streams provides desirable homesites with extraordinary aesthetic appeal. The stream itself affords a valuable recreation facility and easy access to adjacent bay areas for small boats. Past developments throughout this area have demonstrated that the highest types of residential development will tend to concentrate along and near the streams. Highland Bayou furnishes an excellent example of this fact. Although many of the areas of lowest elevation would be attractive because of nearness to the stream, developers tend to avoid such areas because of frequent flooding from even minor floods. It is in the areas where only the largest floods will cause flooding at infrequent intervals that much of the flood damage problem develops. Many people move into such areas without being aware of the probability of flooding. Others, although aware of the problem, locate in the area and trust that their period of occupancy will be in the probable lengthy period between floods. For these reasons it is a foregone conclusion that the very largest floods will cause major damages and much suffering and hardship for the people involved. Accordingly, for the small difference in cost, it is believed that full protection against the standard project flood should be provided for the area adjacent to Highland Bayou, even though the benefits appear to be maximized for protection against a somewhat smaller flood, having a probable recurrence interval of about 100 years.

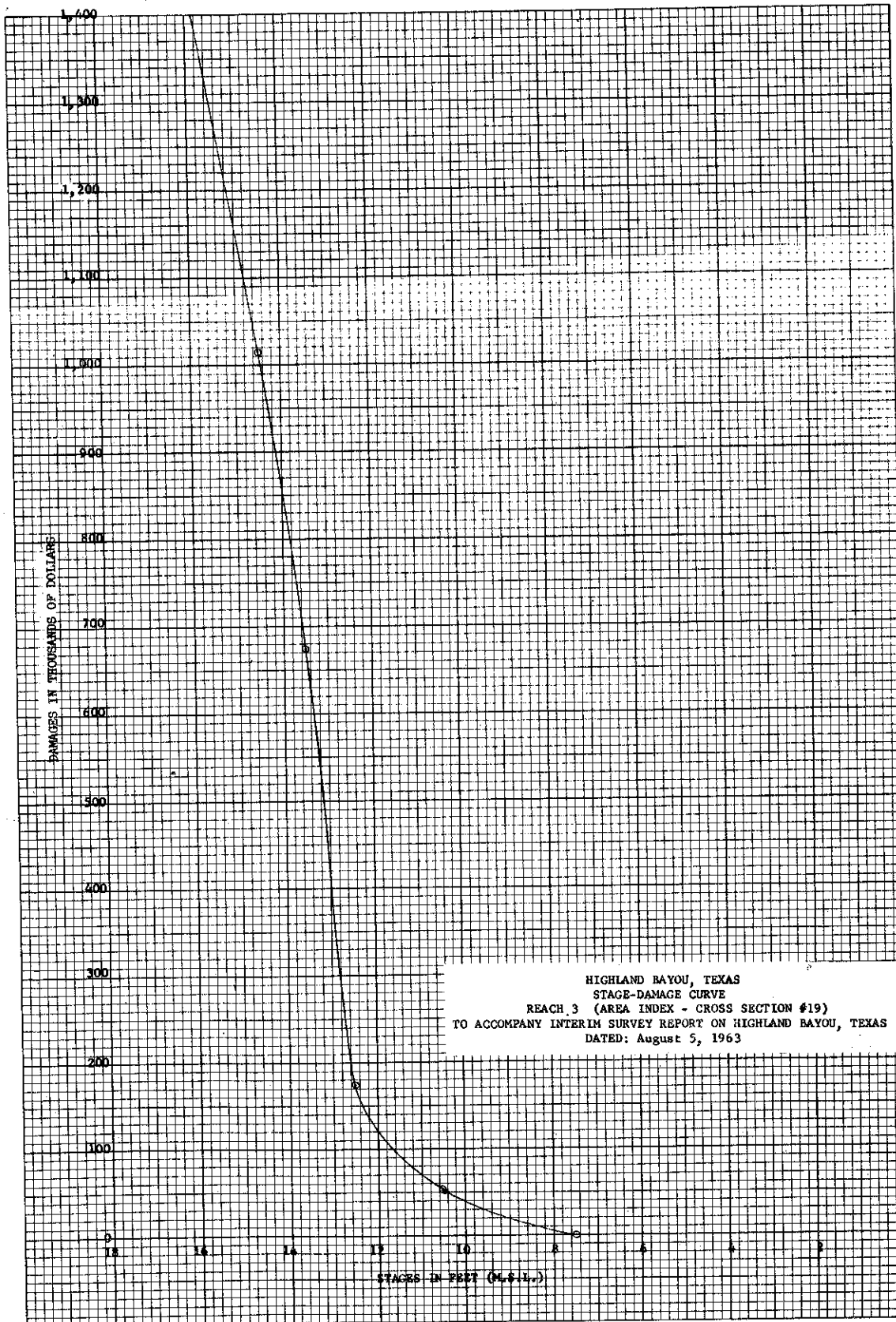
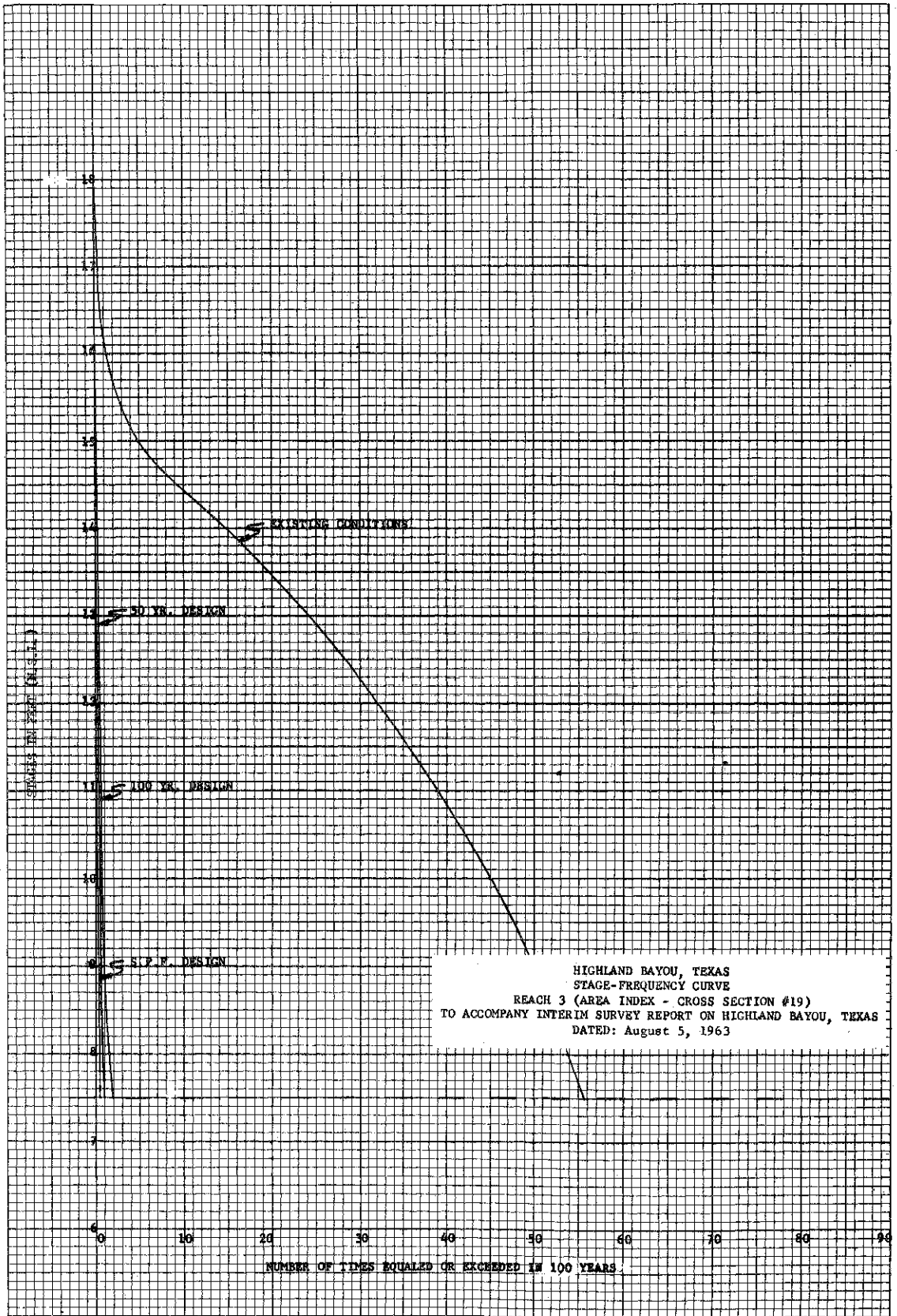
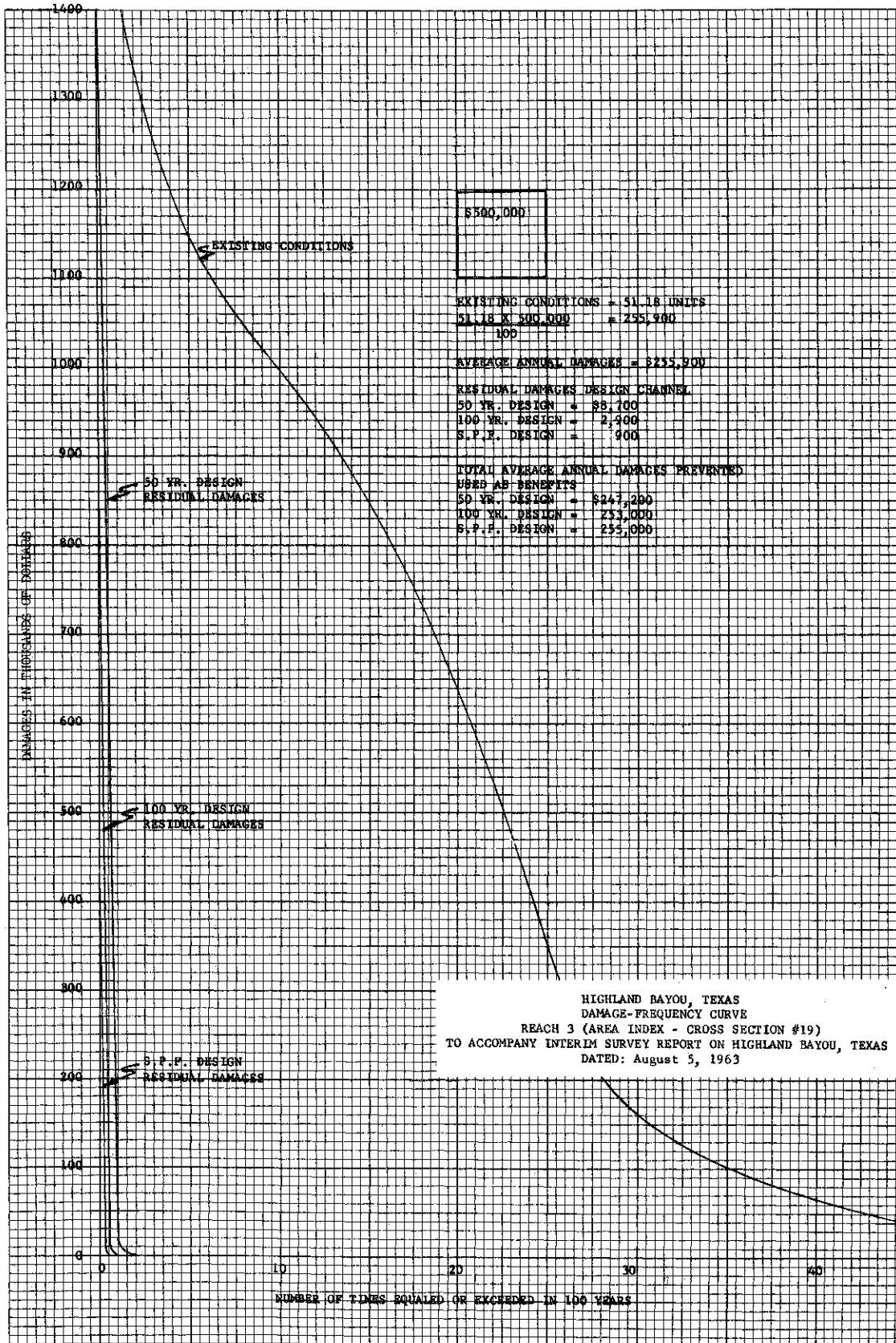


EXHIBIT 1
APPENDIX II





INTERIM SURVEY REPORT
ON
HIGHLAND BAYOU, TEXAS
ECONOMIC BASE STUDY

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INTERIM SURVEY REPORT
ON
HIGHLAND BAYOU, TEXAS

ECONOMIC BASE STUDY

1. General.- Highland Bayou, as shown in exhibit 5, meanders in a generally southeasterly direction through the Texas City-La Marque-Hitchcock complex of the mainland of Galveston County and empties into Jones Bay, an arm of West (Galveston) Bay. The city of Hitchcock lies generally south of Highland Bayou at elevations ranging from about 10 feet to about 20 feet above mean sea level. Hitchcock is an incorporated city, and, though small, nearly quintupled in population during the decade 1950-1960.

2. Hitchcock has a population (1960) of 5,216 with some 50 business establishments, a bank, a post office, as well as a manufacturer of plastic boats. The city is served by Texas State Highway 6 leading to Galveston some 15 miles distant and is located about 4 miles west of Interstate Highway 45 leading to Houston. The refinery and petrochemical complex at Texas City is located about 9 miles from Hitchcock. While most of Hitchcock's employed residents commute to work in Texas City or Galveston, a smaller number travel daily to industrial plants in the Houston-Pasadena area about 40 miles to the northeast. The Gulf, Colorado, and Santa Fe Railroad parallels Highway 6 and provides rail service to the city.

3. The land area between Hitchcock and West (Galveston) Bay to the south is generally of low elevation and undeveloped. The natural ground cover is largely salt grass in this area, and the land is devoted to grazing, rice farming, and some petroleum and natural gas production.

4. The city of La Marque, directly east of and adjacent to Hitchcock, lies north of Highland Bayou and on both sides of Interstate Highway 45. La Marque was incorporated as a city during the past decade and had a 1960 population of 13,969. Its growth pattern has been similar to that of Hitchcock. The city has a bank, post office, newspaper, and some 220 business establishments. La Marque is served by the Missouri Pacific Railroad, Interstate Highway 45, and State Highways 3, 146, and FM-1765.

5. Texas City adjoins La Marque on the east and had a population of 32,065 in 1960. The city is highly industrialized and has about 345 business and industrial establishments, including 3 large petroleum refineries, a tin and rare metals smelter, four major chemical plants, three printing and publishing companies, a steel fabricator, a building materials company, the Galveston County Memorial Hospital, and a manufacturer of compressed acetylene gas.

6. The Texas City Terminal Railway provides rail service to Texas City and connects with the Southern Pacific; Missouri Pacific; Missouri-Kansas-Texas; Chicago, Rock Island, and Pacific, and the Santa Fe Railway systems. Several State highways connect Texas City with Interstate Highway 45. The Texas City Channel, a Federal navigation project, affords deep-draft water transportation to Texas City and connects with the Gulf Intracoastal Waterway system near Galveston. In the year 1961, over 16,400,000 tons of commerce were moved over the Texas City Channel.

7. In addition to the incorporated cities, several unincorporated communities and settlements are located in the mainland portion of Galveston County. The population of these areas and the intervening rural areas constitutes about 28 percent of the total mainland population of Galveston County. These unincorporated communities are largely dependent upon the Texas City industries and are a portion of the Texas City-La Marque-Hitchcock industrial-urban complex. The total area of this complex covers about 302 square miles and includes farm and pasture land as well as the presently developed industrial-urban areas.

8. In order to estimate the probable future development of the mainland portion of Galveston County and to estimate benefits to be derived from the project under consideration, various parameters were selected to determine a likely rate of growth. These parameters will be discussed in the following paragraphs.

9. Population.- It must be emphasized that the Highland Bayou study area lies within the Galveston-Texas City Standard Metropolitan Statistical Area and that there is some evidence of a tendency to form a "strip city" between the Galveston-Texas City SMSA and the much larger Houston SMSA about 45 miles to the northwest, with attendant urbanization of the study area. It is believed that the past population growth pattern of the Texas City-La Marque-Hitchcock complex, shown in table A below, more nearly indicates the probable future growth rate of the complex and of the study area than does a projection of the growth rate of the Galveston-Texas City SMSA. This assumption is based upon the fact that the major city of Galveston, itself, showed an increase of only 0.9 percent in population between 1950 and 1960, while the complex, not subjected to rigid geographical boundaries and vehicular traffic restrictions imposed by an island location and possessing a more youthful and growing economy, showed a far higher population growth in the same period.

TABLE A

POPULATION OF MAINLAND PORTION OF GALVESTON COUNTY
(1940-1960)

	(Year)		
	1940	1950	1960
Study area population	20,311	46,498	73,189
	20.2 (thousand)*	47.1 (thousand)*	74.8 (thousand)*
Percent of increase (for 10-year period)		128.9	57.4

*Estimates from Survey of Buying Power

10. The foregoing table A demonstrates the fact that the population estimates published in Sales Management's Survey of Buying Power are remarkably close to the actual count made by the United States Department of Commerce, Bureau of the Census for the years 1940, 1950, and 1960. Actual populations reported by the Bureau of the Census were used, however, in establishing growth trends and in projecting future increases in order to assure the most nearly accurate bases for these trends and projections.

11. The population of Galveston County outside of the city of Galveston is slightly larger than the population of the Texas City-La Marque-Hitchcock complex because the small villages of Port Bolivar, Gilchrist, and High Island on the Bolivar Peninsula are also included. However, the population of these small villages represented about 3 percent of the County population outside of the city of Galveston and is considered as having a negligible effect on growth projections of the Texas City-La Marque-Hitchcock complex.

12. Because of the manner of reporting estimated population, retail sales, and buying income in Survey of Buying Power, these unincorporated settlements are grouped with the much larger mainland communities as shown in tables A, B, F, and G and in figures 1, 5, and 6. Table A above shows an increase of about 57.4 percent in the 1950-1960 decennium which amounts to about 4.625 percent compounded annually for the decade. This growth rate exceeds that of both the State and the Nation; however, to insure a conservative projection of population increase over a 100-year period, the projected growth rate of Galveston County outside of the city of Galveston will be equated to that for the State for the period 1960-2060.

13. The United States census for the year 1960 shows a population for the State of Texas of 9,579,677, and the estimated population, derived from studies contained in appendix VII - Economic Base Study of the Comprehensive Survey Report on Trinity River and Tributaries, Texas, indicates a population of about 48.6 million in Texas by the year 2060. The indicated total growth

factor of 5.05 for the 100-year period would require an increase of about 1.63 percent compounded annually, compared to an estimated factor of projected growth of 4.02 and an annual increase of about 1.39 percent for the nation during the same period. The projected growths appear in table B.

TABLE B
POPULATION AND FACTORS OF PROJECTED GROWTH

Year	United States	Texas	Study area
	(in thousands)		
<u>POPULATION</u>			
1940	132,165	6,415	20.3
1950	151,326	7,711	46.5
1960	179,323	9,579	73.2
1970	206,000	11,400	102.5
2020	422,000	27,700	205.8
2060	720,000	48,600	370.0
<u>FACTORS OF PROJECTED GROWTH</u>			
1960-1970	1.15	1.19	1.40
1960-2020	2.35	2.89	2.81
1960-2060	4.02	5.07	5.05

The projected future population of the Study Area, compared with that of the State of Texas and of the United States to the year 2060, is shown on figure 1. The factor of projected growth in table B of the Study Area for the period 1960-2060 multiplied by the Study Area's population indicates an extrapolated estimate of about 370,000 persons dwelling in that area by 2060. This should indicate virtually complete areal urbanization not later than 2060 of all land lying seven feet or more above mean sea level if the projected rate of growth is maintained. A higher growth rate could reasonably be estimated, based on growth experienced in the decade from 1950 to 1960, and would indicate that the area could well be occupied at an earlier date.

14. Bank deposits.- The increase in bank deposits in the Texas City-La Marque-Hitchcock complex is shown in table C. The increase in bank deposits for this area compared with that of the State of Texas for the same period is shown in figure 2 of this exhibit. The information for the local area was compiled from the total deposits of all of the mainland banks in Galveston County as of the 31st of December for each year. Any projection of future deposits, however, from data on hand would not necessarily be reliable because of wide fluctuations in these deposits that have been caused at various times by events

frequently unrelated to areal growth. Some of these events are: change of depository of Galveston County funds in 1961 from Galveston City banks to mainland banks, heavy deposits of money obtained from settlement of insurance claims for damages resulting from Hurricane Carla in 1961, and the opening of new mainland banks with the probable transfer of funds from other banks close at hand but not necessarily within the complex.

TABLE C

BANK DEPOSITS

(in thousands of 1960 constant dollars)

Year	Study area	Annual percent change	Texas	Annual percent change
1952	25,046	-	9,365,582	-
1953	25,177	0.5	9,807,431	4.7
1954	27,688	9.9	10,480,408	6.9
1955	32,258	16.5	10,885,819	3.9
1956	36,045	11.7	11,041,215	1.4
1957	33,801	(-) 6.2	10,726,309	(-) 2.9
1958	32,926	(-) 2.6	11,703,101	9.1
1959	33,716	2.4	11,727,522	0.2
1960	34,166	1.3	12,298,780	4.9

15. Building permits.- The issuance of building permits, table D, in the Texas City-La Marque-Hitchcock complex, shown on figure 3, indicates wide variations that are not closely related to the long range economy of the complex. The variations have been caused not only by fluctuations in the national economy but also by new industrial plant construction or expansion of existing industry within the city limits of La Marque and Texas City. Municipal annexations also play their part by adding construction in the municipalities which would not have been counted had there been no annexation. Although incorporated, no building permits are presently required for construction in Hitchcock, and none were required in La Marque prior to 1954, when it was first incorporated as a city.

TABLE D

BUILDING PERMITS FOR TEXAS CITY AND LA MARQUE

(in thousands of 1960 constant dollars)

Year	Value	Annual percent change
1954	9,470	-
1955	12,395	30.9
1956	9,963	(-) 19.6
1957	8,427	(-) 15.4
1958	8,813	4.6
1959	6,756	(-) 23.4
1960	6,579	(-) 2.6

16. Rendered municipal tax values.- The rendered municipal tax values in table E are considered to be more reliable as a parameter in this case than bank deposits and building permits within the Texas City-La Marque-Hitchcock complex; however, these values are subject to wide and rather erratic fluctuations caused by the sudden addition of properties to the tax rolls through incorporation or annexation and should be used with caution. It is interesting to note that the periods of stability of growth after major fluctuations tend to more nearly parallel the decade's population increase. These curves, however, were not projected beyond 1960 because of the trend resulting from erratic increases. (See figure 4.)

TABLE E

RENDERED MUNICIPAL TAX VALUES
TEXAS CITY AND LA MARQUE

(in thousands of 1960 constant dollars)

Year	Value	Annual percent change
1951	53,091	-
1952	71,401	34.5
1953	70,826	(-) 0.8
1954 (1)	96,944	36.9
1955 (2)	109,655	13.1
1956	114,596	4.5
1957	117,120	2.2
1958	121,727	3.9
1959	124,472	2.3
1960	128,869	3.5

(1) La Marque incorporated. (2) Texas City annexed West Texas City.

17. Retail sales.- The estimated volume of retail sales for each year from 1940 to 1960, inclusive, is reported in table F in 1960 constant dollars from actual dollar value estimated in Survey of Buying Power for each of these years for the state of Texas, Galveston County, and Galveston County less Galveston City. Although the last includes the small communities located on Bolivar Peninsula, it is believed that virtually all of the retail sales reported outside of Galveston City are assignable to the mainland portion of Galveston County because of the relatively small retail trade potential on Bolivar Peninsula, which has only small grocers, service stations, and bait and sporting goods as retail outlets. The comparative sales are shown graphically in figure 5.

TABLE F
RETAIL SALES

(in thousands of 1960 constant dollars)

Year	Texas	Annual percent of change	Galveston County	Annual percent of change	Mainland portion of Galveston County	Annual percent of change
1940	3,903,508	-	66,203	-	13,890	-
1941	4,124,624	5.7	69,953	5.7	13,160	(-) 5.5
1942	4,152,647	0.7	68,151	(-) 2.6	12,885	(-) 2.1
1943	4,571,669	10.1	80,072	17.5	14,636	13.6
1944	4,876,657	6.7	81,608	1.9	16,897	15.4
1945	5,223,651	7.1	97,275*	19.2	20,134*	19.2
1946	6,702,554	28.3	112,941	16.1	23,371	16.1
1947	7,178,782	7.1	122,756	8.7	25,411	8.7
1948	7,665,094	6.8	138,492	12.8	28,668	12.8
1949	7,760,109	1.2	145,437	5.0	30,105	5.0
1950	9,368,206	20.7	153,829	5.8	44,456	47.7
1951	9,377,346	0.1	145,350	(-) 5.5	42,006	(-) 5.5
1952	9,951,601	6.1	167,630	15.3	48,445	15.3
1953	10,099,513	1.5	167,894	0.2	48,451	0.2
1954	9,918,442	(-) 1.8	171,535	2.2	51,419	6.0
1955	10,422,418	5.1	160,892*	(-) 6.2	51,326*	(-) 0.2
1956	10,926,415	4.8	150,248	(-) 6.2	51,232*	(-) 0.2
1957	11,113,026	1.7	147,053	(-) 2.1	51,138	(-) 0.2
1958	11,007,506	(-) 0.9	143,798	(-) 2.2	51,283	0.3
1959	11,628,151	5.6	148,025	2.9	61,447*	19.8
1960	11,507,575	1.0	152,251	2.9	71,611	16.5

Factors of increase, period 1940-1960: 2.9 (Texas) 2.3 (Galveston County)
5.1 (Mainland portion of Galveston County)

* Interpolated

18. From the factors of increase in table F, it may be seen that the 1940-1950 rate of increase in retail sales was about 1.8 times as great for the mainland portion of Galveston County as for the state, and about 2.2 times as great as the increase experienced by Galveston County as a whole. While this increase may not continue indefinitely, it is believed that the rate of increase will not be less than that of the state as a whole for the life of the project.

19. Disposable income.- The disposable income is that income available for the purchase of goods and services after taxes. A comparison of the disposable incomes for the state of Texas, Galveston County, and the mainland portion of Galveston County for the period 1940 to 1960, inclusive, is presented in table G below computed in terms of 1960 constant dollars from actual dollar values estimated by Survey of Buying Power for those years. As in the case of retail sales, all of Galveston County except Galveston City is included in these statistics, but virtually all of the disposable income outside of Galveston City is to be found on the mainland portion of the county in the Texas City-La Marque-Hitchcock complex. Graphical comparisons of the relative increases in disposable income for Texas, Galveston County, and the mainland portion of Galveston County are shown on figure 6.

TABLE G

DISPOSABLE INCOME

(in thousands of 1960 constant dollars)

Year	Texas	Annual percent of change	Galveston County	Annual percent of change	Mainland portion of Galveston County	Annual percent of change
1940	6,030,382	-	104,215	-	12,048	-
1941	6,498,752	7.8	112,310	7.8	12,984	7.8
1942	7,955,345	22.4	141,839	26.3	16,314	25.6
1943	10,066,060	26.5	192,690	35.9	35,115	115.2
1944	10,280,736	2.1	190,469	(-) 1.2	32,093*	(-) 8.6
1945	9,444,493	(-) 8.1	174,520*	(-) 8.4	29,071*	(-) 9.4
1946	9,947,975	5.3	158,570	(-) 9.1	26,049	(-) 10.4
1947	10,335,187	3.9	160,068	0.9	26,411	1.4
1948	10,441,516	1.0	207,821	29.8	35,719	35.2
1949	10,273,889	(-) 1.6	212,011	2.0	50,123	40.3
1950	11,933,277	16.2	226,175	6.7	79,046	57.7
1951	11,902,719	(-) 0.3	214,755	(-) 5.0	84,533	7.0
1952	12,862,928	8.1	242,313	12.8	115,170	36.2
1953	13,982,413	8.7	242,488	0.1	113,646	(-) 1.3
1954	13,897,474	(-) 0.6	243,459	0.4	102,959	(-) 9.4
1955	14,561,769*	4.8	235,258*	(-) 3.4	97,033*	(-) 5.8
1956	15,226,064	4.6	227,058	(-) 3.4	91,108*	(-) 6.1
1957	15,044,659	(-) 1.2	222,737	(-) 1.9	85,183	(-) 6.5
1958	15,560,696	3.4	230,675	3.6	94,675	11.1
1959	15,948,223	2.5	247,664	7.4	113,684*	20.1
1960	16,888,189	5.9	264,652	6.9	132,693	11.7

Factors of increase, period 1940-1960: 2.8 (Texas) 2.5 (Galveston County)
11.0 (Mainland portion
of Galveston County)

* Interpolated

20. The factors of increase in disposable income for Texas, Galveston County, and the mainland portion of Galveston County over the period 1940-1960, inclusive, indicate that the disposable income for the mainland portion of Galveston County increased at a rate equal to about 3.9 times that of Texas and 4.4 times that of Galveston County as a whole. This rate of increase in disposable income indicates a strong and growing economy, and, while the rate may decrease in the future, it is believed that it will remain equal to or greater than that of the state during the project life.

21. New industrial growth.- Two new industries, though not located in Galveston County, will undoubtedly exert a strong influence on the increasing urbanization of the complex. The first of these new industries is a petrochemical plant located on Chocolate Bayou in Brazoria County, about 17 miles southwest of Hitchcock. This plant is owned by the Monsanto Chemical Company and is integrated in its operations with the large Monsanto Chemical Plant in Texas City. The new plant was put in operation late in 1962, and, according to a Monsanto Chemical Company brochure, it employs about 425 men and women and has an annual production capacity of about 2.5 billion pounds of ethylene and other hydrocarbon chemicals. Ethylene is the major product at the present time, and most of this chemical is transported 23 miles by pipeline to the Monsanto plant at Texas City for feedstock and conversion into various chemical products. A large acreage has been reserved near this new plant for the location of new industries which would depend upon this plant for their feedstocks. The new Monsanto plant is located about equidistant from Hitchcock and Alvin, and, as the new industrial area expands and employment increases, there is no doubt that residential development will be further stimulated in both cities.

22. A new major activity that will stimulate additional development in the Texas City-La Marque-Hitchcock complex is the Manned Spacecraft Center of the National Aeronautics and Space Administration, which is now under construction on Clear Creek, about 11 miles north of the La Marque-Texas City area. It is certain that this activity will attract a large supporting complex of manufacturing, technical processing, and research activities. Numerous major companies have acquired, or are investigating and planning for plant sites near the Manned Spacecraft Center. Its full impact on the adjacent cities and the surrounding area cannot be fully foreseen at this time, but it undoubtedly is one of the major developments of recent times. The further development of the Texas City-La Marque-Hitchcock complex will be greatly stimulated by its proximity to the Manned Spacecraft Center.

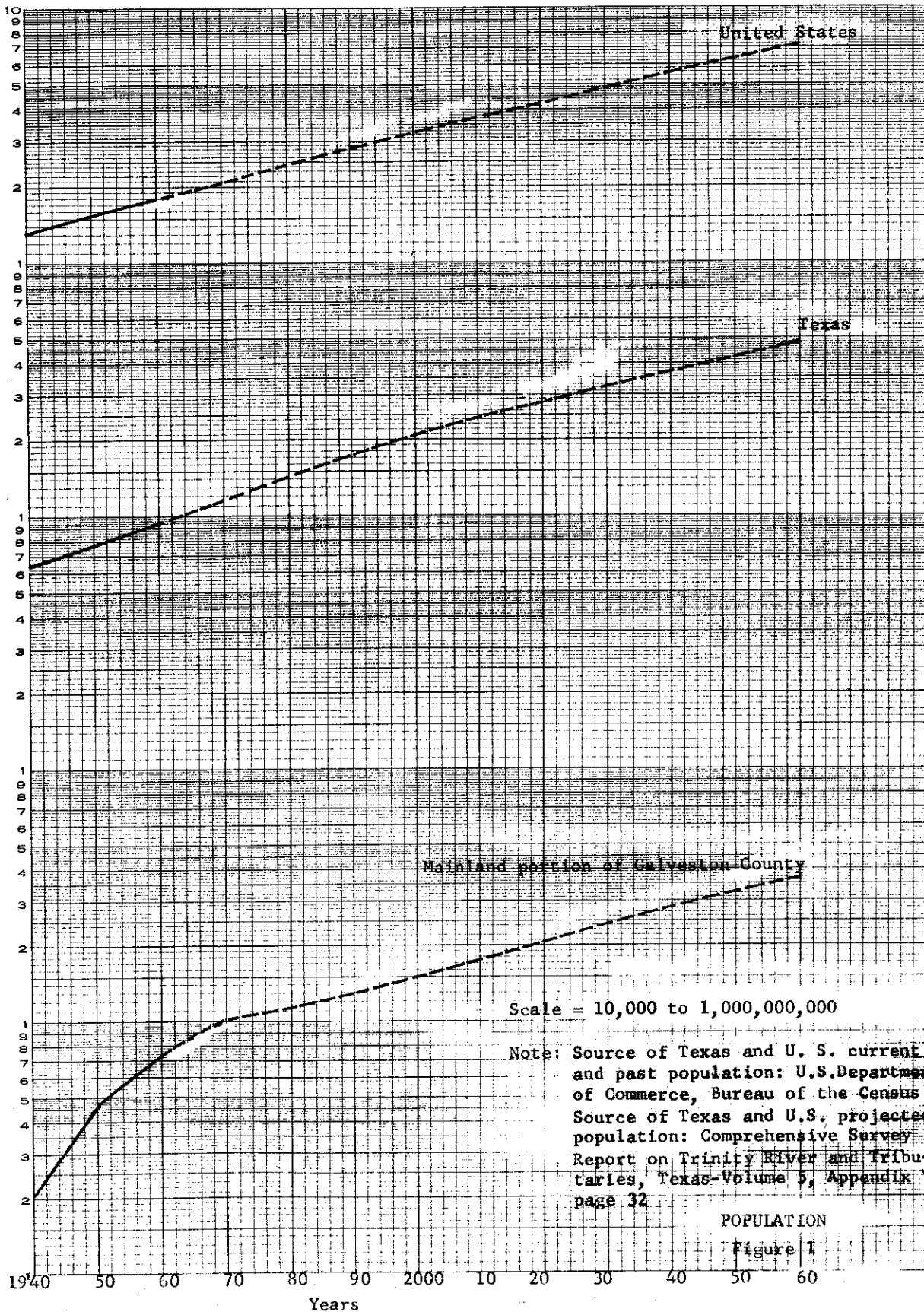
23. Summary.- Studies of the six parameters considered for purposes of estimating future economic activity in the project area indicate that the population parameter is least susceptible to relatively short range erratic fluctuations. The population parameter would provide the most reliable basis for estimating probable economic development during the project life. Small geographic areas, largely dependent upon a simple economy of one or two basic enterprises, such as petroleum refining or petrochemical production, are subject to extreme economic variations from comparatively minor changes in the local industrial activity. As shown in paragraph 15, recent incorporation and annexation actions involving communities within the basic complex and the nonuniformity of requirements for building permits impair the usefulness of this normally valid parameter for projection purposes.

24. In most instances bank deposits are a fairly reliable barometer of business activity within a given area. In this instance, however, abnormal growth was shown as a result of heavy deposits from insurance settlements of damage caused by a major disaster and the change of depository of public funds. These factors of heavy influence during the comparatively short period of record tend to obscure and override any pattern of normal change that might otherwise have been evident. This is illustrated by the comparison shown in table C, of the annual percent change in bank deposits for the study area and the state. The parameter based on municipal tax values has also been influenced to abnormal proportions by annexation and incorporation variations that cannot be readily identified and separated from the totals. These deviations discount the value of this parameter for projection of future economic growth. A parameter based on retail sales indicates that the rate of increase runs well ahead of that of the state and the county; however, this increase is probably not as great as it should be because of the undoubted effect of the proximity of the major city of Houston and the excellent road system serving that city. At present, the large retail outlets in Houston offer great competition for the retail dollar available in the mainland area. This effect should, however, tend to gradually diminish in favor of local retail outlets as the urbanization of the area causes an increase in traffic volume which in turn should result in a decrease in individual mobility with more localized buying. The parameter of disposable income runs well ahead of that of Texas and Galveston County, which indicates a potentially rich field for retail business as urbanization increases. The industrialization of the mainland area with attendant higher wages and salaries gives the mainland of Galveston County an advantageous position in comparison to that of the state and county as a whole. These parameters are complementary and lend support to the parameter of population, which was judged to be the most valid indicator in estimating possible levels of future economic growth. While all parameters presented were considered, that of increase in population was given the most weight in overall evaluation.

25. Tests of degree of reliability of the population parameter and supporting data or retail sales and disposable income included comparison of the projected growth in population of the Texas City-La Marque-Hitchcock complex with that predicted for the state of Texas. Comparative growth rates for the Texas City-La Marque-Hitchcock complex and the state of Texas are as follows:

	<u>Population</u>		<u>Compound rate of growth</u>	<u>2060 population percent of 1960 population</u>
	<u>1960</u>	<u>2060</u>		
Mainland-Galveston County	73,200	370,000	1.63%	505%
State of Texas	9,579,000	48,597,000	1.64%	507%

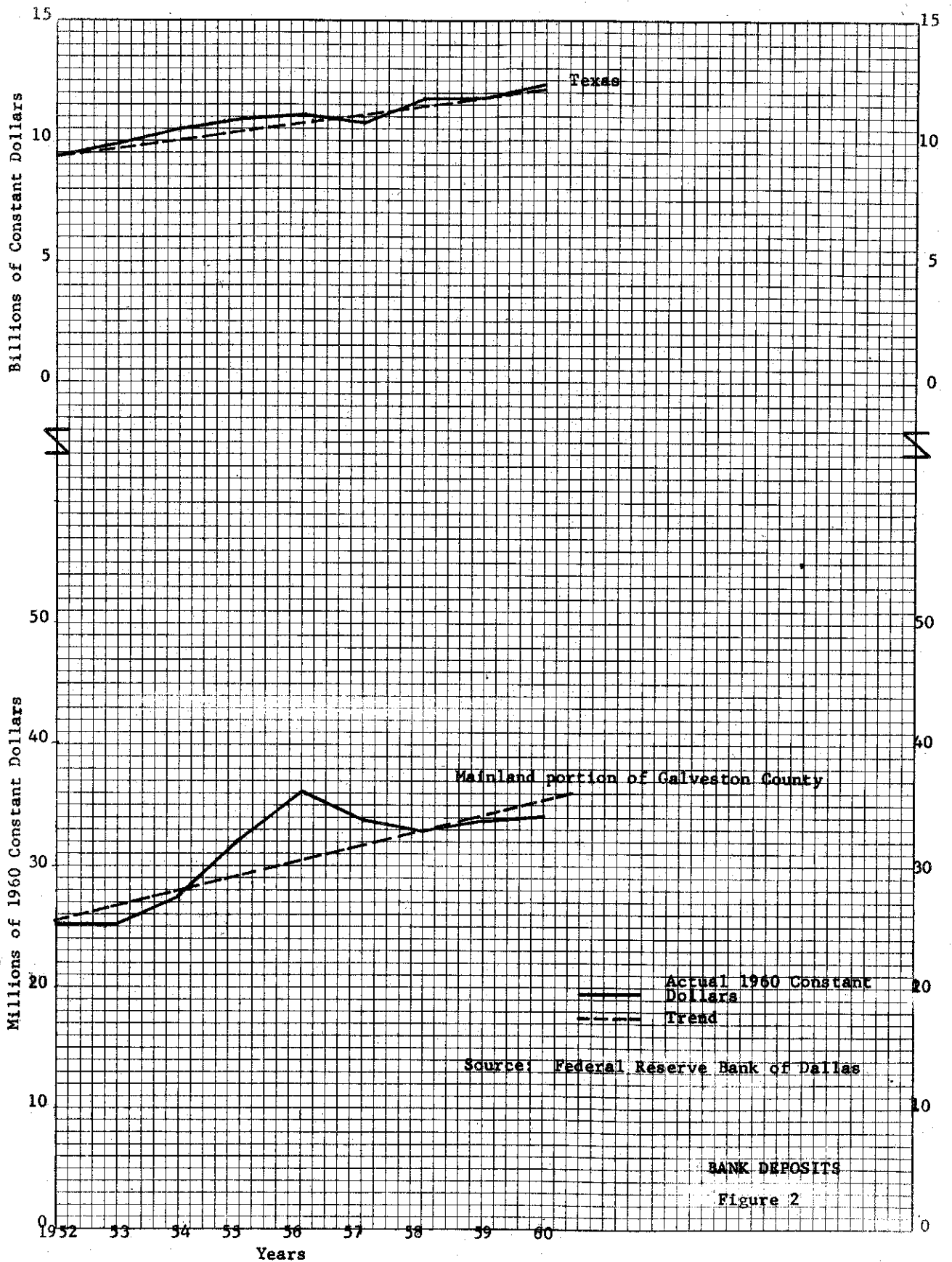
This comparison was also made of the experienced and projected population of the Standard Metropolitan Statistical Areas for Houston and for Galveston-Texas City. The Houston Standard Metropolitan Statistical Area experienced a 10-year gain of 54.1 percent to 1,243,158 in 1960, while the Galveston-Texas City SMSA experienced a 24.1 percent growth to 140,364 during the same period. The weighted annual average rate of these growths is about 5.1 percent. If the 1950-1960 annual numerical growth is projected to the year 2060, the indicated population at that time would be about 600 percent of that reported for 1960. If the estimated numerical growth for 100 years is translated into a compounded annual percentage rate for the period, the annual rate of increase would be about 1.8 percent, which is slightly above that forecast for the state. This rate would indicate a population of about 433,700 persons residing in the Texas City-La Marque-Hitchcock complex by 2060. It is recognized, however, that the short period of statistical data available for the Texas City-La Marque-Hitchcock complex may render predictions susceptible to a lesser degree of accuracy, and, in the interest of conservatism, a projected growth rate of 1.6 percent annual increase has been adopted for this study.

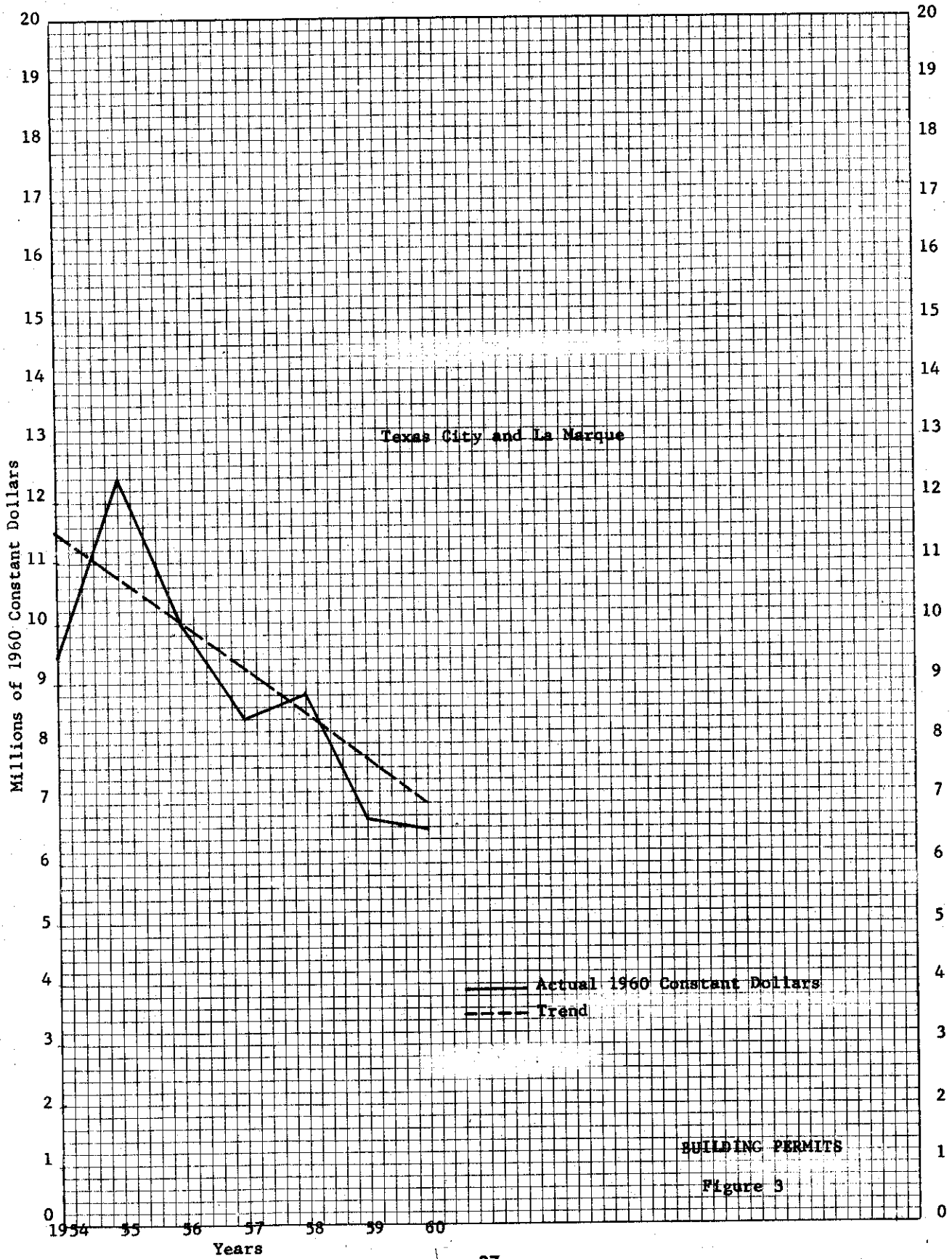


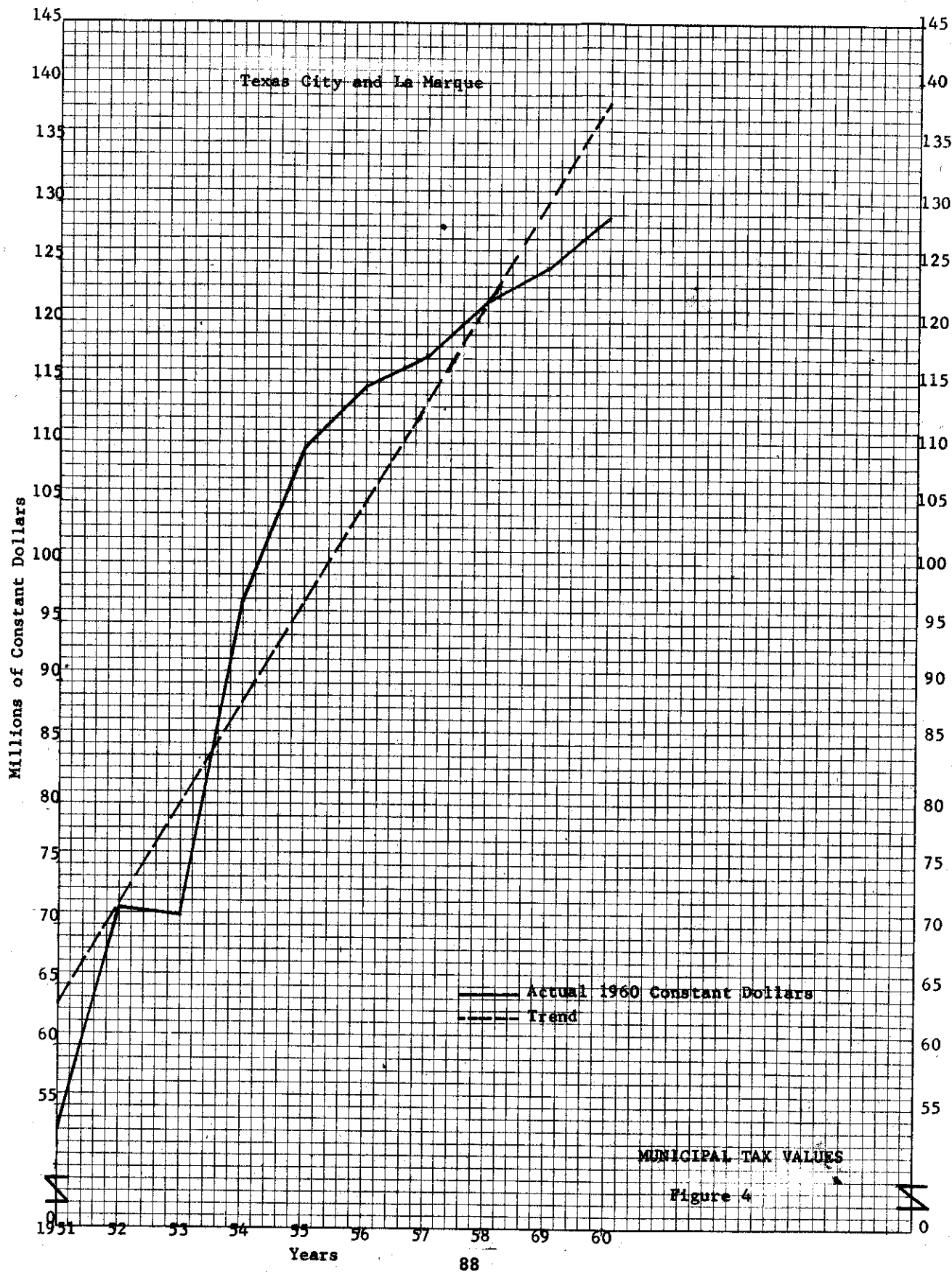
Scale = 10,000 to 1,000,000,000

Note: Source of Texas and U. S. current and past population: U.S. Department of Commerce, Bureau of the Census. Source of Texas and U.S. projected population: Comprehensive Survey Report on Trinity River and Tributaries, Texas-Volume 5, Appendix VII, page 32

POPULATION
Figure 1

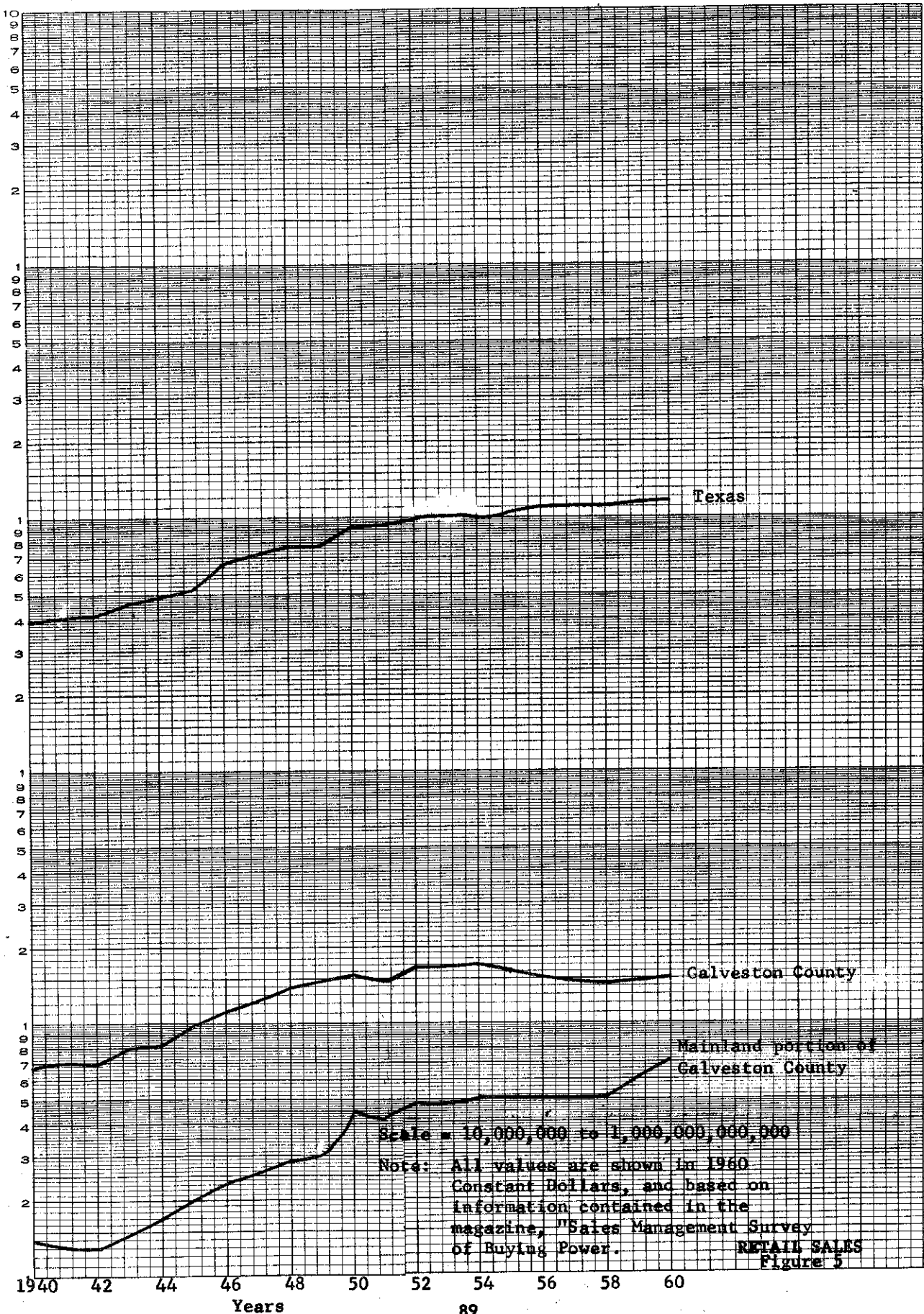






MUNICIPAL TAX VALUES

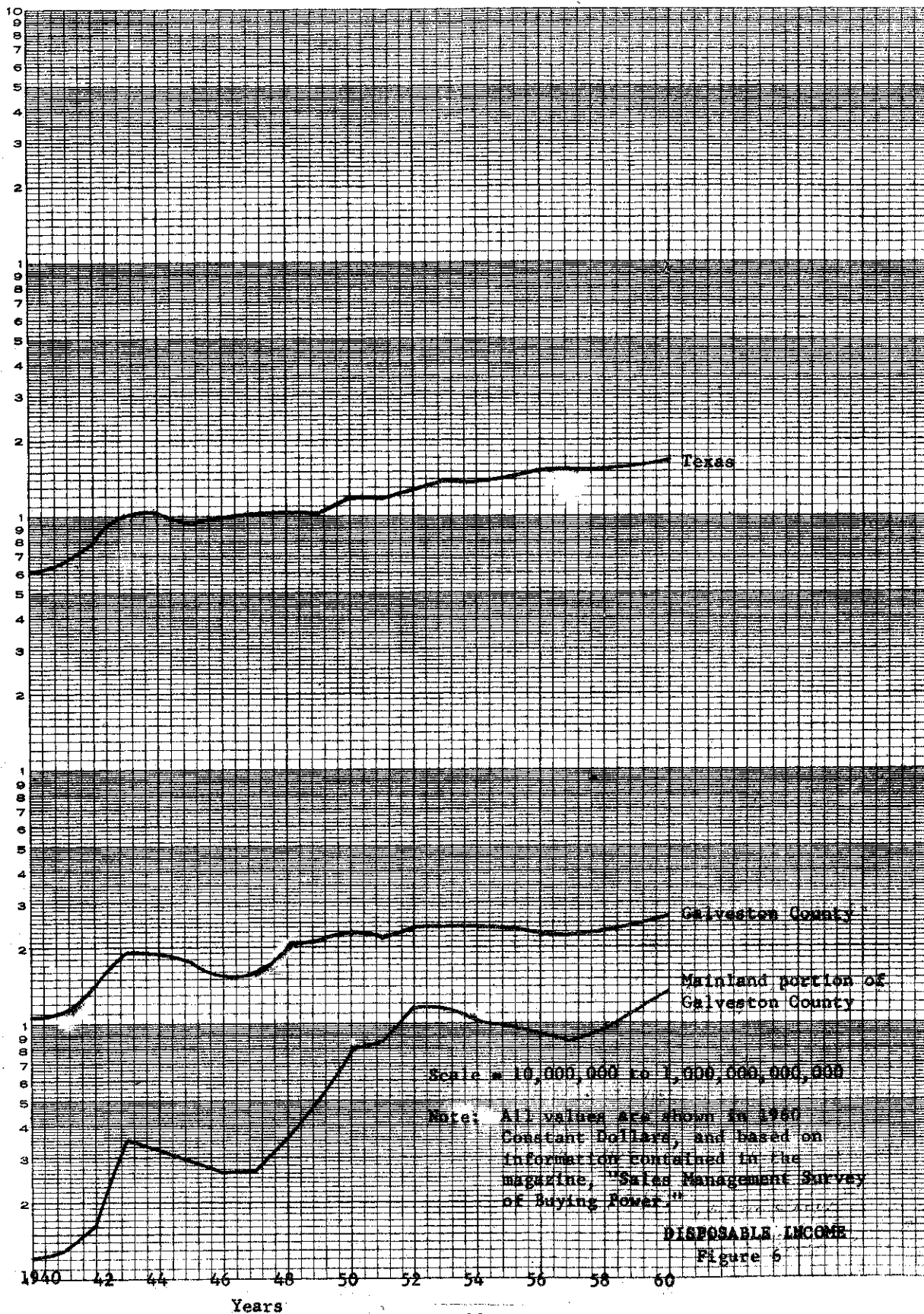
Figure 4



Scale = 10,000,000 to 1,000,000,000,000

Note: All values are shown in 1960 Constant Dollars, and based on information contained in the magazine, "Sales Management Survey of Buying Power."

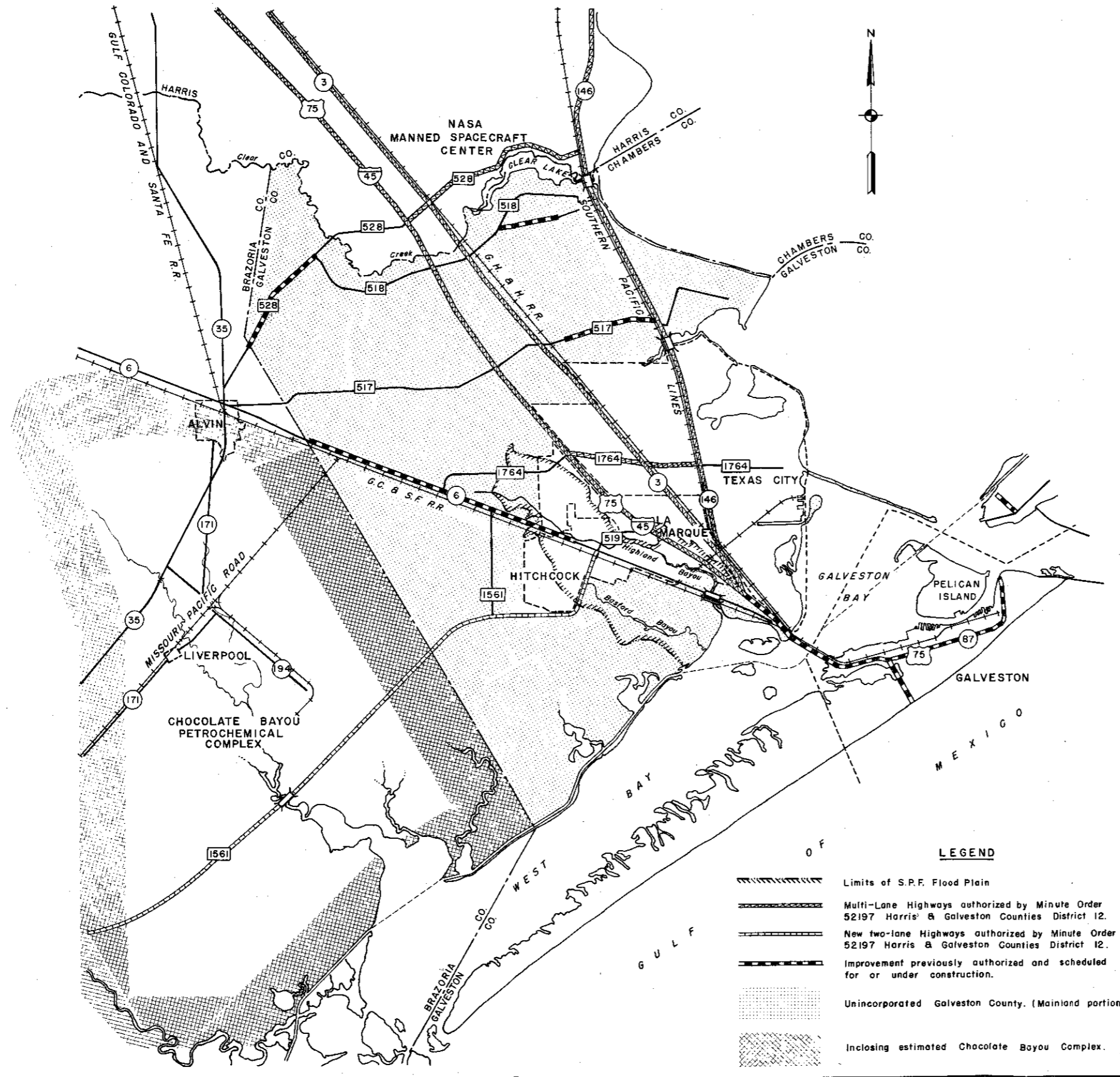
RETAIL SALES Figure 5



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- LEGEND**
- Limits of S.P.F. Flood Plain
 - Multi-Lane Highways authorized by Minute Order 52197 Harris & Galveston Counties District 12.
 - New two-lane Highways authorized by Minute Order 52197 Harris & Galveston Counties District 12.
 - Improvement previously authorized and scheduled for or under construction.
 - Unincorporated Galveston County. (Mainland portion)
 - Including estimated Chocolate Bayou Complex.

HIGHLAND BAYOU, TEXAS

ECONOMIC BASE STUDY MAP

SCALE OF MILES
0 1 2 3 4 5

U.S. ARMY ENGINEER DISTRICT GALVESTON, TEXAS AUG 1963

TO ACCOMPANY INTERIM SURVEY REPORT ON
HIGHLAND BAYOU, BRAZORIA-GALVESTON SCD, TEXAS
DATED: AUGUST 5, 1963

EXHIBIT: 5 APPENDIX: II FILE: GALV. 314-39

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INTERIM SURVEY REPORT
ON
HIGHLAND BAYOU, TEXAS

APPENDIX III
ENGINEERING AND COST DATA

INTERIM SURVEY REPORT
ON
HIGHLAND BAYOU, TEXAS

APPENDIX III

ENGINEERING AND COST DATA

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EXHIBITS

(Only Exhibit 1 printed)

<u>Exhibit number</u>	
1	Locality map
2	Boring plan and soil profile
3	Bridge profiles

INTERIM SURVEY REPORT
ON
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APPENDIX III

ENGINEERING AND COST DATA

1. Scope.- This appendix presents information pertinent to the planning of a Federal project to provide flood protection on the watershed of Highland Bayou in Galveston County, Texas. Data presented in this appendix relate particularly to existing and proposed improvements, first costs, annual charges, subsurface conditions, rights-of-way costs, channel construction, spoil disposal methods and maintenance costs for the proposed flood protection project.

2. General.- Runoff to Highland Bayou from heavy rains has been increased by construction of drainage laterals and extensive urban development on the watershed and now causes frequent and serious flooding along the bayou.

3. The following plans were investigated to determine the most economical and effective plan for prevention of flood damages to property in the Highland Bayou flood plain.

a. Plan A - Enlarge and rectify the natural channel of Highland Bayou to carry the entire runoff from a standard project flood.

b. Plan B - Enlarge and rectify the Highland Bayou channel and construct a diversion channel from a point near stream mile 9.50 southward and westward to Halls Bayou via Willow Bayou.

c. Plan C - Enlarge and rectify the Highland Bayou channel and construct a diversion channel from a point near stream mile 9.50 southward to Karankawa Bayou.

d. Plan D - Enlarge and rectify the Highland Bayou channel and construct a diversion channel from a point near stream mile 8.65 southward and eastward to Jones Bay via Basford Bayou.

4. The most economical plan of improvement proved to be the Basford Bayou diversion route via Basford Bayou to Jones Bay (plan D). Cost comparisons of the four plans are shown in table A of this appendix.

5. A survey investigation to consider the feasibility of modifying the authorized hurricane flood protection project for Texas City and vicinity to extend protection to the western part of La Marque and the Hitchcock vicinity is in progress. During the investigation covered by this report, the relation of flood control improvements for Highland Bayou to possible extension of the authorized hurricane flood protection

project was considered. Because of the time required for completion of the hurricane flood protection study and the urgency of the Highland Bayou flood problem, it was not deemed advisable to combine the two studies and delay submission of this report. The terminal point, elevation of the upper limit of the protected area and economic justification for the proposed hurricane flood protection remain to be determined. However, several plans were investigated in a preliminary manner with a view toward diverting portions of the flow of Highland Bayou along a route terminating west of the proposed hurricane flood protection extension as follows:

a. Plan A - (Highland Bayou without diversion).- Considerable ponding area would be available on the lower marsh reaches of the bayou for ponding of interior drainage during periods of high tides.

b. Plan B - (Willow Bayou Diversion).- There is no area available for ponding on Willow Bayou, consequently pumping facilities for the entire runoff from the upper Highland Bayou and the Willow Bayou watersheds would be required. In addition tidal control and drainage structures would be required at Willow Bayou, Basford Bayou, and Highland Bayou.

c. Plan C - (Karankawa Bayou Diversion).- The features discussed above on Willow Bayou would also apply to the Karankawa Bayou Diversion route.

d. Plan D - (Basford Bayou Diversion).- The Basford Bayou watershed affords an area that would pond part of the runoff on the Basford-Highland watersheds, which would reduce pumping costs considerably. In addition, the Basford Diversion route would reduce, by one, the number of tidal control and drainage structures necessary for a hurricane flood protection project.

Based on the incomplete data, the topography of the watershed does not appear to be favorable for diversion along a route terminating west of the proposed hurricane flood protection extension; however, there is no question that interior drainage of a hurricane protection enclosure would be greatly simplified if a substantial diversion of this nature for Highland Bayou flows could be effected. Study of this problem will be continued and completed under the hurricane flood protection study. If the hurricane flood protection is found justified and a diversion of this type practicable, appropriate modification of the Highland Bayou project would be recommended in the report on hurricane flood protection, with necessary design changes being effected during preconstruction planning for the Highland Bayou project.

6. Construction costs, methods and schedules.- The average costs of construction prevailing in the area in August 1963 were used in preparing the detailed estimates of first cost for the project.

7. Excavation of the channels would be accomplished by the use of draglines, power shovels, motorized and towed scrapers. Excavated material from most reaches of the two channels would be spoiled along the rights-of-way or used to fill adjoining low areas. In several reaches where development along the banks would prevent deposition of spoil, excavated material would be hauled to offsite disposal easements.

8. A diversion dam would be constructed at Highland Bayou stream mile 8.7 to divert all the runoff from the watershed above that point into the proposed Basford diversion channel. The dam would have a length of 85 feet, crown width of 20 feet, and crown elevation of 15 feet above mean sea level. The side slopes would be one vertical on three horizontal. Materials excavated from the channel would be used in construction of the dam. Erosion control for side slopes and crown of dam would be provided by sprigging and overseeding with bermuda grass.

9. Berms, thirty feet wide, would be provided along the rights-of-way to facilitate the maintenance of the project. Berms and side slopes above water level will be turfed and overseeded for erosion control.

10. Relocations.- A total of 23 pipelines would be lowered below the design channels to prevent obstruction. It would be necessary to lengthen 3 road bridges and 1 railroad bridge to span the new channel widths. A total of 7 new road bridges and 1 new railroad bridge would be constructed. One abandoned wooden service road bridge would be removed.

11. The estimated construction period for the project is twenty-four months.

12. Annual charges.- Estimates of interest and amortization of construction costs included in the annual charges are based on 3.0 percent interest on the investment. Amortization of the investment is computed for a period of 100 years. The annual charges also include the estimated annual costs for operation and maintenance of the proposed improvements. The estimated annual charges for the recommended project are shown in table E.

13. Rights-of-way and spoil easements.- Acquisition of rights-of-way easements on approximately 305 acres of land would be required for channel enlargement and diversion channel. Permanent easements on about 110 acres would be required for berms. In addition, spoil disposal easements would be required for about 249 acres. An additional 171 acres of the submerged beds of both Highland and Basford Bayous would be required and were considered to be State land subject to public improvement not requiring acquisition for rights-of-way. The values for rights-of-way, perpetual easement, and spoil easement acreages used in preparing the estimates of first cost were determined by qualified appraisers.

14. Maintenance and operation.- Maintenance and operation would consist of removing shoals to maintain the channel capacities and maintaining and mowing the grass cover on berms and side slopes. The estimate of annual maintenance of the project is presented in table C.

15. Subsurface investigation.- Seven Shelby tube borings were drilled along the bank of Highland Bayou and one boring along the proposed route of the Basford diversion channel to determine the subsurface conditions. The location and logs of these borings are shown on exhibit 2 of this appendix.

16. The Highland Bayou entrenchment is in the stiff to hard clays and sandy clays of the Beaumont clay formation, which contains occasional pockets of calcareous materials and fragmented shell. In its lower reaches the bayou bed consists of recent clay, sand, and silt deposits which overlie the Beaumont clay. All soils encountered are readily excavated by dragline.

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TABLE A

ESTIMATES OF FIRST COST FOR
PROJECTS INVESTIGATED
(August 1963 prices)

Item	Estimated cost			
	Plan A(1)	Plan B(2)	Plan C (3)	Plan D (4)
<u>Federal first cost</u>				
01.0 Lands and damages	\$ 30,000	\$ 14,000	\$ 14,000	\$ 14,000
02.0 Relocations	71,000	129,000	129,000	123,000
09.0 Channels	3,455,000	4,164,000	3,584,000	2,818,000
30.0 Engineering and design	315,000	387,000	336,000	267,000
31.0 Supervision and administration	329,000	406,000	351,000	278,000
Total Federal first cost	4,200,000	5,100,000	4,414,000	3,500,000
<u>Non-Federal first cost</u>				
Lands and damages	2,100,000	830,000	766,000	623,000
Relocations	480,000	840,000	840,000	747,000
Total non-Federal first cost	2,580,000	1,670,000	1,606,000	1,370,000
Total first cost	6,780,000	6,770,000	6,020,000	4,870,000

- (1) Plan A - Highland Bayou without diversion.
- (2) Plan B - Highland Bayou and diversion through Willow Bayou.
- (3) Plan C - Highland Bayou and diversion through Karankawa Bayou.
- (4) Plan D - Highland Bayou and diversion through Basford Bayou.

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ON
HIGHLAND BAYOU, TEXAS

TABLE B

ESTIMATES OF FIRST COST FOR
IMPROVEMENTS TO AFFORD VARIOUS DEGREES
OF PROTECTION ALONG ROUTE OF PLAN D
(August 1963 prices)

<u>Item</u>	<u>Estimated cost</u>		
	<u>Plan D (1)</u>	<u>Plan D (2)</u>	<u>Plan D (3)</u>
<u>Federal first cost</u>			
01.0 Lands and damages	\$ 14,000	\$ 14,000	\$ 14,000
02.0 Relocations	79,000	107,000	123,000
09.0 Channels	1,837,000	2,240,000	2,818,000
30.0 Engineering and design	173,000	212,000	267,000
31.0 Supervision and administration	181,000	222,000	278,000
Total Federal first cost	<u>2,284,000</u>	<u>2,795,000</u>	<u>3,500,000</u>
<u>Non-Federal first cost</u>			
Lands and damages	398,000	461,000	623,000
Relocations	578,000	674,000	747,000
Total non-Federal first cost	<u>976,000</u>	<u>1,135,000</u>	<u>1,370,000</u>
Total first cost	3,260,000	3,930,000	4,870,000

- (1) Plan D-(1) - Protection from 50-year storm.
- (2) Plan D-(2) - Protection from 100-year storm.
- (3) Plan D-(3) - Protection from Standard Project Flood.

INTERIM REPORT
ON
HIGHLAND BAYOU, TEXAS

TABLE C

ESTIMATES OF INVESTMENTS AND ANNUAL
CHARGES FOR IMPROVEMENTS TO AFFORD VARIOUS
DEGREES OF PROTECTION ALONG ROUTE OF PLAN D
(August 1963 prices)

<u>Item</u>	<u>Plan D (1)</u>	<u>Plan D (2)</u>	<u>Plan D (3)</u>
<u>Federal investment</u>			
Federal first cost	\$2,284,000	\$2,795,000	\$3,500,000
Interest during construction	68,500	83,900	105,000
Total Federal investment	<u>2,352,500</u>	<u>2,878,900</u>	<u>3,605,000</u>
<u>Non-Federal investment</u>			
Non-Federal first cost	976,000	1,135,000	1,370,000
Interest during construction	29,300	34,100	41,100
Total non-Federal investment	<u>1,005,300</u>	<u>1,169,100</u>	<u>1,411,100</u>
<u>Federal annual charges</u>			
Interest on Federal investment	70,500	86,300	108,100
Amortization of Federal investment	3,800	4,700	5,900
Maintenance and operation	None	None	None
Total Federal annual charges	<u>74,300</u>	<u>91,000</u>	<u>114,000</u>
<u>Non-Federal annual charges</u>			
Interest on non-Federal investment	30,100	35,100	42,500
Amortization on non-Federal investment	1,600	1,900	2,500
Maintenance and operation	32,000	35,000	37,000
Total non-Federal annual charges	<u>63,700</u>	<u>72,000</u>	<u>82,000</u>
Total annual charges	138,000	163,000	196,000

- (1) Plan D-(1) - Protection from 50-year storm.
(2) Plan D-(2) - Protection from 100-year storm.
(3) Plan D-(3) - Protection from Standard Project Flood.

INTERIM REPORT
ON
HIGHLAND BAYOU, TEXAS

TABLE D

DETAILED ESTIMATES OF FIRST COST
FOR PLAN OF IMPROVEMENT
(PLAN D)

Item	: Unit : quantity	: Unit : cost	: Quantity	: Cost
1. Federal first cost				
(01.0) <u>Lands and damages</u> - Fed. title review				
(a) Highland Bayou	Tract	\$ 100.00	75	\$ 7,500
(b) Basford diversion	Tract	100.00	45	4,500
Subtotal, lands and damages				12,000
Contingencies, 15%				2,000
Total, lands and damages				14,000
(02.0) <u>Relocations</u>				
(a) Highland Bayou				
(1) Railroad bridge, Mi. 0.75	Bents	1,400.00	10	14,000
(b) Basford diversion				
(1) Railroad bridge, Mi. 7.16	L.F.	400.00	220	88,000
Subtotal, relocations				102,000
Contingencies, 20%				21,000
Total, relocations				123,000
(09.0) <u>Channels</u>				
(a) Highland Bayou				
(1) Clearing and grubbing	Acre	150.00	90	13,500
(2) Excavation				
a. Mi. 0.00 - Mi. 4.75	C.Y.	0.30	1,792,000	537,600
b. Mi. 4.75 - Mi. 7.22	C.Y.	0.55	491,100	270,110
c. Mi. 7.22 - Mi. 8.65	C.Y.	0.45	31,465	14,160
d. Mi. 8.65 - Mi. 11.83	C.Y.	0.35	456,100	159,640
e. Dam, Mi. 8.65	C.Y.	0.60	2,725	1,640
(3) Turfing, side slopes	Acre	350.00	13	4,550
(4) Seeding, berms	Acre	125.00	67	8,380
(b) Basford diversion				
(1) Clearing & grubbing	Acre	150.00	10	1,500
(2) Excavation				
a. Mi. 0.00 - Mi. 5.21	C.Y.	0.30	2,540,000	762,000
b. Mi. 5.21 - Mi. 7.53	C.Y.	0.45	1,250,000	562,500
(3) Turfing, side slopes	Acre	350.00	7	2,560
(4) Seeding, berms	Acre	125.00	44	5,500
Subtotal, channels				2,343,640
Contingencies, 20%				474,360
Total, channels				2,818,000

TABLE D (Cont'd)

Item	: Unit : quantity	: Unit : cost	: Quantity	: Cost
(30.0) <u>Engineering and design</u>				\$ 267,000
(31.0) <u>Supervision and administration</u>				278,000
Total Federal first cost				<u>3,500,000</u>
2. <u>Non-Federal first cost</u>				
<u>Lands and damages</u>				
(a) <u>Highland Bayou</u>				
(1) Rights-of-way	Acre	\$ 400.00	5.9	2,360
	Acre	1,200.00	7.6	9,120
	Acre	1,500.00	40.0	60,000
	Acre	2,500.00	16.0	40,000
	Acre	4,000.00	1.9	7,600
	Acre	3,500.00	3.3	11,550
	Acre	800.00	33.8	27,040
	Acre	1.00	157.5	158
(2) Perpetual easements	Acre	360.00	2.7	972
	Acre	1,080.00	6.1	6,588
	Acre	1,350.00	10.7	14,445
	Acre	2,250.00	7.2	16,200
	Acre	3,600.00	2.4	8,640
	Acre	720.00	22.5	16,200
(3) Spoil disposal easements	Acre	60.00	3.0	180
	Acre	180.00	3.8	684
	Acre	225.00	20.0	4,500
	Acre	375.00	8.0	3,000
	Acre	600.00	1.0	600
	Acre	525.00	1.7	893
	Acre	264.00	79.0	20,900
	Acre	120.00	12.5	1,500
(4) Legal & administrative costs	Tract	500.00	75	37,500
(b) <u>Basford diversion</u>				
(1) Rights-of-way	Acre	250.00	72.2	18,050
	Acre	500.00	67.6	33,800
	Acre	1,500.00	55.2	82,800
	Acre	1.00	13.0	13
(2) Perpetual easements	Acre	225.00	23.2	5,220
	Acre	450.00	19.1	8,595
	Acre	1,350.00	16.9	22,815

TABLE D (Cont'd)

Item	Unit	Unit	Quantity	Cost
	quantity	cost		
(b) Basford diversion (cont'd)				
(3) Spoil disposal easements	Acre	37.50	36.1	\$ 1,354
	Acre	75.00	33.8	2,535
	Acre	225.00	27.6	6,210
	Acre	120.00	22.8	2,736
(4) Legal & administrative costs	Tract	500.00	45	22,500
Subtotal, lands & damages				<u>497,258</u>
Contingencies, 25%				<u>125,742</u>
Total, lands & damages				<u>623,000</u>
<u>Relocations</u>				
(a) Highland Bayou				
(1) Pipeline, 30" C.I., Mi. 1.47	L.F.	20.00	400	8,000
(2) Pipelines, (2) 6" steel, Mi. 2.38	L.F.	4.00	400	1,600
(3) Pipeline, 4" steel, Mi. 2.47	L.F.	3.50	350	1,225
(4) Pipeline, 6" steel, Mi. 2.48	L.F.	3.75	350	1,313
(5) Pipelines, (2) 4" steel, Mi. 2.48	L.F.	4.00	350	1,400
(6) Pipeline, 3" steel, Mi. 2.48	L.F.	3.50	350	1,225
(7) Pipelines, (2) 4" steel, Mi. 2.63	L.F.	4.00	350	1,400
(8) Pipeline, 4" steel, Mi. 2.73	L.F.	3.50	350	1,225
(9) Pipeline, 6" steel, Mi. 2.77	L.F.	3.75	350	1,313
(10) Hwy bridge, Mi. 5.18	L.F.	485.00	100	48,500
(11) Pipeline, 6" steel, Mi. 5.18	L.F.	4.00	100	400
(12) Pipeline, 4" steel, Mi. 5.85	L.F.	3.50	300	1,050
(13) Pipeline, 4" steel, Mi. 6.00	L.F.	3.50	300	1,050
(14) Pipeline, 3" steel, Mi. 6.41	L.F.	3.50	300	1,050
(15) Pipeline, 2" steel, Mi. 6.82	L.F.	3.00	300	900
(16) Hwy bridge, Mi. 7.22	L.F.	485.00	22	10,670
(17) Pipelines, (2) 2" steel, Mi. 7.22	L.F.	3.00	20	60
(18) Pipeline, 6" steel, Mi. 7.55	L.F.	4.00	20	80
(19) Pipeline, 3½" steel, Mi. 7.92	L.F.	3.75	200	750
(20) Pipeline, 8" steel, Mi. 8.56	L.F.	6.00	200	1,200
(21) Hwy bridge, Mi. 9.42	L.F.	400.00	40	16,000
(22) Service road bridge, Mi. 9.02	L.F.	180.00	130	23,400
(23) Pipeline, 8" steel, Mi. 9.02	L.F.	6.00	200	1,200
(24) Service road bridge, Mi. 10.46	L.F.	180.00	110	19,800
(25) Service road bridge (remove), Mi. 11.52	L.S.	-	-	200

TABLE D (Cont'd)

Item	: Unit : quantity	: Unit : cost	: Quantity	: Cost
(b) Basford diversion				
(1) Street bridge, Mi. 5.21	L.F.	400.00	220	\$ 88,000
(2) Street bridge, Mi. 5.69	L.F.	400.00	220	88,000
(3) Street bridge, Mi. 6.07	L.F.	400.00	210	84,000
(4) Hwy bridge, Mi. 6.84	L.F.	485.00	210	101,850
(5) Hwy bridge, Mi. 7.19	L.F.	485.00	220	106,700
(6) Administrative costs	L.S.	-	-	10,000
Subtotal, relocations				<u>623,561</u>
Contingencies, 20%				<u>123,439</u>
Total, relocations				<u>747,000</u>
<u>Total non-Federal first cost</u>				1,370,000
3. <u>Total first cost</u>				4,870,000

TABLE E

ESTIMATES OF INVESTMENTS AND ANNUAL CHARGES

PLAN D

(PLAN OF IMPROVEMENT)

(Construction period - 24 months)
 (Interest rates - 3.0%)
 (Amortization period: 100 years)

<u>Federal investment</u>	
Federal first cost	\$ 3,500,000
Interest during construction	105,000
Total Federal investment	<u>3,605,000</u>
<u>Non-Federal investment</u>	
Non-Federal first cost	1,370,000
Interest during construction	41,100
Total non-Federal investment	<u>1,411,100</u>
<u>Federal annual charges</u>	
Interest on Federal investment	108,100
Amortization of Federal investment	5,900
Maintenance and operation	None
Total Federal annual charges	<u>114,000</u>
<u>Non-Federal annual charges</u>	
Interest on non-Federal investment	42,500
Amortization on non-Federal investment	2,500
Maintenance and operation	37,000
Total non-Federal annual charges	<u>82,000</u>
<u>Total annual charges</u>	196,000

Note: Prices are as of August 1963.

TABLE F
PERTINENT DATA
PLAN D
(PLAN OF IMPROVEMENT)

<u>Location</u>	
Stream	Highland Bayou
Channel-mile limits	0.0 to 11.8
Stream	Basford Bayou
Channel-mile limits	0.0 to 7.5

<u>Design data (Standard Project Flood)</u>	
Maximum 24-hour storm rainfall, inches	21.3
Peak discharge at mouth of Highland Bayou, cubic ft. per sec.	10,700
Peak discharge at mouth of Basford Bayou, cubic ft. per sec.	12,400

<u>Channel improvement</u>	
Length of Highland Bayou before improvement, miles	14.4
Length of Highland Bayou for proposed channel improvement, miles	11.8
Length of Basford Bayou before improvement, miles	5.4
Length of Basford Bayou with proposed diversion channel	7.5
Channel enlargement and realinement for Highland Bayou:	

<u>Mileage limits</u>	<u>Channel excavation cubic yards</u>	<u>Bottom widths natural earth channel</u>	<u>Side slopes</u>
0.00 - 4.75	1,792,000	240' - 150'	1:3
4.75 - 7.22	491,000	150' - 50'	1:2.5 to 1:3
7.22 - 8.65(1)	31,500	50' - 10'	1:2.5 to 1:3
8.65 - 11.83	456,000	90' - 45'	1:2.5 to 1:3
	<u>2,770,500</u>		

Channel enlargement and realinement for Basford Bayou diversion channel:

<u>Mileage limits</u>	<u>Channel excavation cubic yards</u>	<u>Bottom widths natural earth channel</u>	<u>Side slopes</u>
0.00 - 5.21	2,540,000	140' - 130'	1:3
5.21 - 7.53	1,250,000	130' - 90'	1:2.5 to 1:3
	<u>3,790,000</u>		

(1) Data for diversion dam at mile 8.65 on next page.

TABLE F (Cont'd)

Channel diversion dam at mile 8.65 on Highland Bayou:

<u>Length</u>	<u>Crown width</u>	<u>Crown elevation</u>	<u>Side slopes</u>
85 ft.	20 ft.	15 ft. (msl)	1:3

Location of bridges

<u>Highland Bayou bridges</u>	<u>Miles above mouth</u>	<u>Necessary alterations</u>
G.C. & S.F. Railroad	0.75	Extend 10 bents
State Highway 6 (Proposed)	1.44	None
State Highway 6	1.45	None
Texas City Junction R.R.	2.44	None
Vauthier Road	5.18	Extend 100 feet
F.M. 519 Road	6.84	None
John Palmer Road	7.22	Extend 20 feet
F.M. 2004 Road	7.89	None
Camp Wallace Road	9.42	Extend 40 feet
Service road culvert	9.02	Remove culvert; construct new bridge
Service road culvert	10.46	Remove culvert; construct new bridge
Wooden bridge	11.52	Remove abandoned bridge

Basford diversion bridges

Second St. South	5.21	New
Center St.	5.69	New
Shiro Road	6.07	New
Tacquard Road	6.84	New
G.C. & S.F. Railroad	7.16	New
State Highway 6	7.19	New

Utility crossings

<u>Highland Bayou</u>	<u>Miles above mouth</u>	<u>Type of crossing</u>	<u>Necessary alterations</u>
Waterline, 30"	1.47	Underground	Lower
Pipelines, (2) 6"	2.38	Underground	Lower
Oil line, 4"	2.45	Underground	Lower
Pipeline, 6"	2.48	Underground	Lower
Pipelines, (2) 4"	2.48	Underground	Lower
Pipeline, 3"	2.48	Underground	Lower
Pipelines, (2) 4"	2.63	Underground	Lower
Gas line, 4"	2.73	Underground	Lower
Oil line, 6"	2.77	Underground	Lower
Gas line, (on bridge) 6"	5.18	Aerial	Extend 125'

TABLE F (Cont'd)

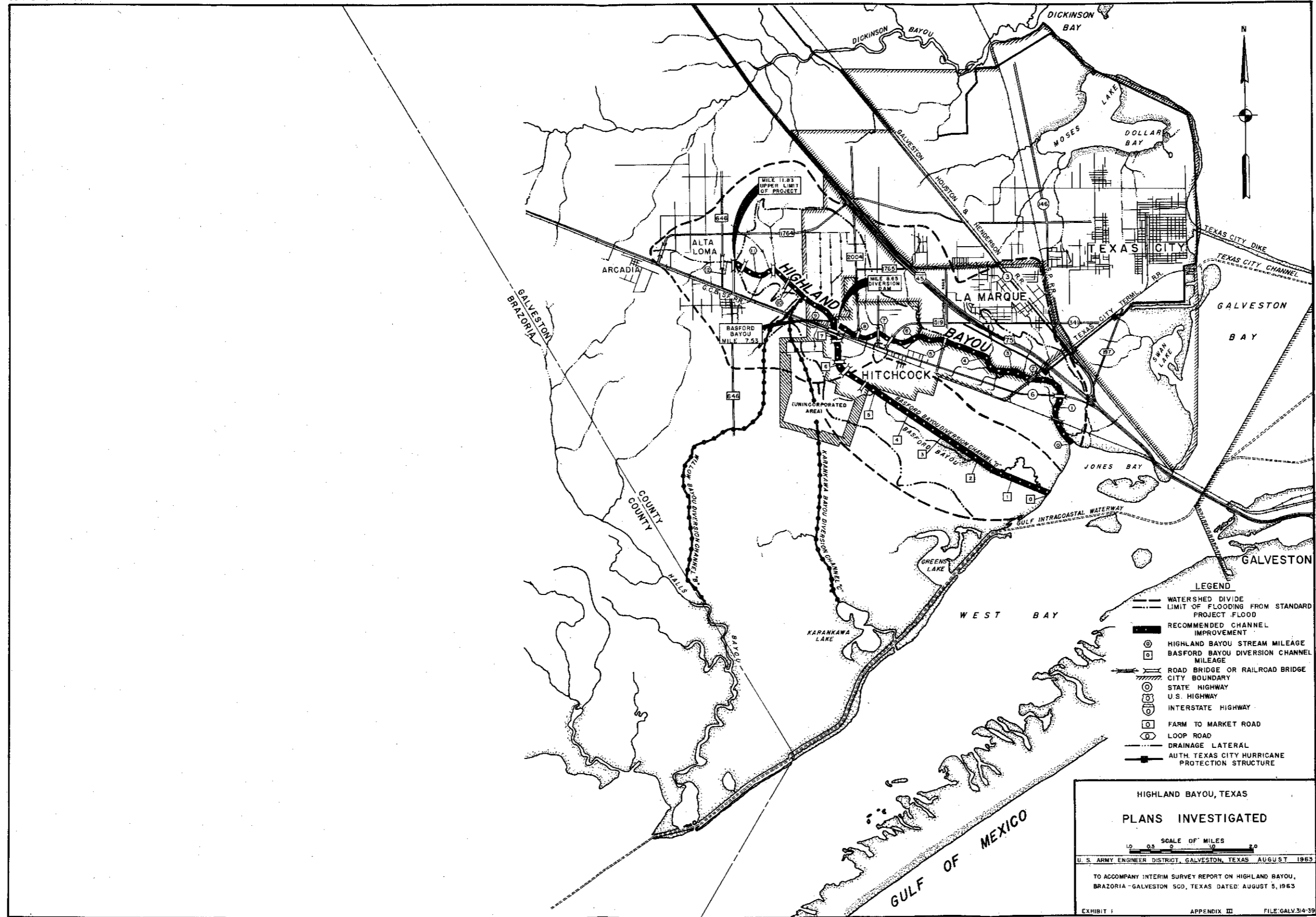
Utility crossings (cont'd)

<u>Highland Bayou</u>	<u>Miles above mouth</u>	<u>Type of crossing</u>	<u>Necessary alterations</u>
Gas line, 4"	5.85	Underground	Lower
Gas line, 4"	6.00	Underground	Lower
Oil line, 3"	6.41	Underground	Lower
Gas line, 2"	6.82	Underground	Lower
Waterline, (on bridge) 6"	6.84	Aerial	None
Pipelines (on bridge), (2), 2"	7.22	Aerial	Extend 20'
Gas line, 6"	7.55	Underground	Lower
Pipeline, 10"	7.68	Aerial	None
Pipeline, 16"	7.68	Aerial	None
Sewer lines (on bridge)(2), 6"	7.89	Aerial	None
Gas line, 3-1/2"	7.92	Underground	Lower
Waterline, 8"	8.56	Underground	Lower
Salt waterline, 8"	9.02	Aerial	Lower

Rights-of-way

	<u>Highland Bayou (acres)</u>	<u>Basford Bayou diversion channel (acres)</u>	<u>Total for both watersheds (acres)</u>
Rights-of-way (for excavated channel)	110(2)	195	305
Perpetual easements (work areas)	51	59	110
Spoil disposal easements (for excavated material)	129	120	249

(2) Additional 171 acres submerged by bayou water considered State land subject to public improvement.



47-541 O-65 (Face blank p. 110)

INTERIM SURVEY REPORT

ON

HIGHLAND BAYOU, TEXAS

APPENDIX IV

COMMENTS BY OTHER AGENCIES

INTERIM SURVEY REPORT
ON
HIGHLAND BAYOU, TEXAS

APPENDIX IV

COMMENTS BY OTHER AGENCIES

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INTERIM SURVEY REPORT
ON
HIGHLAND BAYOU, TEXAS

APPENDIX IV

COMMENTS BY OTHER AGENCIES

INTRODUCTION

In accordance with the Interagency Agreement on Coordination of Water and Related Land Resources Activities approved by the President on May 26, 1954, draft copies of the Main Report and appendixes were sent to other Federal agencies at field level for review. Letters from these agencies containing their comments and replies where appropriate are presented in this appendix.



UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE

P. O. BOX 1306
ALBUQUERQUE, NEW MEXICO

May 17, 1963

District Engineer
Corps of Engineers, U. S. Army
Post Office Box 1229
Galveston, Texas

Dear Sir:

This letter constitutes the Bureau of Sport Fisheries and Wildlife report on the effects of proposed development relative to the Brazoria-Galveston Soil Conservation District, Highland Bayou, Project, Texas, on fish and wildlife resources. This report has been prepared under the authority and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). It has been coordinated with the Bureau of Commercial Fisheries and has received the concurrence of the Texas Game and Fish Commission by letter dated May 6, 1963, signed by Mr. Eugene A. Walker, Director of Program Planning, a copy of which is enclosed.

The purposes of the project are to provide drainage and flood protection in the vicinity of Alta Loma, Camp Wallace, La Marque, and Hitchcock, Texas.

It is our understanding that the proposed developments will include channel improvements of Highland Bayou; construction of a diversion dam on Highland Bayou at stream mile 8.6, about 1.2 miles northwest of Hitchcock, Texas; and construction of a diversion channel from the diversion dam south and east to Jones Bay, crossing Basford Bayou about midway above its mouth.

Drainage upstream from the diversion dam will be routed to Jones Bay by way of Basford Bayou. Drainage downstream from the diversion dam will flow down Highland Bayou to Jones Bay.

Channel improvements for the proposed project are listed in Table 1.

EXHIBIT 1
APPENDIX IV

Table 1. Channel improvements in Highland and Basford Bayous

<u>Reach</u>		<u>Bottom</u>	<u>Bank</u>	
<u>From</u> <u>Mile</u>	<u>To</u> <u>Mile</u>	<u>Width</u> <u>(feet)</u>	<u>Average Elevation</u> <u>at Top of Bank</u> <u>(ft. m.s.l.)</u>	
<u>Highland Bayou</u>				
0	3	240	-10.0	
3	4	200-240	-10.0	
4	5	120-200	-10.0 to -9.5	
5	6	90-120	-9.5 to -9.0	
6	7	50-90	-9.0 to -6.5	
7	8.6	10-50	-6.5 to -0.5	
<u>Highland Bayou above Diversion Dam</u>				
8.6	10	70-90	-3.5 to +0.5	
10	11	50-70	+0.5 to +5.5	
11	11.8	45-50	+5.5 to +12.0	
<u>Basford Bayou</u>				
0	4	142	-10.0 to -8.5	
4	5	130-142	-8.5 to -7.5	
5	6	110-130	-7.5 to -5.5	
6	7.5	90-110	-5.5 to -3.5	

Several reaches of Highland Bayou will be rectified. The cutoff portions of the bayou will be kept open to the newly constructed channel. All spoil removed from channel improvements and construction will be placed on land.

The project will influence to a minor degree the fish and wildlife resources associated with the watersheds of Highland and Basford Bayous. It will not affect the estuarine habitat in Jones or West Bays.

The Highland Bayou Project area lies in the Coastal Prairie Region of Texas, where elevations range from sea level to about 30 feet. Rice is the most important crop, with vegetables and fruit as lesser crops. Dairying and cattle ranching are important to the economy of the area but industries are increasing rapidly and influencing the economy.

Highland Bayou is about 14 miles long and drains into Jones Bay of the West Bay system. Its upper reach is intermittent but the lower 9 miles are tidal. The stream receives return flows from irrigated ricefields along much of its length. Much of the watershed, primarily along State Highway No. 6 and along the Bayou, has undergone rapid residential development in the past few years. Industries have been established in the watershed and nearby areas. Marinas have been constructed in the lower portion of Highland Bayou. These types of development are expected to expand for many years to come.

Basford Bayou is a shorter stream than Highland Bayou. It also drains into Jones Bay. Its upper reach is dry, except when it carries runoff from irrigated ricefields and rains. Its lower reach is tidal. Some residences and industries have been developed in this watershed, and more are anticipated in the near future. A marina is proposed in the lower reach of the Bayou.

Freshwater fish habitat is of minor importance in both Highland and Basford Bayous, but the tidal reaches have moderate quality fish habitat. Moderate amounts of sport fishing occur in the lower reach of Highland Bayou, but lack of access points precludes much sport fishing in Basford Bayou.

Improvement of the channel in Highland Bayou and diversion of its flows to the newly constructed Basford Bayou channel will not affect significantly the fish habitat in the project area.

Wildlife in the project area includes bobwhites, mourning doves, cottontails, fox squirrels, gray squirrels, muskrats, minks, raccoons, opossums, snipes, woodcocks, clapper rails, coots, ducks, and geese.

Upland-game habitat throughout the project area is of low quality due to heavy pasturing and to a shortage of brush areas. Upland-game hunting and fur trapping are insignificant. The marshes of the project area are of low quality and receive only light use by waterfowl. Waterfowl hunting is of minor importance.

The proposed plan of development will have insignificant effects on wildlife habitat and hunting in the project area.

The project will provide no benefits to fish and wildlife. Neither will it provide means for enhancing these resources.

This report has been prepared on the basis of data made available by the Corps of Engineers through February 21, 1963. Any modifications of the project plan should be brought to the attention of the Texas Game and Fish Commission and the Bureau of Sport Fisheries and Wildlife.

We appreciate the opportunity extended to us to comment on this proposed project development.

Sincerely yours,



Carey H. Bennett
Acting Regional Director

Enclosure

Copies (10)

Distribution:

- (4) Executive Secretary, Texas Game and Fish Commission, Austin, Texas
- (2) Regional Director, Bureau of Commercial Fisheries, Region 2,
St. Petersburg Beach, Florida
- (2) Director, Biological Laboratory, Bureau of Commercial Fisheries,
Galveston, Texas
- (2) Regional Director, Bureau of Mines, Region 4,
Bartlesville, Oklahoma
- (1) Regional Coordinator, Southwest Field Committee, U. S. Department
of the Interior, Muskogee, Oklahoma
- (2) Field Supervisor, Branch of River Basin Studies, Bureau of Sport
Fisheries and Wildlife, Fort Worth, Texas

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AUSTIN



W. J. CUTBIRTH, JR.
ASST. EXECUTIVE SECY.
AUSTIN

H. A. WALSH
EL PASO

AUSTIN, TEXAS

May 6, 1963

Mr. Carey H. Bennett, Chief
Division of Technical Services
Bureau of Sport Fisheries and Wildlife
P. O. Box 1306
Albuquerque, New Mexico

Dear Mr. Bennett:

In answer to your letter of May 1, 1963, with copies of a draft of your report concerning the proposed developments relating to the Brazoria-Galveston Soil Conservation District, Highland Bayou, Texas, this is to extend our concurrence with the report as presented.

Sincerely yours,

Eugene A. Walker
Eugene A. Walker, Director
Program Planning

em

Copy to Mr. John Degani, RBS

EXHIBIT 2
APPENDIX IV

COUNTY COMMISSIONERS COURT

PETER J. LA VALLE
COUNTY JUDGE
IRWIN P. DANTIN
1ST PRECINCT
JIMMIE VACEK
SECOND PRECINCT
PAUL HOPKINS
THIRD PRECINCT
JACK LAWRENCE
FOURTH PRECINCT
JOHN R. PLATTE
COUNTY CLERK



THE COUNTY OF GALVESTON

GALVESTON, TEXAS

COUNTY OFFICIALS

H. H. TREACCAR
DISTRICT CLERK
JULES DAMIANI, JR.
CRIMINAL DISTRICT ATTORNEY
KENNETH MCKINNEY, ASSESSOR
AND COLLECTOR OF TAXES
HUDSON J. CARO, SR.
COUNTY AUDITOR
TROY O. JOHN
COUNTY TREASURER
HERBERT E. SCHMIDT
COUNTY ENGINEER
J. B. KLINE, SHERIFF
PAUL A. MILLIGAN
COUNTY SURVEYOR
HUGH GIBSON, JR., JUDGE
JUVENILE & COUNTY NO. 2

July 16, 1963

Colonel James S. Maxwell
District Engineer
U. S. Army Engineer District, Galveston
P. O. Box 1229
Galveston, Texas

Re: Highland Bayou Flood Control Project

Dear Colonel Maxwell:

The advance copy of your interim report on Highland Bayou, Texas, which was delivered to the Galveston County Commissioners during a conference on July 11, 1963, is returned herewith. It is requested ten copies of the final report be reserved for Galveston County Commissioners Court.

The Galveston County Commissioners Court will act for local interests in all matters pertaining to the proposed Highland Bayou flood-control project. If the proposed project is subsequently authorized by Congress for construction, the Commissioners Court will undertake all reasonable efforts, within the limits of its legal and financial capability, to insure that the required items of local cooperation are provided.

Sincerely yours,

PETER J. LA VALLE
County Judge
Galveston County, Texas

PJL:mh

CC: The Hon. Paul Hopkins
County Commissioner, Precinct #3
Virgil Schultz, County Engineer

EXHIBIT 3
APPENDIX IV

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE
REGIONAL OFFICE
1114 Commerce Street
Dallas 2, Texas

PUBLIC HEALTH SERVICE

July 18, 1963

Your reference:
SWNGW-2c

District Engineer
U. S. Army Engineer District, Galveston
Corps of Engineers
606 Santa Fe Building
Galveston, Texas

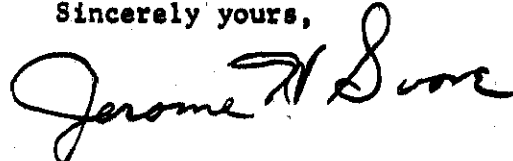
Attention: Mr. Kenneth Heagy, Chief
Engineering Division

Dear Sir:

We have reviewed the Interim Report on Highland Bayou, Texas. Prevention of flooding in the vicinity of Hitchcock and La Marque, Texas, will create a better environment for good public health.

We are returning the report in accordance with your request. The opportunity to review this report is appreciated.

Sincerely yours,



JEROME H. SVORE
Regional Program Director
Water Supply & Pollution Control

Enclosure

EXHIBIT 4
APPENDIX IV

UNITED STATES DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE

P. O. Box 648

Temple, Texas 76502

July 29, 1963

Colonel James S. Maxwell
District Engineer
U. S. Corps of Engineers
606 Santa Fe Building
P. O. Box 1229
Galveston, Texas

Dear Colonel Maxwell:

Thank you for the opportunity to review a draft of the "Interim Survey Report on Highland Bayou, Texas".

The report contains the results of investigations of existing flood problems along Highland Bayou, which flows through La Marque and Hitchcock, Texas. Average annual damages from flooding of Highland Bayou are estimated to be \$313,000 under existing conditions.

This proposed plan of improvement would consist of enlargement and rectification of the natural channel of Highland Bayou and diversion of flows from the upper part of the watershed through a diversion channel following generally along Basford Bayou to Jones Bay. The estimated first cost to the Federal Government for the recommended works of improvement is estimated to be \$3,500,000. The report shows the proposed improvements would be justified with a benefit-cost ratio of 3.6:1.0.

Highland Bayou watershed consists of about 38 square miles (24,320 acres) and is located entirely within Galveston County. The flood plain includes approximately 20,000 acres, of which residential and commercial developments occupy about 2,000 acres. Population increases projected for the next 100 years would require about 8,000 additional acres. It was pointed out that about 8,000 acres lie below 7 feet elevation and are subject to threat of floods from hurricane tides at relatively frequent intervals and probably would remain undeveloped unless the threat were removed. The report states that flood control improvements on Highland Bayou would have little or no effect on development of this land.

On page 16 the report states "Both the existing and projected development in the Highland Bayou flood plain is fully urban in character and represents a high type of residential and commercial development". From information reviewed in the report, we were unable to determine land use in the watershed outside the delineated flood plain.

Drainage investigations by technicians of this Service in cooperation with personnel of your staff were completed for the U. S. Study Commission - Texas.

EXHIBIT 5
APPENDIX IV

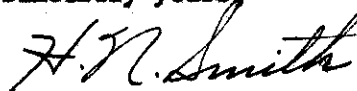
Field data indicated that drainage problems exist in a large portion of the Highland Bayou watershed. Major outlets were found to be inadequate in some of the area needing drainage. The works of improvement proposed in the report should alleviate the drainage problems to some extent by providing major outlets.

The Soil Conservation Service has no existing or planned projects which would be adversely affected by the proposed Highland Bayou project. In view of the composition of the project area, this Service has no suggestions for changes in the report. Technicians reviewing the draft found it to be complete, well prepared and easily read.

The advance copy of the interim report on Highland Bayou, Texas, is returned, as requested.

If we can assist you in any way, please let me know.

Sincerely yours,

A handwritten signature in cursive script that reads "H. N. Smith".

H. N. Smith
State Conservationist

Enclosure (1)



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
Area IV

ROOM 206 FEDERAL BUILDING
BARTLESVILLE, OKLAHOMA

OFFICE OF
Area Director

August 30, 1963

Mr. T. V. Elam, Acting Chief
Engineering Division
Corps of Engineers
U.S. Army Engineer District, Galveston
P. O. Box 1229
Galveston, Texas

Your Reference No: SWNGW-2c

Dear Mr. Elam:

Thank you for sending us an advance copy of the interim report on Highland Bayou, Texas, for field level review. We apologize for our delay in reviewing the report.

Your proposed plan consists of improvement of the channel of Highland Bayou, construction of a diversion dam and a diversion channel following generally along Basford Bayou to Jones Bay. The ratio of average annual benefits to average annual costs is 3.6 to 1.0.

A review of available office data indicates that the proposed construction would have no adverse effect on mineral resources in the area; therefore, the Area Office of the Bureau of Mines has no objection to the proposed construction. No field examination was made.

Sincerely yours,

Robert S. Sanford
Acting Area Director
Area IV

EXHIBIT 6
APPENDIX IV

INTERIM SURVEY REPORT
ON
HIGHLAND BAYOU, TEXAS

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. Requests by local interests.- At a public hearing held in Hitchcock, Texas, on November 21, 1961, Galveston County Commissioners' Court requested the construction of local flood protection improvements that would protect the Hitchcock-La Marque area against flooding from Highland Bayou.
3. Improvements considered.- The flood protection improvements requested by local interests were found, with certain modifications, to afford the most feasible means of providing local flood protection to the areas along Highland Bayou. The principal modification provides for diversion of runoff from the upper reaches of the Highland Bayou watershed through a diversion channel extending generally along Basford Bayou to Jones Bay rather than along Karankawa Bayou to Karankawa Bay, as requested by the local interests. Cost analysis for all plans investigated were made on a basis of a 100-year project life.
4. The improvements proposed under the recommended plan of improvement have been discussed with the local interests that would provide the cooperation required for the improvements if and when adopted. They have expressed satisfaction with the recommended plan of improvement.