TRINITY RIVER AND TRIBUTARIES, TEXAS

LETTER

FROM

THE SECRETARY OF THE ARMY

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY, DATED NOVEMBER 29, 1963, SUBMITTING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, ON A REVIEW OF THE REPORTS ON, AND A SURVEY OF THE TRINITY RIVER AND TRIBUTARIES, TEXAS, MADE PURSUANT TO SEVERAL CONGRESSIONAL AUTHORIZATIONS LISTED IN THE REPORT

IN FIVE VOLUMES

VOLUME II

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VOLUME INDEX

COMPREHENSIVE SURVEY REPORT

ON

TRINITY RIVER AND TRIBUTARIES, TEXAS

U. S. ARMY ENGINEER DISTRICTS
FORT WORTH AND GALVESTON
CORPS OF ENGINEERS
FORT WORTH AND GALVESTON, TEXAS

JUNE 1962

COMPREHENSIVE SURVEY REPORT
ON
TRINITY RIVER AND TRIBUTARIES, TEXAS

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PROJECT FORMULATION

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ON
TRINITY RIVER AND TRIBUTARIES, TEXAS

APPENDIX I - PROJECT FORMULATION

GENERAL

1. PURPOSE AND SCOPE.- This appendix is concerned with formulation processes used in connection with projects investigated and recommended as desirable adjuncts to the existing, under construction, and authorized projects in the Trinity River Basin. It also presents data on allocation of costs to project purposes and to Federal and non-Federal interests.

2. The first part of the project formulation presented herein covers the broad aspects and concepts used, some of the more significant criterion and design, and legal constraints specifically applicable to the Trinity River Basin. This general presentation is followed by the methodology and rationale used as a basis for conclusions as to the best solution to the individual water resources problems and needs such as flood control, water supply, water quality control, waterway extensions, and recreation and fish and wildlife. Finally, detailed information is presented relative to individual elements of the recommended plan. The addition of investigated water resources projects to the existing Trinity River Plan created infinite systems of units, levels of accomplishment, and sizes of projects. The basic objective of the subject study has been to select the best combination of variables that is compatible with comprehensive basin planning. Conventional design and formulation techniques have been used to evolve the obtainable combination of additions and modifications to the existing and authorized system of projects in the Trinity River Basin. Stated briefly, tentative additions to the existing system were developed to solve existing and foreseeable water resources problems, demands of the area and then modifications thereof were tested by additions or deletions of meaningful increments as to their benefits, cost, and accomplishment of economic, hydrologic and design objectives.

3. RELATIONSHIP TO OTHER APPENDIXES.- Most of the physical information and data presented in this appendix consist of summations and integration of data and information taken from other appendixes of this report. The information contained herein on the supplies of water to be expected in the Trinity River Basin and the existing and future requirements for municipal and industrial, quality control, water transportation, agricultural and similar uses was obtained from the comprehensive presentation thereon as given in Appendix II on Hydrology, Hydraulic Design and Water Resources. Information on the frequency and magnitude of floods in the basin and presentation of the operational

problems of existing reservoirs was secured on the basis of detailed information contained in Appendix II. Hydrologic objectives relative to reservoir storages and operation requirements for various reservoir project purposes and design criteria for sizing of channels and levee projects have been summarized from data contained in Appendix II. Most of the basic design data of tentative plans considered in these studies were based on hydrologic data presented in Appendix II. Information used herein on the extent of flooding, flood damages, and flood benefits accruing to various schemes of development, was obtained from information presented in Appendix IV on Flood Control Economics or from supporting data developed in connection with the preparation of that appendix. Water supply benefits used herein are based on information contained in a report prepared by the Department of Health, Education and Welfare, Public Health Service, which is included as Exhibit 1 to Appendix II. The demand for recreational and fish and wildlife opportunities and the benefits therefor were summarized from information presented in Appendix V on General Recreation and Fish and Wildlife. The prospective waterway commerce and savings in transportation costs used herein were obtained from Appendix III on Navigation and Navigation Economics and from supporting data connected with that appendix. Costs and annual charges for various projects were summarized from data and supporting information used in connection with Appendix VI on Cost Estimates, Geology, and Design Information.

4. FORMULATION CONCEPTS.- The ultimate aim of the plan for the Trinity River Basin, in common with all other productive activities, is to satisfy human needs and desires. The broad principles and objectives followed in the formulation of the projects recommended herein are (a) that the goods or services to be produced by the recommended projects have value only to the extent that there will be a need and demand for the product, (b) that the overall plan considered the expanding needs and well-being of all the people and provided for a balanced program with the least investment in water and related land resources and funds, (c) that the scale of development is such as to provide, where practicable, the maximum excess benefits over cost, and (d) that the program of development be so devised as to permit ultimate development of the full natural resources of the basin when and if the need arises beyond the economic time basis used in this study. The first of these principles and objectives required the appraisal of the existing and future water resources needs and problems of the basin and established a planning criteria for selection of projects which are capable of meeting the residual needs and the solutions of multiple water resources problems in a timely manner. The second principle required the selection of the most favorable projects for a balanced plan after full consideration of all alternatives. Inherent in this principle was the goal to insure maximum flexibility and adaptability of projects recommended for possible other uses should actual conditions develop in the future that would not be consistent with the imperfect techniques now available to project conditions that are expected to

prevail in the next 50 years or so. The third principle required the determination of costs and benefits of individual projects of various dimensions, sizes, and allocations of cost to the various project purposes in order to determine the limits, where practicable, of the optimum development.

5. BASIC CONSIDERATIONS APPLICABLE TO THE TRINITY RIVER BASIN.- Within the framework of the above recorded formulation concepts there were certain physical, legal, and design objectives that were adopted as goals or constraints to consider in the formulation process that lead to the selection of projects recommended herein. No single principle, objective, criteria or constraint is the sole determinant of projects to be included or excluded as desireable adjuncts to the Trinity River Plan. All these concepts, goals, and objectives were used in the rationale for selection of the projects recommended. The projects recommended have very favorable benefit cost ratios and otherwise promote economic efficiency in water resources development even though it was not practicable in each economic test to provide maximum excess benefits over cost. The more important physical, legal and design objectives and constraints are presented below by project purposes.

6. Flood control.-

a. Protection of urban areas against standard project floods would be provided if economically feasible.

b. The objective for flood protection to rural areas was to provide protection against a recurrence of a 50-year flood to the extent practicable within reasonable economic efficiency.

c. A period of 30 to 40 days was considered desirable for evacuation of flood control storage in existing and proposed reservoir projects to provide efficient operation.

d. Full cognizance was given to the long range waterflow retardation and land conservation programs of the Soil Conservation Service as such programs related to hydrologic and economic aspects of the affected projects recommended in this report.

e. The beneficial effects that will result from flood plain information studies authorized by Public Law 86-645, July 1960, were taken into account. Recognition was also given the beneficial effects of existing and proposed flood warning and flood forecasting programs of the United States Weather Bureau.

7. Supplies for water.-

a. Reservoir capacities for supplies of water were developed in consonance with the State of Texas' expressed policy of maximum practical development of the water resources of the individual basins.

b. Demands for supplies of water in the Trinity River Basin were met with supplies from within the basin, including ground water.

c. The planning for the supply of water was in full agreement with existing water rights (Permit 1970) and priorities of use established by the State of Texas.

d. Planning for suppies of water has been fully coordinated with the plans of municipalities, Trinity River Authority and the Texas Water Commission.

e. Supplies of water were developed to be of suitable quality to meet standards of purity of the United States Public Health Service.

f. The estimates of water storage yield in projects considered for this report took into account the effect the existing and proposed program of the Soil Conservation Service would have during the critical dry period.

8. Navigation.-

a. Waterway channel dimensions and alignment in the Trinity River Basin were made to be compatible with the inter-connected inland waterways system of the United States and to accommodate efficiently the barge carrier equipment expected to use the waterway.

b. The waterway was so located in the basin to afford water transportation to shippers and receivers of prospective commerce. On the Trinity River this dictated extension of the existing navigation channel to prospective users in the Dallas-Fort Worth complex. In so doing, the channel would provide low cost water transportation to the middle basin, thereby enhancing the possibilities of making it economically possible to accelerate development of natural resources in the area and the commercial and industrial establishments associated with such activities.

c. Transit of pleasure craft on the waterway was considered to be feasible and practical as a concurrent movement with commercial tows.

9. Recreation and fish and wildlife.-

a. In planning for water resources development in the basin, facilities for recreation and fish and wildlife were provided to the maximum practicable extent for satisfying expected visitor demands. A framework plan was developed for the useful life of the projects recommended.

b. The proposals of the Fish and Wildlife Service and the Texas Game and Fish Commission for preservation and enhancement of fish and wildlife resources of the basin were incorporated in the planning where feasible. This includes recognition of the potential of a wildlife refuge on Tennessee Colony Reservoir and releases of fresh water to Galveston Bay when available.

10. COMPREHENSIVE PLAN.- Many improvements for developing water resources in the basin have been constructed in past years by both Federal and non-Federal interests. The first major water supply reservoir in the Trinity River Basin was constructed in Dallas on White Rock Creek in 1911. The first levee improvement district for protection of rural property was organized in 1909.

11. The comprehensive plan developed for the Trinity River Basin includes the existing, under-construction and authorized water improvement facilities within the basin; a number of improvements which have been recommended in separate reports but have not as yet been authorized; and the additional improvements required to bring the overall system into balance and satisfy the present and future water and related land resources development needs to the maximum practicable extent. The proposed additional improvements are separated into categories of those proposed for immediate authorization and construction and those improvements proposed for inclusion in the long-range plan but not recommended to be authorized for construction at this time. Pertinent data on projects that constitute the comprehensive plan are summarized in table 1, followed by plate 1 which shows the location of these projects in the basin.

TABLE 1

COMPREHENSIVE PLAN - RESERVOIRS

Name	Owner	Location Stream	Mile	Total drainage area above (sq mi)	Total storage capacity (acre-feet)	Dependable yield in year 2020 MGD(1)	Purpose(2)
EXISTING, UNDER CONSTRUCTION AND AUTHORIZED							
FEDERAL RESERVOIRS							
Benbrook	Corps of Engineers	Clear Fork	15.0	433	258,600	6.5	FC-Con-Nav-R-F&W
Grapevine	Corps of Engineers	Denton Creek	11.7	694	435,500	18.1	FC-Con-Nav-R-F&W
Garza-Little Elm	Corps of Engineers	Elm Fork	30.0	1,658	1,002,900	86.0	FC-Con-R-F&W
Lavon	Corps of Engineers	East Fork	55.9	777	423,400	35.5	FC-Con-R-F&W
Navarro Mills(3)	Corps of Engineers	Richland Creek	63.9	316	212,200	18.1	FC-Con-R-F&W
Bardwell(3)	Corps of Engineers	Waxahachie Creek	6.0	171	117,800	4.2	FC-Con-R-F&W
1,200 Small detention res(4)	Soil Conservation Serv.	(Headwater & tributary areas throughout basin)		3,679(4)	1,301,966(4)	0	FC
NON-FEDERAL RESERVOIRS(5)							
Amon Carter	City of Bowie	Big Sandy Creek	31.0	103	19,900	0	Con
Bridgeport	Tarrant Co. WC&ID #1	West Fork	626.2	1,114	270,900	50.4	Con
Eagle Mountain	Tarrant Co. WC&ID #1	West Fork	583.3	1,974	182,600	17.5	Con
Lake Worth	City of Fort Worth	West Fork	572.1	2,069	33,700		Con
Marine Creek	Tarrant Co. WC&ID #1	Marine Creek	4.7	10	15,400	0	FC-Con
Weatherford	City of Weatherford	Clear Fork	39.8	106	19,400	0.6	Con
Arlington	City of Arlington	Village Creek	8.0	136	45,700	5.8	Con
Mountain Creek	Dallas P&L Co.	Mountain Creek	4.1	289	24,200	0	Con
North Lake	Dallas P&L Co.	So. Fork - Grapevine Cr.	0.5	2.3	17,100	0	Con
White Rock	City of Dallas	White Rock Creek	12.0	99	12,300	1.9	Con
Forney(3)	City of Dallas	East Fork	31.8	1,074	490,000	58.8	Con
Tawakoni (Iron Bridge)(6)	Sabine River Authority	Sabine River	-	-	-	174.0	Con
Terrell	City of Terrell	Muddy Cedar Creek	9.8	13	8,300	0.6	Con
Trinidad	Texas P&L Co.	(7)	-	-	6,200	0	Con
Cedar Creek(3)	Tarrant Co. WC&ID #1	Cedar Creek	11.1	1,013	678,900	173.2	Con
Waxahachie	Ellis Co. WID #1	So. Prong - Waxahachie Cr.	0.5	31	13,500	1.9	Con
Halbert	City of Corsicana	Elm Creek	0.7	12	7,420	0	Con
Flat Creek (8)	City of Athens	Flat Creek	-	-	-	6.0	Con
Livingston (3)	Trinity River Authority	Trinity River	129.2	16,606	1,750,000	670.9	Con
Anahuac	Chambers & Liberty Co.						
	Nav. Dist.	(9)	-	129	35,300	13.4	Con
RECOMMENDED FOR FEDERAL AUTHORIZATION IN PREVIOUSLY SUBMITTED REPORTS							
Lavon (enlargement)(10)	Corps of Engineers	East Fork	55.9	777	685,700	42.7(11)	FC-Con-R-F&W
Wallisville(12)	Corps of Engineers	Trinity River	3.9	17,760	55,700	(13)	Con-Nav-S-R-F&W
RECOMMENDED FOR FEDERAL AUTHORIZATION IN THIS REPORT							
Lakeview	Corps of Engineers	Mountain Creek	7.2	272	488,700	30.4	FC-Con-R-F&W
System Roanoke	Corps of Engineers	Denton Creek	31.4	604	249,900	23.9(15)	FC-R-F&W
System Grapevine	Corps of Engineers	Denton Creek	11.7	-	-		FC-Con-Nav-R-F&W
System Aubrey	Corps of Engineers	Elm Fork	60.0	682	899,900	65.3(16)	FC-Con-R-F&W-Q
System Garza-Little Elm	Corps of Engineers	Elm Fork	30.0	-	-		FC-Con-R-F&W
Tennessee Colony	Corps of Engineers	Trinity River	339.2	12,687	3,366,800	290.8	FC-Con-Nav-R-F&W-Q
RECOMMENDED FOR INCLUSION IN LONG RANGE PLAN BUT NOT FOR AUTHORIZATION AT THIS TIME							
Boyd	-	West Fork	604.7	1,707	639,200	31.7	(17)
Richland Creek	-	Richland Creek	5.2	714	1,045,200	169.3	(17)
Tehuacana	-	Tehuacana Creek	11.2	356	295,300	56.9	(17)
Upper Keechi	-	Upper Keechi Creek	11.0	486	134,500	54.3	(17)
Hurricane	-	Hurricane Bayou	7.0	91	151,900	17.5	(17)
Lower Keechi	-	Lower Keechi Creek	8.9	162	173,000	25.2	(17)
Bedias	-	Bedias Creek	19.2	327	376,700	94.4	(17)
Harmons	-	Harmons Creek	10.5	47	79,100	16.8	(17)
Gail	-	Gail Creek	25.3	91	169,900	31.0	(17)
Mustang	-	Mustang Creek	23.7	84	157,700	25.2	(17)
Caney	-	Caney Creek	7.7	74	135,600	25.2	(17)
Long King	-	Long King Creek	22.9	57	186,200	34.9	(17)
Capers Ridge	-	Trinity River	63.0	17,436	841,500	98.0	(17)

(1) Areal or primary yield in million gallons per day based on a recurrence of the 1950-1957 drought period under 2020 conditions of watershed development. For the projects where zero yield is shown these projects have been designed for watershed conditions other than year 2020 and for a period of runoff less critical than the recurrence of the 1950-1957 drought. (Does not include return flow)

(2) FC - Flood control
Con- Water supply
Nav- Navigation
R - Recreation
S - Salinity intrusion control
F&W- Fish and wildlife conservation
Q - Water quality control

(3) Under construction or authorized

(4) Totals for 1,200 reservoirs - 288 constructed, including 4 of greater than 5,000 acre-feet storage capacity

(5) Only those reservoirs with total storage of 5,000 acre-feet or greater are listed.

(6) Import from Sabine River Basin for City of Dallas

(7) Off-channel on left bank of Trinity River above mouth of Cedar Creek

(8) Import from Neches River Basin for City of Athens

(9) Off-channel - Turtle Bay

(10) Report not printed at this time

(11) Net increase in yield resulting from increased conservation storage

(12) House Doc. 215, 87th Cong., 1st Sess.

(13) Included with yield of Livingston

(14) With proposed reallocation of flood control storage from Grapevine to Roanoke

(15) Increase yield as a result of exchange of storage with Roanoke

(16) Increase in yield from the Garza-Little Elm - Aubrey system

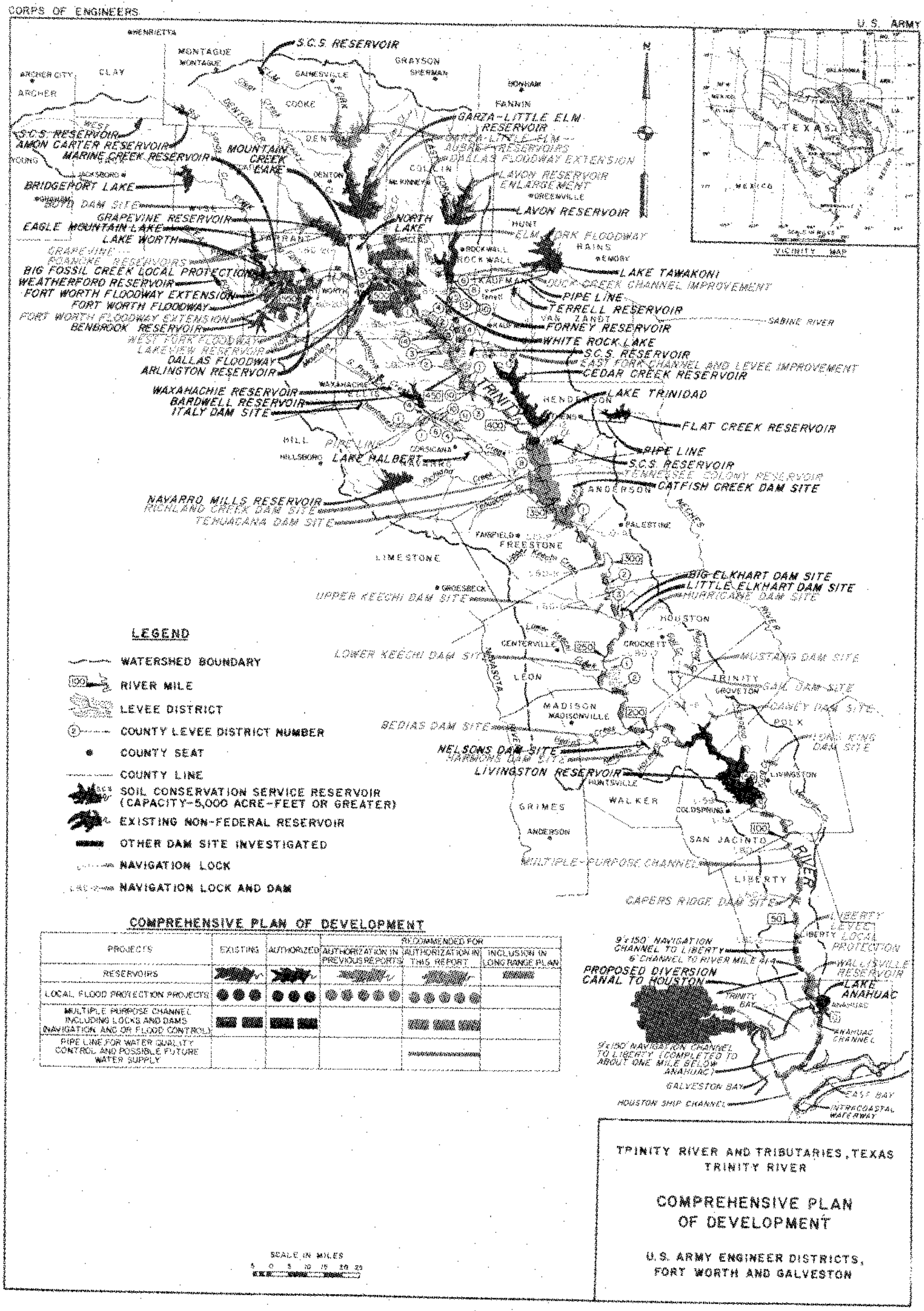
(17) Conservation with probable flood control and other purposes

TABLE 1 (Cont'd)

COMPREHENSIVE PLAN - OTHER IMPROVEMENTS

Project	Location: Stream or locality	Location: Mile	to Mile	Type of improvement	Remarks
				EXISTING, UNDER CONSTRUCTION AND AUTHORIZED	
LOCAL FLOOD PROTECTION PROJECTS					
Federal					
Fort Worth Floodway	Clear Fork	0	1.6	Channel improvement & levees	Existing
	West Fork	564.7	570.4	Channel improvement & levees	Authorized
	West Fork	551.3	564.7	Channel improvement & levees	Existing
Big Fossil Creek Floodway (City of Richland Hills)	Big Fossil Creek	0	3.3	Channel improvement & levees	Authorized
Dallas Floodway	Elm Fork	0	3.5	Channel improvement & levees	Existing
	West Fork & Trinity River	497.4	508.7	Channel improvement & levees	Existing
Non-Federal					
Agricultural levees	Trinity River and tributaries	-	-	Levees	Existing - 38 active local levee districts
FEDERAL NAVIGATION PROJECTS					
Trinity River, Channel to Liberty (9x150-foot channel)					
Houston Ship Channel to Anahuac	Galveston & Trinity Bays	0(1)	23.2(1)	Channel improvement	Constructed - not maintained
Anahuac to Liberty	Trinity River	23.2(1)	48.9(1)	Channel improvement	Authorized
				RECOMMENDED FOR FEDERAL AUTHORIZATION IN PREVIOUSLY SUBMITTED REPORTS	
LOCAL FLOOD PROTECTION PROJECTS					
Fort Worth Floodway	Clear Fork	1.6	10.4	Channel improvement & levees	
East Fork Channel Improvement	East Fork	0	31.8	Channel improvement & levee rehab.	
				RECOMMENDED FOR FEDERAL AUTHORIZATION IN THIS REPORT	
MULTIPLE-PURPOSE CHANNEL IMPROVEMENT					
Houston Ship Channel to Fort Worth	Trinity River & West Fork	0	369.8(2)	Channel enlargement, rectification, & navigation locks and dams	For navigation, flood control, recreation, and fish and wildlife
LOCAL FLOOD PROTECTION PROJECTS					
West Fork Floodway	West Fork	505.5	551.5	Channel improvement & levees	To connect Fort Worth & Dallas Floodways
Elm Fork Floodway	Elm Fork	0	29.4	Channel improvement & levees	Lower end connects with Dallas Floodway
	Denton Creek	0	11.1	Channel improvement & levees	
Dallas Floodway Extension	Trinity River	487.7	498.1	Channel improvement & levees	Downstream extension to Five-Mile Cr.
Duck Creek Channel Improvement	Duck Creek	10.4	17.5	Channel improvement	
Liberty Local Protection Project	Trinity River	34	44.5	Levees	

(1) Channel mile
(2) Channel mile - natural river mile 551.5


CORPS OF ENGINEERS
U.S. ARMY
S.C.S. RESERVOIR
GARZA-LITTLE ELM RESERVOIR
AMON CARTER RESERVOIR
MARINE CREEK RESERVOIR
MOUNTAIN CREEK LAKE
BRIDGEPORT LAKE
LAVON RESERVOIR ENLARGEMENT
LAVON RESERVOIR
GRAPEVINE RESERVOIR
EAGLE MOUNTAIN LAKE
LAKE WORTH
NORTH LAKE
BIG FOSSIL CREEK LOCAL PROTECTION
WEATHERFORD RESERVOIR
FORT WORTH FLOODWAY EXTENSION
FORT WORTH FLOODWAY
BENBROOK RESERVOIR
DALLAS FLOODWAY
ARLINGTON RESERVOIR
LAKE TAWAKONI
PIPE LINE
TERRELL RESERVOIR
FORNEY RESERVOIR
WHITE ROCK LAKE
CEDAR CREEK RESERVOIR
SABINE RIVER
WAXAHACHIE RESERVOIR
BARDWELL RESERVOIR
ITALY DAM SITE
LAKE TRINIDAD
FLAT CREEK RESERVOIR
LAKE HALBERT
CATFISH CREEK DAM SITE
NAVARRO MILLS RESERVOIR
BIG ELKHART DAM SITE
LITTLE ELKHART DAM SITE
NELSONS DAM SITE
LIVINGSTON RESERVOIR
PROPOSED DIVERSION CANAL TO HOUSTON
LAKE ANAHUAC
GALVESTON BAY
HOUSTON SHIP CHANNEL
TRINITY RIVER
VICINITY MAP
LEGEND
WATERSHED BOUNDARY
RIVER MILE
LEVEE DISTRICT
COUNTY LEVEE DISTRICT NUMBER
COUNTY SEAT
COUNTY LINE
SOIL CONSERVATION SERVICE RESERVOIR (CAPACITY-5,000 ACRE-FEET OR GREATER)
EXISTING NON-FEDERAL RESERVOIR
OTHER DAM SITE INVESTIGATED
NAVIGATION LOCK
NAVIGATION LOCK AND DAM
COMPREHENSIVE PLAN OF DEVELOPMENT
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AUTHORIZED
RECOMMENDED FOR
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U.S. ARMY ENGINEER DISTRICTS, FORT WORTH AND GALVESTON

PLATE I

12. PROJECTS EXISTING, UNDER-CONSTRUCTION, AND RECOMMENDED IN PRIOR REPORTS - IMPROVEMENTS IN PLAN.- The Corps of Engineers program in the basin includes six major reservoir projects, of which four are completed, one is under-construction and one is authorized for construction. The Corps program also includes a shallow-draft navigation project from the Houston Ship Channel to Liberty, which has been partly constructed. The Soil Conservation Service has a program underway for land treatment measures and for construction of 1,200 small flood detention reservoirs in headwater and tributary areas throughout the basin, of which 288 have been completed with the remainder scheduled to be completed before 2020. About 100 reservoirs of all sizes have been constructed in the basin by various state and local government agencies and private concerns. Fifteen of the locally constructed reservoirs, which have been completed, and three which are under construction, have storage capacity of 5,000 acre feet or more. The cities of Dallas and Terrell have made agreements with the Sabine River Authority for importing water from Lake Tawakoni on the Sabine River. The City of Athens has made arrangements for importing water from the Flat Creek Reservoir in the Neches River Basin. Imports from these sources are included as part of the water resource yield from the comprehensive plan and are expected to total 172 million gallons per day in 2020 and 180 million gallons per day in 2070.

13. The Federal reservoirs primarily provide flood control and water conservation storage, although two provide storage for navigation. Recreational facilities have been provided at all of the completed reservoirs. For the most part, the non-Federal reservoirs provide water conservation storage; however, they are also used extensively for recreational purposes. Total storage available in all of the existing, under-construction and authorized reservoirs is about 7.3 million acre-feet, about equally divided between the Federal and non-Federal reservoirs.

14. Because of urgent problems in local areas, separate reports have been submitted previously recommending enlargement of the Lavon Reservoir, near Dallas, and construction of the Wallisville Reservoir near the mouth of the Trinity River. The Lavon enlargement would provide over 262,000 acre-feet of additional storage capacity for water conservation and recreational purposes. The recommended Wallisville Reservoir would serve several purposes, including prevention of salinity intrusion into irrigation water pumped from the lower river, water conservation, navigation, recreation and fish and wildlife conservation. For water conservation the reservoir would be operated in combination with the Livingston Reservoir which is now under construction.

15. The existing project for navigation on the Trinity River provides for a 9 x 150-foot channel extending from the Houston Ship Channel

through Galveston and Trinity Bays and the Trinity River to Liberty, Texas, a total distance of about 49 miles. The 23-mile reach extending through the bays from the Houston Ship Channel to Anahuac has been constructed. The channel was not constructed in the Trinity River because of salt water intrusion problems. The recently submitted report recommending construction of the Wallisville Reservoir also recommends a navigation lock at the dam and immediate construction of the authorized project channel upstream to mile 33.8 to connect with a spur channel owned by the Texas Gulf Sulphur Company.

16. Three existing and authorized Federal local flood protection projects will provide flood protection to portions of the cities of Fort Worth, Richland Hills and Dallas. These projects include about 23 miles of improved channels and about 45 miles of levees, which form floodways through parts of the cities. Extension of the Fort Worth Floodway for a distance of about 7 miles on Clear Fork and channel improvement and rehabilitation of local levees along a 32-mile reach on East Fork have been recommended in previously submitted reports. Figure 1 shows the location of the existing and authorized projects in the Trinity River Basin.

17. There are 38 active organized agricultural levee improvement districts in the Trinity River Basin. These districts have approximately 341 miles of levees that are maintained by local interests. The levees provide various degrees of protection to about 181,000 acres of land along the Trinity River and tributaries. From time to time many of these levees have been damaged by major floods and have been restored to their original grade and section by the Corps of Engineers under emergency flood damage repair authority. Eleven of these local districts have levees located along the Trinity River in a 55-mile reach downstream from Dallas. Pertinent data on these local protection projects are given in table 2 and their locations are shown on figure 1 and plate 2.

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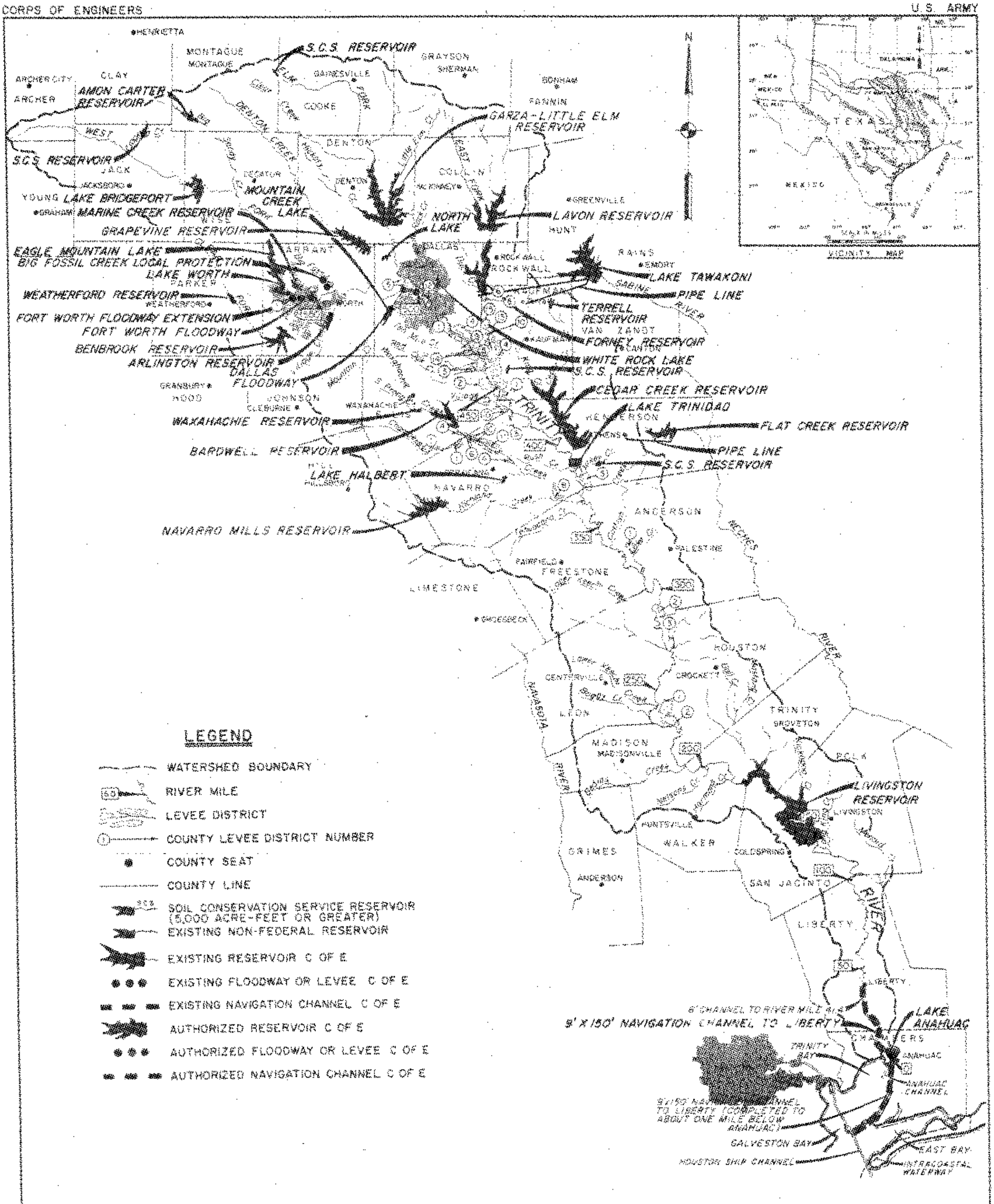


FIGURE 1

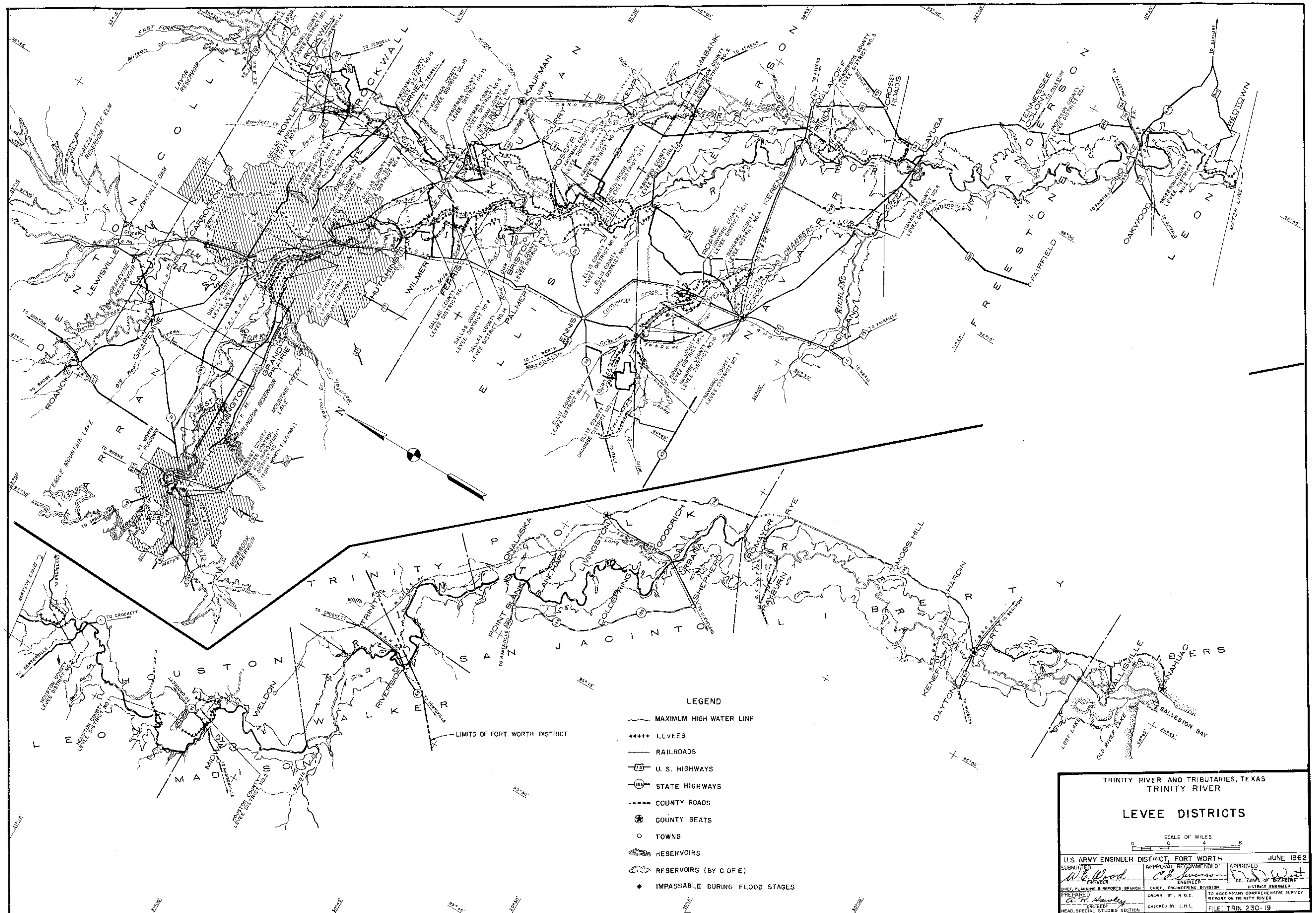
EXISTING AND AUTHORIZED IMPROVEMENTS

SCALE IN MILES

TABLE 2

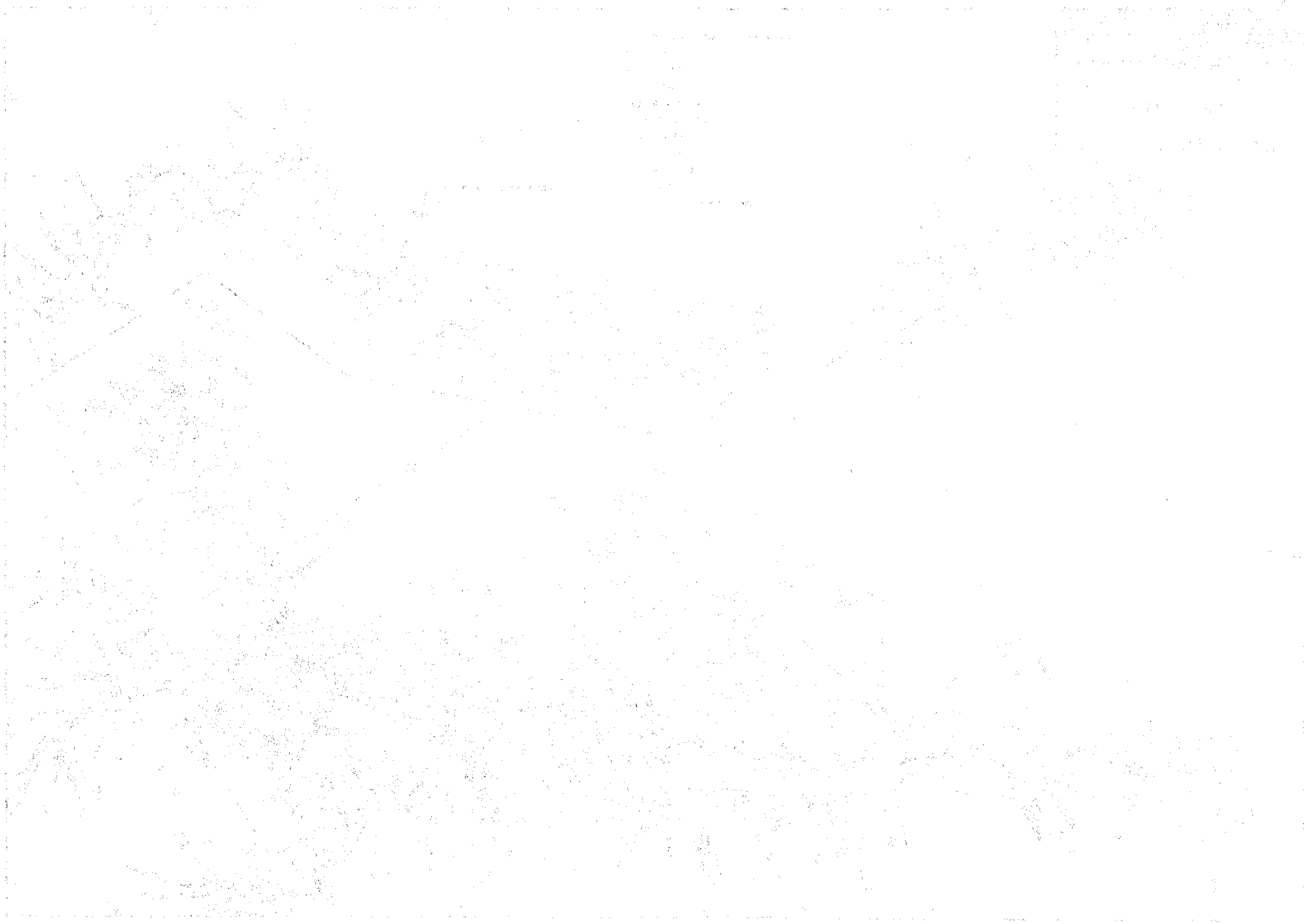
NON-FEDERAL LEVEE DATA

LEVEE IMPROVEMENT DISTRICT County	District No.	Length (Miles)	Gage Reference	Over-Topping Stage (Feet)	Approx. Area Protected (Acres)	Overtopped by Flood of
Dallas	#5	14.6	Dallas	52	5,000	1942
Dallas	#12	0.2	Dallas	47	59	1949
Dallas	#1	9.6	Dallas	45	3,366	1942, 1949
Dallas	#2	9.0	Dallas	45	2,080	1935, 1942, 1949, 1957
Dallas	#14	5.2	Dallas	45	2,400	1935, 1942, 1948, 1949
Dallas	#4	16.1	Dallas	48	17,700	
Ellis	#3	15.0	Dallas	47	8,229	1942, 1958
Ellis	#2	16.8	Rosser	40	11,100	1942, 1946
Kaufman	#1	6.8	Rosser	50	7,380	
Henderson	#1	10.1	Rosser	40	4,216	
Ellis) Navarro)	#10) #3)	4.2	Rosser	42	1,840	
Henderson	#3	28.3	Trinidad &) Mabank)	47 25	17,000	1942, 1945
Anderson	#1	5.5	Long Lake	52	2,583	1942, 1945
Anderson	#2	6.9	Long Lake	48	5,740	1957, 1958
Houston	#3	10.0	Long Lake	52	5,140	
Houston	#1	6.8	Midway	48	7,380	1957
Houston	#2	10.5	Midway	49	9,626	
Rockwall	#1	3.9	Rockwall	22	1,875	
Dallas	#6	12.8	Rockwall	20	3,969	
Kaufman	#6	2.5	Rockwall	20	663	1935, 1938, 1942, 1949
Kaufman	#8	3.8	Rockwall	20	876	1942
Kaufman	#15	5.2	Crandall	24	2,745	1957, 1958
Kaufman	#13	6.4	Crandall		926	
Kaufman	#10	2.4	Crandall	21	1,499	1944, 1945, 1946, 1950 1957, 1958
Kaufman	#5	6.6	Crandall	21	2,133	1935, 1945, 1946, 1957, 1958
Kaufman	#4	26.0	Rosser &) Crandall)	38 22	12,130	1935, 1949, 1957, 1958
Ellis	#1	8.0	-		5,936	
Ellis	#11	2.0	-		1,500	
Navarro	#1	3.9	-		1,000	
Ellis	#4	8.9	-		900	1944, 1945
Navarro	#6	3.2	-		1,462	
Navarro	#10	14.0	Corsicana	25	7,000	
Navarro	#11	5.8	Corsicana	25	3,000	
Navarro	#4	8.7	Corsicana	25	2,608	
Navarro	#8	6.5	Corsicana	25	3,100	
Kaufman	#7	6.4	Mabank	23	3,800	1945, 1957
Henderson	#2	1.8	Mabank	23	1,282	1945, 1957



LEGEND
MAXIMUM HIGH WATER LINE
LEVEES
RAILROADS
U. S. HIGHWAYS
STATE HIGHWAYS
COUNTY ROADS
COUNTY SEATS
TOWNS
RESERVOIRS
RESERVOIRS (BY C OF E)
IMPASSABLE DURING FLOOD STAGES
LIMITS OF FORT WORTH DISTRICT
TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER
LEVEE DISTRICTS
SCALE OF MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
JUNE 1962
SUBMITTED
ENGINEER
CHIEF, PLANNING & REPORTS BRANCH
APPROVAL RECOMMENDED
ENGINEER
CHIEF, ENGINEERING DIVISION
APPROVED
COL. CORPS OF ENGINEERS
DISTRICT ENGINEER
PREPARED
ENGINEER
HEAD, SPECIAL STUDIES SECTION
DRAWN BY: R.O.C.
CHECKED BY: J.H.L.
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER
FILE: TRIN 230-19

PLATE 2



18. ADDITIONAL IMPROVEMENTS RECOMMENDED IN THIS REPORT.- A number of improvements are recommended for immediate authorization and construction to satisfy the existing and immediately prospective needs for additional flood protection, water transportation and water conservation, with its related uses. Three multiple-purpose reservoirs are recommended, in addition to the Roanoke Reservoir which would be operated for flood control only. The flood control storage in Roanoke is to effect an exchange of flood control storage in the existing Grapevine Reservoir and allow additional storage in Grapevine for water conservation and general outdoor and fish and wildlife recreation purposes. The proposed Aubrey Reservoir, in addition to its conservation storage, would allow a similar exchange of flood control storage and added conservation storage in the existing Garza-Little Elm Reservoir. The other recommended reservoirs are Lakeview at mile 7.2 on Mountain Creek, and Tennessee Colony at mile 339.2 on the Trinity River.

19. A multiple-purpose channel improvement from the Houston Ship Channel to Fort Worth is recommended for inclusion in the comprehensive plan to provide for barge navigation from the Houston Ship Channel to Fort Worth and to provide increased discharge capacity. Sufficient channel section is provided to contain within banks some flows resulting from local runoff downstream from the reservoirs and flood discharge releases from flood control storage in upstream reservoirs. A system of navigation dams would provide a series of slackwater pools between major main stem reservoirs and navigation locks would lift and lower vessel traffic between the navigation pools.

20. In conjunction with the multiple-purpose channel improvement, levee improvements would be provided to extend and connect the Fort Worth and Dallas Floodways on the West Fork and to extend the Dallas floodway downstream to Five Mile Creek. Levees and channel improvements would be made on the Elm Fork to provide a floodway extending from its mouth upstream to about Carrollton, with improved channels extending farther upstream on Elm Fork to the Garza-Little Elm Reservoir and on Denton Creek to Grapevine Reservoir. Levees would be provided along the left bank of the Trinity River to provide flood protection to the city of Liberty, Texas, about 48 miles above the river mouth. Channel rectification would be provided on Duck Creek for the protection of the City of Garland.

21. Although the magnitude of overall development within the basin can be predicted with reasonable accuracy, it is not possible to foresee the exact patterns in all localities. It is probable that future developments may indicate needs for local adjustment or supplements to the comprehensive plan, which are expected to be possible of accomplishment with no loss of overall efficiency. Reservoir sites are needed to meet long term needs and it is important that the most favorable sites be preserved for development when and as needed.

22. The Bureau of Reclamation, U. S. Department of the Interior, has formulated a long-range plan for transporting water from the water-surplus river basins in East Texas to areas of water deficiency in the central and southern parts of the state. The plan, described in Senate Document No. 57, 83rd Congress, 1st Session, in part, would provide for a system of canals, natural channels and appurtenant control sturctures to comprise a transporting system roughly paralleling the Gulf coast. Although detailed plans have not been developed, the tentative, schematic plans call for a water holding reservoir on the lower Trinity River, probably in the general vicinity of the proposed Capers Ridge Reservoir. This is one of the reservoirs recommended in this report for inclusion in the long range Trinity River plan to satisfy a portion of the projected water requirements for the lower basin, but its authorization is not recommended at this time.

FLOOD PROBLEMS

23. GENERAL.- Flooding is a serious problem in the Trinity River Basin. Throughout the basin, the streams are meandering and in general have small channel capacities in proportion to the areas drained. Consequently, floods are experienced at frequent intervals throughout the entire river system. Peak discharges of the 1957 and 1958 floods under then existing conditions at various points in the basin are given in the tabulation below.

Gage	Stream	Drainage Area (Sq Mi)	Bankfull Capacity (cfs)	Peak Discharge (1000 cfs) 1957	Peak Discharge (1000 cfs) 1958
Liberty	Trinity	17,539	20,000	88.1	58.8
Romayor	Trinity	17,192	40,000	93.0	58.2
Riverside	Trinity	15,619	53,000	97.7	66.8
Oakwood	Trinity	12,912	24,000	91.8	95.4
Rosser	Trinity	8,162	9,000	56.0	34.0
Dallas	Trinity	6,120	13,000	75.3	23.2
Grand Prairie	West Fork	3,070	7,000	59.2	9.20
Fort Worth	West Fork	2,627	23,000	26.8	7.85
Carrollton	Elm Fork	2,457	5,000	13.7	7.72
Rockwall	East Fork	840	1,300	43.0(2)	6.0
Grand Prairie	Mountain Creek	289	4,000	25.4(1)	9.80(1)
Richland	Richland Creek	737	3,000	44.6	33.4
Corsicana	Chambers Creek	971	4,000	23.2	38.2

(1) Estimated from change in reservoir contents and releases from Mountain Creek Reservoir

(2) Affected by major levee breaks

24. The flood-control work to date has been primarily in the portion of the basin upstream from Richland Creek, the area in which are located the most extensive concentrations of urban and agricultural developments in the Trinity River Basin. These projects have served to control flood runoff and reduce flood discharges from an area on which the most damaging floods of record in the basin have been generated. Major floods have on occasion been generated in the basin area below the confluence of Richland Creek and the main stem of the Trinity River, but records show that the

magnitude of such floods has not been as great as those which originated upstream. When runoff from the lower basin is augmented by concurrent runoff from the upper basin, the resulting increase in volume and duration of flood flows as they progress downstream causes major floods. Existing flood-control works afford a high degree of protection to some areas of the basin from damages which would result from the recurrence of floods equal in magnitude to those of record. The effectiveness of those works was demonstrated during the 1957 flood in the upper reaches of the basin during which the operation of the existing flood-control projects is credited with prevention of flood damages estimated to be $85 million.

25. In the Trinity River Basin, there are about one and one-half million acres of land subject to being flooded, of which over 700,000 acres are situated along the main stem and lower reaches of the principal tributaries, with the remainder lying in the upland tributary area. Approximately 85 percent of the total value of all property subject to flood damage within the one and one-half million acres of the flood plain area is in the upper basin, with the largest concentration in the Dallas-Fort Worth area. The flood plain under study in this report which has not been reported on by separate investigations comprises about 605,000 acres of land, of which about 18,600 acres are urban or suburban and the remainder is either improved lands or unimproved grazing lands. The total value of physical property in this flood plain is about 327 million dollars under present conditions of basin development; however, with the projected widespread increase in population, industrial expansion, and service facilities, this value is expected to increase to about 1, 3.5, and 5.4 billion dollars in 1970, 2020, and 2070, respectively. The average annual damages within the flood plain, based on the condition of 1960 reservoirs and flood plain development, including Navarro Mills and Bardwell Reservoirs and previously recommended improvements, amount to about $2,300,000. It is anticipated, based on the widespread increase in population and industrial expansion, that progressively, for at least the next century, many changes will take place in the flood plain with respect to development, changed land use, and urbanization. On the basis of the projected development with the 1960 system of reservoir projects and the recurrence of the hydrologic cycle during the period 1970-2070, the average annual flood damage is estimated to be about 15.4 million dollars. Pertinent data on area subject to overflow, value of property and crops, flood damages and similar information are summarized in table 3.

TABLE 3
PERTINENT DATA AREA-SUBJECT TO FLOODING

Stream	Reach	Land Area (acres) Rural	Land Area (acres) Urban and Suburban	Total	Value of Physical Property	Value of (1) Annual Corps Grown	Estimated Damages From Recurrence of 1957 Flood	Average Annual Damages 1970-2070
West Fork and Clear Fork	From Lake Worth Dam on West Fork and Benbrook Dam on Clear Fork to mouth of Elm Fork	22,944	2,389	25,333	$ 76,219,000	$ 299,500	$ 2,807,000	$ 3,624,400
Trinity River	From mouth of Elm Fork to mouth of East Fork	49,533	9,647	59,180	49,165,000	2,465,300	1,580,000	3,491,400
Trinity River	From mouth of East Fork to U. S. Highway 287	115,910	0	115,910	56,163,000	3,503,700	1,199,000	226,300
Trinity River	From U. S. Highway 287 to U. S. Highways 79 and 84	70,528	0	70,528	9,823,000	1,168,000	749,000	270,300
Trinity River	From U. S. Highway 79 and 84 to mouth of Bedias Creek	123,060	0	123,060	23,105,000	6,919,000	4,492,000	2,768,100
Trinity River	From mouth of Bedias Creek to Santa Fe R.R. crossing	41,372	0	41,372	40,432,000	1,804,800	1,260,000	324,900
Trinity River	From Santa Fe R.R. crossing to mouth	139,100	10	139,110	24,602,000	366,900	1,862,000	2,122,800
Elm Fork and Denton Creek	From Lewisville Dam on Elm Fork and Grapevine Dam on Denton Creek to mouth of Elm Fork	24,053	5,337	29,390	32,520,000	721,300	638,000	1,895,200
Mountain Creek	From Lakeview Dam site to U. S. Highway 80	0	857	857	7,509,000	0	116,000	481,800
Duck Creek	Vicinity of Garland, Texas	0	363	363	7,337,000	0	503,000	224,400
	TOTAL	586,500	18,603	605,103	$326,875,000	$17,248,500	$15,206,000	$15,429,600

(1) Assuming no damage from floods

26. RESERVOIR REGULATION PROBLEMS.- Floods experienced subsequent to the completion of the Corps of Engineers reservoir projects in the upper Trinity Basin revealed that a serious problem of inadequate channel capacity exists on the Trinity River and tributaries. The problem of insufficient channel capacities was particularly evident during the April-June 1957 flood, when the Trinity River Basin experienced heavy rainfall almost daily. Recent encroachments, together with certain channel deficiencies that previously existed, have limited flood-control releases from existing upstream reservoirs to such an extent as to materially reduce their effectiveness for providing flood protection.

27. Channel capacities on the Trinity River below Dallas vary from about 9,000 second-feet in the vicinity of Rosser, up to 53,000 second-feet in the vicinity of Riverside, and then down to 20,000 second-feet in the vicinity of Liberty. Under present conditions of watershed development, with the existing reservoirs in operation, flows at or above bankfull capacity originating on the uncontrolled area, are experienced on an average of once a year at Rosser and Liberty, and about every 4 years at Riverside. As a result of this channel deficiency, flooding is produced by the occurrence of storms over the uncontrolled area and controlled flood water releases must be significantly reduced; consequently, the effectiveness of the flood-control storage in upstream reservoirs is seriously impaired. In addition to damages produced directly by overflow from the Trinity River, serious losses in numerous levee districts are sustained from interior flooding attributable to the inability of drainage structures to discharge local runoff into the river during high stages.

28. A channel deficiency presently exists on the East Fork where the capacity is only 500 to 1,200 second-feet, although under the present plan for Lavon Reservoir, regulation is made to 2,000 second-feet at Crandall. However, a channel capacity of 5,000 second-feet has been recommended in "Review of Reports on Trinity River and Tributaries, Texas, Covering the East Fork Watershed" dated November 1, 1961. Another critical area is on the Trinity River in the vicinity of Rosser where the existing channel capacity is only 9,000 second-feet. Under the present plan of regulation for the upper Trinity River reservoirs, regulation is to 13,000 second-feet at Dallas and this discharge combined with the previously recommended 5,000 second-feet on the East Fork will produce a regulated flow of 18,000 second-feet at Rosser. The recommended Lakeview Reservoir would contribute an additional 4,000 second-feet, increasing the regulation at Dallas and Rosser to 17,000 and 22,000 second-feet, respectively. On the Trinity River below the recommended Tennessee Colony Reservoir the minimum bankfull capacity of 20,000 second-feet is in the vicinity of Liberty.

29. During flood periods, releases from the Corps of Engineers reservoirs will be augmented by releases from local interests reservoirs

and by uncontrolled releases from Soil Conservation Service waterflow retardation structures. Among local interests reservoirs, the system of reservoirs on the West Fork above Fort Worth will probably make the largest contribution. During the 1957 floods Lake Worth spilled for over two months with the daily spills averaging about 5,000 second-feet. Investigations based upon preliminary data indicate that the combined releases from existing and proposed Soil Conservation Service waterflow retardation structures on the West Fork of the Trinity River upstream from Dallas will be about 2,000 second-feet with an additional contribution of about 3,000 second-feet between Dallas and Rosser. A similar investigation of the area below the recommended Tennessee Colony Reservoir indicates that combined releases from Soil Conservation Service projects in this area will amount to about 4,000 second-feet plus an additional spill from the long-range water supply reservoirs of about 6,000 second-feet for a total of about 10,000 second-feet.

30. As previously set forth, the present operating discharges at Dallas and Rosser, when corrected for releases from the recommended Lakeview and the previously recommended enlarged Lavon Reservoirs, would increase the regulation at Dallas and Rosser to 17,000 and 22,000 second-feet, respectively. A further increase of 7,000 second-feet at Dallas and 10,000 second-feet at Rosser would provide for releases from other reservoirs, as set forth above.

31. The required channel capacities would then be 24,000 and 32,000 second-feet at Dallas and Rosser, respectively. A channel capacity of about 35,000 second-feet would be required below Tennessee Colony Reservoir for flood-control releases from that reservoir. The additional contribution of 4,000 second-feet from downstream Soil Conservation Service reservoirs, plus the 6,000 second-feet from the long-range water supply reservoirs, (see paragraph above) would bring the total required channel capacity of the lower Trinity River to 45,000 second-feet.

32. Based on the data presented in paragraphs 26 through 31, it is concluded that the channel capacities shown in table 4 would meet the channel requirements for reservoir regulation. The existing channel capacities and the proposed operating discharges are also shown in table 4.

33. Flood routing studies made for this report were based on a regulation to only 8,000 second-feet (existing channel capacity) on the Elm Fork at Carrollton. The proposed channel capacity was subsequently increased to 15,000 second-feet with a proposed operating discharge of 12,000 second-feet at Carrollton. Since the operating discharge of 20,000 second-feet at Dallas would not be changed, the principal effect of the additional channel capacity on the Elm Fork

TABLE 4

CHANNEL REQUIREMENTS FOR RESERVOIR REGULATION

Reach	Existing Avg. Min. Bankfull Capacity (cfs)	Proposed Channel Capacity (cfs)	Proposed Operating Discharge (cfs)
Clear Fork Trinity	8,000	8,000	6,000
West Fork Trinity			
Ft Worth to mouth of Elm Fork	7,000	15,000	12,000
Mountain Creek			
Lakeview Dam to mouth	4,000	4,000	4,000
Elm Fork Trinity			
Denton Creek Grapevine Dam to mouth	6,000	7,000	6,000
Elm Fork Lewisville Dam to Carrollton gage	8,000	10,000	8,000
Carrollton gage to mouth of Elm Fork	8,000	15,000	12,000 (1)
Trinity River			
Dallas Gage	13,000	25,000	20,000
East Fork Trinity			
Forney Damsite to mouth	500-1200	5,000	5,000
Trinity River			
Rosser Gage	9,000	32,000	25,000
Richland Creek			
Navarro Mills Dam to mouth	3,000	3,000	3,000
Chambers Creek			
Waxahachie Creek to mouth	4,000	4,000	4,000
Waxahachie Creek			
Bardwell Damsite to mouth	2,000	2,000	2,000
Trinity River			
Oakwood Gage	24,000	45,000	35,000
Liberty Gage	20,000	45,000	35,000

(1) Operating discharge of 8,000 second-feet used in flood-routing studies for this report.

would be to increase flood releases from the reservoirs on the Elm Fork watershed and reduce those from Benbrook Reservoir on the Clear Fork watershed. Such a regulation would affect only the recession side of the modified hydrographs downstream and would have no effect on modified peak discharges below the reservoirs. For this reason, further routings are not considered necessary for purposes of this report.

34. The time required for the evacuation of the flood-control storage of the reservoirs in the recommended plan, based upon the proposed operating discharges of table 4 are shown in table 5.

TABLE 5

TIME REQUIRED FOR EVACUATION OF FLOOD-CONTROL STORAGE

Reservoir	Flood-control storage (ac.-ft.)	Operating discharge (cfs)	Time required for evacuation of flood-control storage (days)	
			Proposed	Existing
Benbrook	170,350 (1)	6,000		7
Lakeview	136,700	4,000	18	
Grapevine-Roanoke	271,000)	12,000		
Garza-Little Elm-Aubrey	589,900)			
Total Elm Fork Watershed	860,900	12,000	37	
Lavon (enlarged)	275,600	5,000	28	
Tennessee Colony	2,144,300	35,000	31	

(1) Flood-control storage below uncontrolled notch (elevation 710.0) is 76,550 acre-feet.

35. CHANNEL REQUIREMENTS FOR FLOOD CONTROL.- The average minimum bankfull capacity of existing channels and the channel capacities required (in conjunction with the recommended reservoirs) to give varying degrees of flood protection to problem areas on the Trinity River and tributaries are given in table 6.

TABLE 6

CHANNEL REQUIREMENTS FOR FLOOD CONTROL

Reach	Average minimum bankfull capacity of existing channel (cfs)	Channel capacity (1)(cfs) required to provide protection against flood of		
		10-year frequency	25-year frequency	50-year frequency
Elm Fork, Lewisville Dam to Carrollton	8,000	8,200	13,200	18,100
Denton Creek below Grapevine Dam	6,000	4,600	7,000	9,000
Trinity River, Five Mile Creek to head of Tennessee Colony Res.	9,000	36,000	50,000	61,000
Trinity River below Tennessee Colony damsite (2)	20,000	31,500	39,300	43,000

(1) In conjunction with recommended reservoirs.

(2) Most critical area in vicinity of Liberty.

36. SOLUTION TO FLOOD PROBLEMS.- Preliminary investigation of the flood problems in the Trinity River Basin revealed the addition of the Lakeview and Tennessee Colony Reservoirs to the existing flood control system would not preclude the need for additional channel capacities. With increased channel capacities, the effectiveness of existing and recommended reservoirs with flood control storages would be increased significantly. A single-purpose flood control channel plan was investigated by increasing channel capacities, where necessary, downstream from the existing flood-control reservoirs to the mouth of the Trinity River to satisfy the proposed channel capacities shown on table 4. Channel dimensions and design discharges for selected reaches of the flood control channel are presented in table 7.

TABLE 7

CHANNEL DIMENSIONS
FLOOD CONTROL CHANNELS

Channel mile Above mouth Trinity River From	Channel mile Above mouth Trinity River To	Length (miles)	Design Discharge (cfs)	Bottom Width (feet)
		TRINITY RIVER		
11.9 (1)	20.0	8.1	45,000	300
20.0	46.0	26.0	45,000	250
46.0	68.0	22.0	45,000	150
68.0	89.7	21.7	45,000	(2)
89.7	132.5	Livingston Reservoir		
132.5	136.4	3.9	45,000	200
136.4	166.7	30.3	45,000	(2)
166.7	167.0	0.3	45,000	125
167.0	170.1	3.1	45,000	(2)
170.1	184.5	14.4	45,000	125
184.5	191.2	6.7	45,000	(2)
191.2	205.8	14.6	45,000	75
205.8	209.5	3.7	45,000	(2)
209.5	210.5	1.0	45,000	100
210.5	211.7	1.2	45,000	(2)
211.7	212.5	0.8	45,000	100
212.5	214.8	2.3	45,000	(2)
214.8	215.2	0.4	45,000	100
215.2	215.9	0.7	45,000	(2)
215.9	238.0	22.1	45,000	150
238.0	279.6	Tennessee Colony Reservoir		
279.6	298.0	18.4	35,000	200
298.0	312.0	14.0	32,000	125
312.0	331.0	19.0	27,000	125
331.0	Five Mile Creek			
331.0	336.8	5.8	27,000	125
336.8	341.2	4.4	25,000	125
341.2	Dallas Floodway			
341.2	348.8	7.6	25,000	125
348.8	Mouth of Elm Fork			
348.8	351.8	3.0	17,000	30
351.8	373.4	21.6	15,000	30
		ELM FORK		
0	14.3	14.3	15,000	100
14.3	21.8	7.5	10,000	50
		DENTON CREEK		
0	1.9	1.9	7,000	40
1.9	8.9	7.0	7,000	(2)

(1) Head of Wallisville Reservoir.
(2) Cleared existing river channel.

37. PROJECT FORMULATION STUDIES.- The following paragraphs present the sequential steps, procedures and considerations used in the formulation of the plan of development for the Trinity River Basin. First, it was considered basic to any plan of development that channel capacities downstream from flood control reservoirs should be increased for more effective reservoir operation and to relieve flood problems along the channels. The studies revealed that the flood control channel project did not afford sufficient protection to urban areas and that the only means of affording these areas adequate protection was by the addition of levees. Also, the excavated material from the channel project could be disposed of in the construction of the levees. Therefore, the addition of levees to afford protection from the standard project flood was considered as the next phase in developing the plan. With the flood control channel project in operation, there remained considerable flood damages in the rural areas along the main stem. It was found that by the addition of flood control reservoirs at the Lakeview and Tennessee Colony sites, a sufficiently high degree of protection could be afforded to these areas and the reservoirs were considered as the third phase in developing the plan. The remaining flood problem for which remedial measures could be justified was along Duck Creek at Garland, Texas, which was considered as the next added project in the flood control studies. The next phase in developing the plan was the consideration of providing a navigable waterway from the Houston Ship Channel to Dallas and Fort Worth. It was found that a waterway could be justifiably provided and by combining it with the flood control channel savings could be effected by the joint construction. Development of the water resources for municipal and industrial purposes was the next consideration to provide both immediate and long range needs. With the plan developed to this extent further consideration was given to developing the recreation and fish and wildlife aspects of the reservoirs and multiple-purpose channel.

38. SINGLE PURPOSE FLOOD CONTROL CHANNEL.- The investigated plan provided for channel capacities to contain design discharges at bankfull stage, and for a channel alignment that utilizes all existing bridges or bridge locations. The plan provided for the modification of existing highway and railroad bridges where necessary in order to provide required clearance, pier protection, and bank stabilization. Rights-of-way land requirements were considered as was the relocation of pipe lines and other utility lines. Information concerning the preliminary estimates of costs of the principal features of the flood control only channel, the annual charges, the flood control benefits creditable to the channel, and the benefit-cost ratios for selected reaches are shown below.

Stream and Reach	First Cost	Annual Charge	Annual Benefits	Benefit-Cost Ratio
	$	$	$	
Elm Fork & Denton Creek	4,230,000	206,600	1,349,000	6.5
West Fork, Elm Fork to Fort Worth	2,996,000	222,800	944,200	2.8
Trinity River, Dallas Floodway	1,983,000	114,100		
Trinity River, Five Mile Creek to Dallas Floodway	3,575,000	180,000	233,500	1.3
Trinity River, Tennessee Colony to Five Mile Creek	23,217,000	935,200	1,639,900	1.8
Trinity River, Livingston to Tennessee Colony	27,952,000	1,082,300	1,482,800(1)	1.4
Trinity River, Wallisville to Livingston	25,176,000	1,027,200	1,780,400(2)	1.7
Total	89,129,000	3,768,200	7,429,800	2.0

(1) Includes $99,900 benefit for land enhancement
(2) Includes $230,800 benefit for land enhancement

39. Trinity River Main Stem above Five Mile Creek.- The single purpose flood control channel in the West Fork reach, from Fort Worth to the existing Dallas Floodway, would have a design channel capacity of 15,000 cubic feet per second and would require a bottom width of 30 feet. With the channel only plan the frequency of flooding would be reduced from once in 2.4 years to once in 7.7 years and annual damages reduced from $3,624,400 to $2,680,200. The cost of increasing the channel capacity in the existing Dallas Floodway to 25,000 cubic feet per second is included with the cost for the West Fork channel and results in a benefit-cost ratio of 2.8. The design channel capacity in the reach downstream from the existing Dallas Floodway to Five Mile Creek would vary from 25,000 to 27,000 cubic feet per second and would require a bottom width of 125 feet. With the channel only plan the frequency of flooding would be reduced from once in 2.7 years to once in 5.9 to 6.6 years and annual damages would be reduced from $1,216,500 to $983,000 resulting in a benefit-cost ratio of 1.3.

40. Trinity River Main Stem below Five Mile Creek.- The single purpose flood control channel alignment in the 80-mile long natural reach of the Trinity River between Five Mile Creek and the recommended Tennessee Colony Reservoir would have a design channel capacity of 27,000 to 35,000 cubic feet per second and would require bottom channel widths of 125 to 200 feet. In the upper 55-mile reach there are eleven

non-Federal levees that are presently providing various degrees of flood protection to 70,441 acres of agricultural land. Frequency for individual levees varies from once in 50 years to once in 100 years. Annual damages of about $2,501,200 in the reach from Five Mile Creek to the head of Tennessee Colony Reservoir would be reduced to $861,300 with the channel only plan. The annual charges of the channel through this reach would be about $935,200. With the channel only plan operational and with Lakeview Reservoir in the system of existing projects the added protection to the leveed area would be increased to a magnitude in excess of a once in 100-year frequency. Because of the relatively high degree of protection that would be afforded to the agricultural levees by the channel only plan no additional tests were made of the merits of increasing flood protection. However, it should be recognized in preconstruction planning, if the recommended plan is authorized, that it is highly probable that added protection can be realized at nominal cost by placement of excess spoil material from channel work as fill to increase levee heights and sections.

41. Trinity River Main Stem below Tennessee Colony Reservoir.- As previously presented, the channel only plan required for efficient operation of existing and proposed flood control reservoirs would necessitate a channel capacity of 45,000 cubic feet per second in the 340-mile natural reach of the Trinity River below the recommended Tennessee Colony Reservoir. Bankfull capacity in the 156-mile long natural reach between the Tennessee Colony Reservoir and the non-Federal Livingston Reservoir varies from 24,000 to 53,000 cubic feet per second. The 117-mile long natural reach of the Trinity River between Livingston Reservoir and Wallisville Reservoir has existing capacity varying from 20,000 to 53,000 cubic feet per second. The frequency of flooding for the channel only plan is once in 3 years for the Tennessee Colony - Livingston reach, and once in 3.6 years for the Livingston-Wallisville reach. Annual damages would be reduced by the channel only plan in the Tennessee Colony Reservoir-Livingston Reservoir reach from $3,038,400 to $1,655,500 and in the Livingston Reservoir to Wallisville Reservoir reach from $2,447,700 to $898,200. Enhancement benefits would also accrue in these reaches in the amount of $99,900 and $230,900, respectively. Comparison of annual charges to annual benefits for these show ratios of 1.4 and 1.7, respectively. Tests of providing additional increments of channel capacity showed that the optimum channel project would only provide protection from floods of 4-year frequency in the Tennessee Colony Dam-Livingston Reservoir reach, and 3.5-year frequency in the reach downstream from Livingston Reservoir. See figures 2 and 3 for results of these maximization studies.

42. Residual flood problem.- The single-purpose channel project operating with existing reservoirs and other local protection projects, provides a reasonable degree of flood protection to areas located along the Elm Fork and Denton Creek immediately below the Lewisville and Grapevine Dams. The improved channel would also provide a moderate

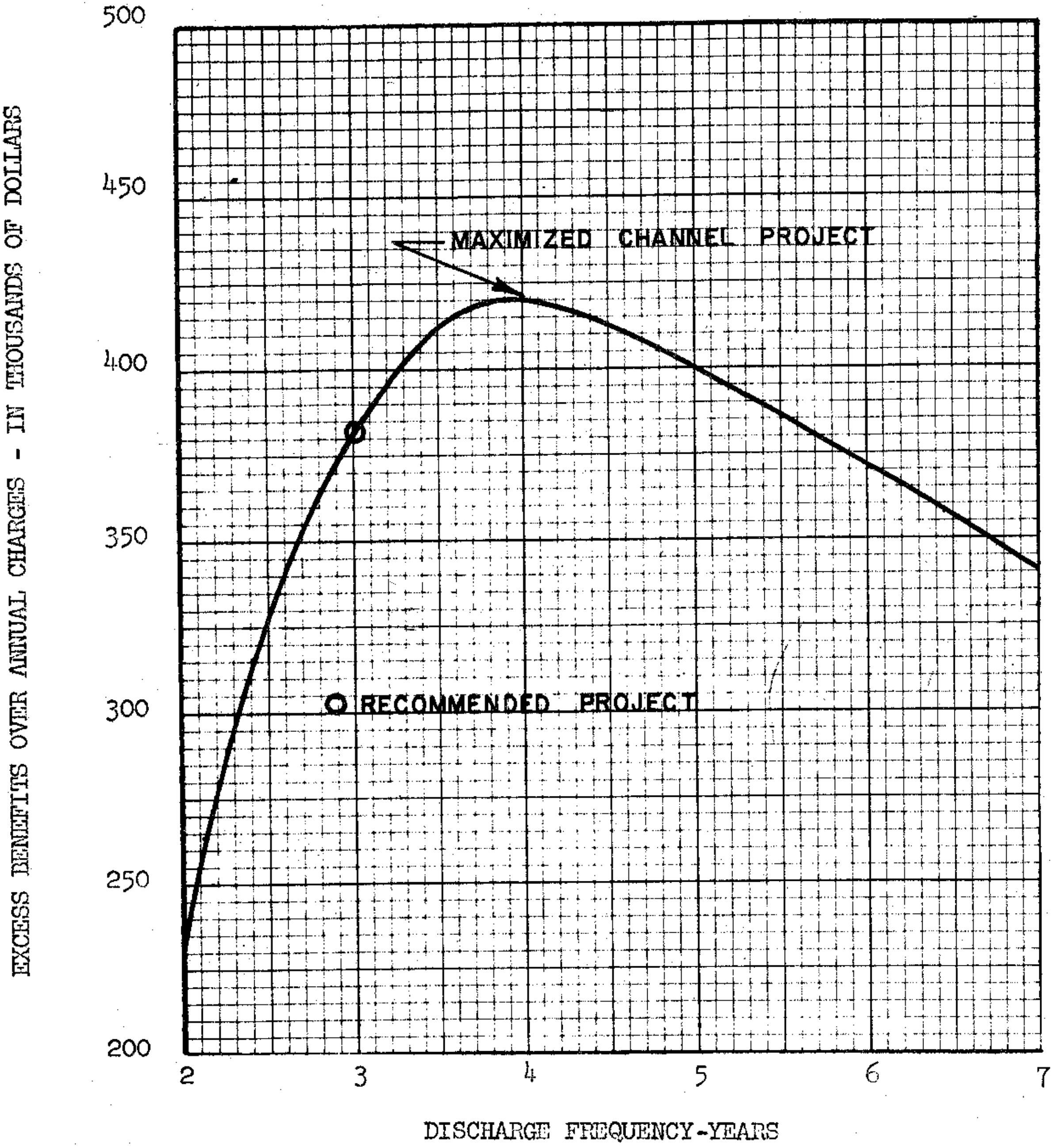


FIGURE 2
FLOOD CONTROL CHANNEL
TENNESSEE COLONY DAM TO HEAD OF LIVINGSTON RESERVOIR
MAXIMIZATION OF EXCESS BENEFITS OVER COSTS
(LAKEVIEW RESERVOIR IN OPERATION)

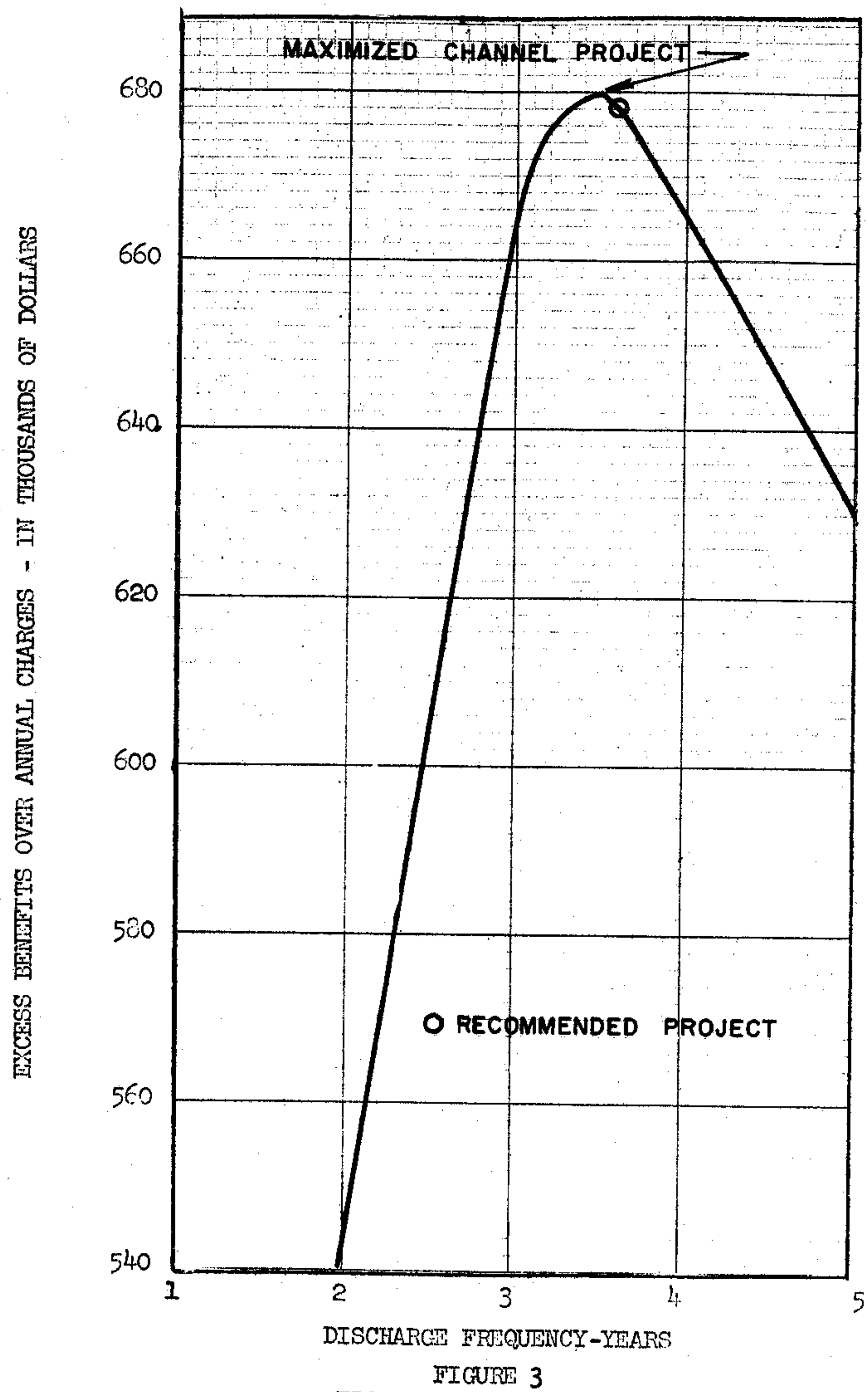


FIGURE 3
FLOOD CONTROL CHANNEL
LIVINGSTON DAM TO HEAD OF WALLISVILLE RESERVOIR
MAXIMIZATION OF EXCESS BENEFITS OVER COSTS
(LAKEVIEW RESERVOIR IN OPERATION)

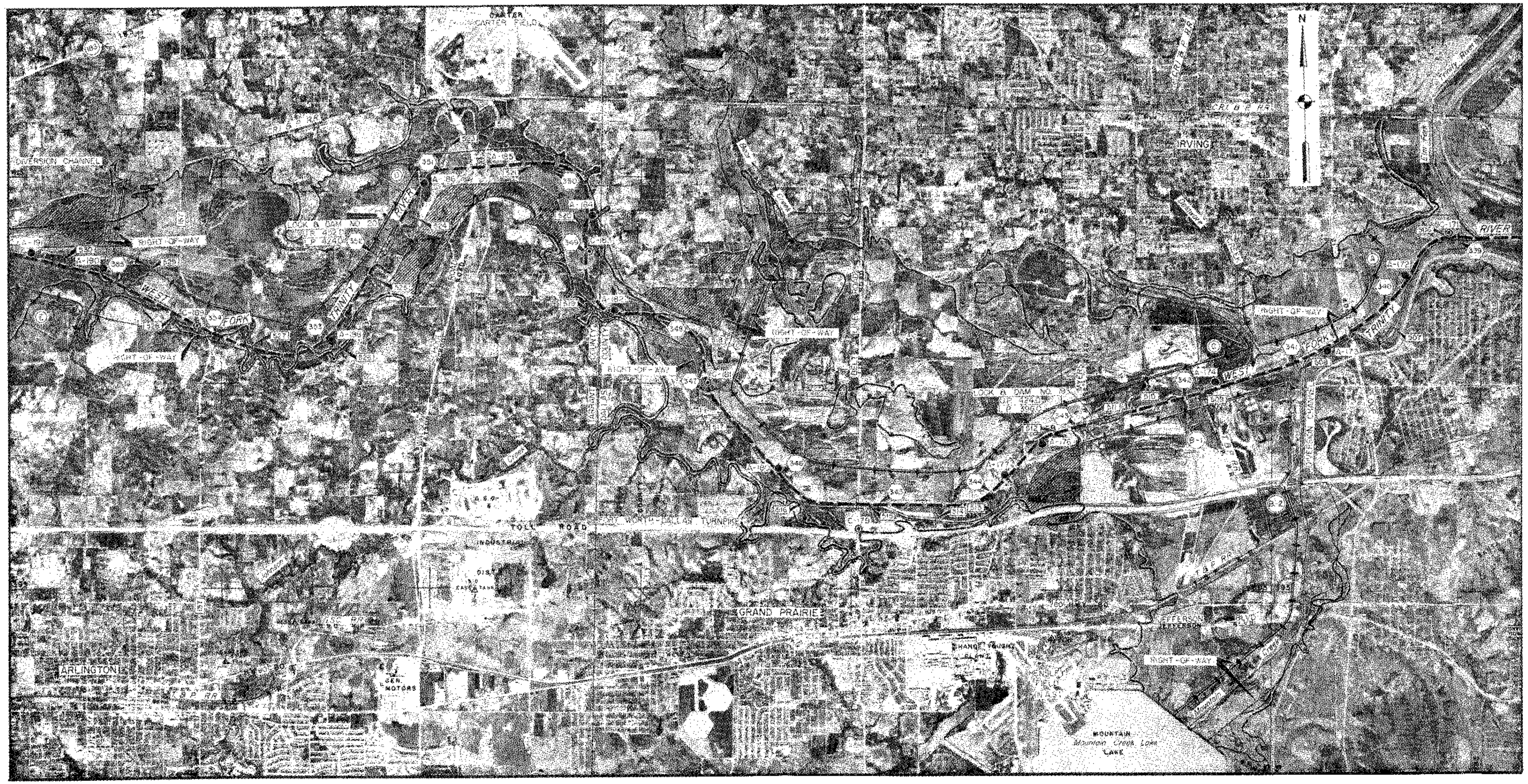
degree of protection to the eleven non-Federal levee districts located along the reach of the Trinity between Five Mile Creek and the head of the recommended Tennessee Colony Reservoir. The residual damages would be significantly high, however, along the Trinity River in the urban complex between the completed floodways in Fort Worth and Dallas. The same conditions prevail for the urban areas below the existing Dallas Floodway and in the downstream reach of Elm Fork at Dallas. A higher degree of protection is desirable along the rural flood plain areas of the Trinity River below the recommended Tennessee Colony Reservoir and additional protection is also needed for the City of Liberty in the lower basin. The magnitude of the residual flood problem is indicated in the following tabulation:

Reach	Flood Frequency (years)	Residual Annual Damages (dollars)
Elm Fork		
Lewisville Dam to Mouth	14.0 - 12.5	541,300
Denton Creek-Grapevine Dam to Elm Fork	25.0	4,900
West Fork		
Existing Floodway at Fort Worth to Existing Floodway at Dallas	7.7	2,680,200
Trinity		
Through Existing Floodway at Dallas	SPF	0
Extension of Existing Dallas Floodway to Five Mile Creek	5.9 - 6.6	983,000
Five Mile Creek to Head of Tennessee Colony Reservoir	4.0 - 7.4	861,300
Tennessee Colony Dam to Head of Livingston Reservoir	3.0	1,655,500
Livingston Dam to Head of Wallisville Reservoir	3.6	898,200

43. WEST FORK FLOODWAY.- As pointed out previously, the considered flood control only channel operating with existing projects would not provide the desired degree of protection to the Fort Worth-Dallas urban complex located along a 31-mile reach of the West Fork. Studies of alternative solutions showed that the most reasonable way to provide the needed flood protection would be by the addition of a levee system. On the basis of preliminary estimates, a project having a relatively wide floodway between levees in combination with a relatively narrow channel, was compared with a project having a

narrower floodway in combination with a wider channel. This study indicated that either plan could be justified. However, the maximum excess of benefits over costs for these two projects would be realized from the plan using the relatively narrow floodway in combination with a relatively wide channel. The channel capacity required for efficient reservoir operation is 15,000 cubic feet per second above Mountain Creek and 17,000 cubic feet per second downstream, and the floodway improvement proposed has a channel capacity of 30,000 cubic feet per second. The added features to the 31-mile long improved channel for flood control extending from the mouth of the Elm Fork at the Dallas Floodway upstream to the end of the existing Fort Worth Floodway include the enlargement and realignment or diversion of about 16.7 miles of tributary channels through the proposed leveed areas; the construction of a parallel levee system through the low areas consisting of about 34.0 miles of levee along the left bank, 9.1 miles of new levee and the rehabilitation of 1.5 miles of existing levee on the right bank of the West Fork and tributary channels. The floodway along the West Fork would be a dedicated floodway maintained free of encroachments and would vary in width from 1,000 feet to 3,000 feet between centerline of levees. It would have sufficient capacity to contain the standard project flood which varies from about 95,000 cubic feet per second at Fort Worth to about 160,000 cubic feet per second at the mouth of Elm Fork. Incremental cost and benefit data for adding the levee works to the single purpose channel are tabulated below. This cost includes all necessary modifications in the existing Dallas Floodway that are necessary for the proper functioning of the West Fork Floodway and are based on Lakeview Reservoir being operational. The plan of improvement and detailed profiles for the West Fork and Tributaries are shown on plates 3 through 8.

Incremental annual cost	$2,118,400
Incremental annual benefits	$2,359,400
Benefit-Cost Ratio	1.1



LEGEND

- NAVIGATION AND FLOOD CONTROL CHANNEL
- DESIGN WATER SURFACE
- HIGH WATER LINE (MAXIMUM OF RECORD)
- NAVIGATION LOCK AND DAM
- RIVER MILEAGE
- CHANNEL MILEAGE
- CORE BORINGS
- AUGER BORINGS
- FILL AREA
- SUMP AREA
- NEW EARTH LEVEES
- EXISTING LEVEES
- STRENGTHEN EXISTING LEVEES
- FEDERAL HIGHWAY
- STATE HIGHWAY
- INTERSTATE HIGHWAY
- FARM TO MARKET ROAD
- EXISTING BRIDGE
- COUNTY LINE
- GRAVITY FLOW DRAINAGE STRUCTURE

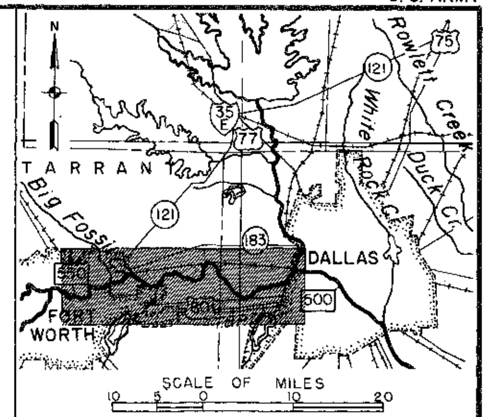
TRINITY RIVER AND TRIBUTARIES, TEXAS
WEST FORK AND TRIBUTARIES
MULTIPLE PURPOSE CHANNEL
AND FLOODWAY

PLAN OF IMPROVEMENT

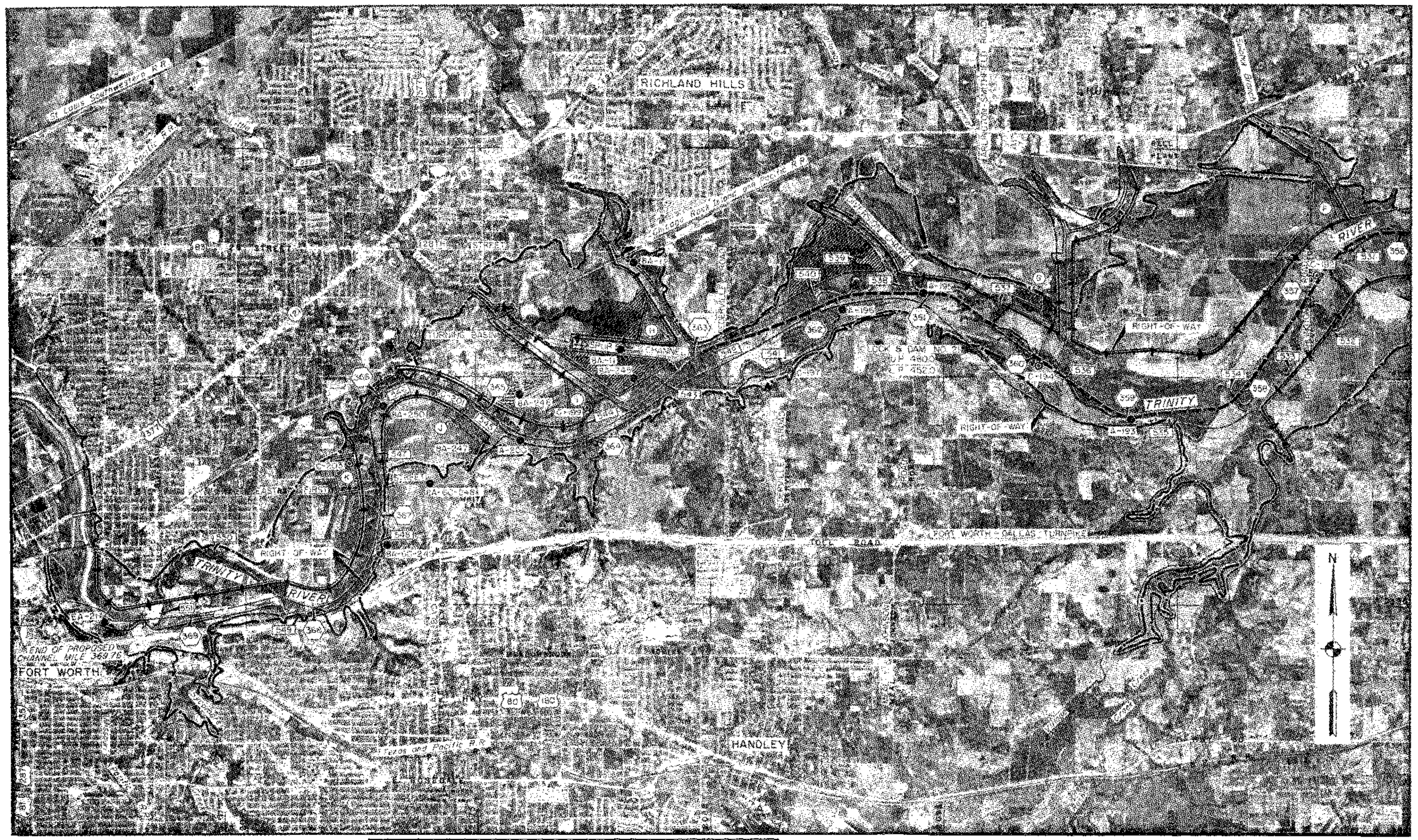
IN 2 SHEETS — SCALE OF FEET 2000 0 2000 4000 — SHEET NO. 1

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
W. C. Wood, ENGINEER, CHIEF PLANNING & REPORTS BRANCH	C. B. Swenson, ENGINEER, CHIEF, ENGINEERING DIVISION	COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: A. W. Hawley, ENGINEER, HEAD, SPECIAL STUDIES SECTION	DRAWN BY: O.E.C. CHECKED BY: J.H.L.	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER. FILE: TRIN 230-19



VICINITY MAP



LEGEND

- NAVIGATION AND FLOOD CONTROL CHANNEL
- DESIGN WATER SURFACE
- HIGH WATER LINE (MAXIMUM OF RECORD)
- NAVIGATION LOCK AND DAM
- RIVER MILEAGE
- CHANNEL MILEAGE
- CORE BORINGS
- AUGER BORINGS
- FILL AREA
- SUMP AREA
- NEW EARTH LEVEES
- EXISTING LEVEES
- STRENGTHEN EXISTING LEVEES
- FEDERAL HIGHWAY
- STATE HIGHWAY
- INTERSTATE HIGHWAY
- FARM TO MARKET ROAD
- EXISTING BRIDGE
- COUNTY LINE
- GRAVITY FLOW DRAINAGE STRUCTURE

DRAINAGE AREA AND SUMP	DRAINAGE AREA		SLUICES			SUMPS			
	ACRES	SQ. MI.	NO. REQ'D.	SIZE	INVERT EL.	DAMAGING STAGE EL.	BOTTOM EL.	CAP. AT DAMAGING STAGE EL. AC-FT.	DESIGN FLOOD WATER SURFACE EL.
A	861	1.35	1	5'X5'	399.0	415.0	398	450	413.7
B-1	672	1.05	1	4'X4'	399.0	422.0	398	350	419.2
B-2	2,317	3.62	1	6'X6'	401.0	422.0	400	1,150	421.9
C	5,000	7.81	2	6'X6'	399.0	426.0	398	2,350	425.5
D	2,273	3.55	1	6'X6'	427.0	456.0	426	1,100	454.7
E	1,488	2.33	1	5'X5'	455.0	477.0	454	750	475.7
F	1,951	3.05	1	6'X6'	455.0	474.0	454	1,000	473.1
G	1,176	1.84	1	4'X4'	455.0	478.0	454	600	477.9
H	1,104	1.73	1	6'X6'	483.0	495.0	482	550	494.8
I	1,324	2.07	1	6'X6	483.0	500.0	482	650	499.0
J	495	0.77	1	4'X4'	483.0	500.0	482	250	498.0
K	1,467	2.29	1	5'X5'	483.0	505.0	482	700	503.7

TRINITY RIVER AND TRIBUTARIES, TEXAS
WEST FORK AND TRIBUTARIES
MULTIPLE PURPOSE CHANNEL
AND FLOODWAY

PLAN OF IMPROVEMENT

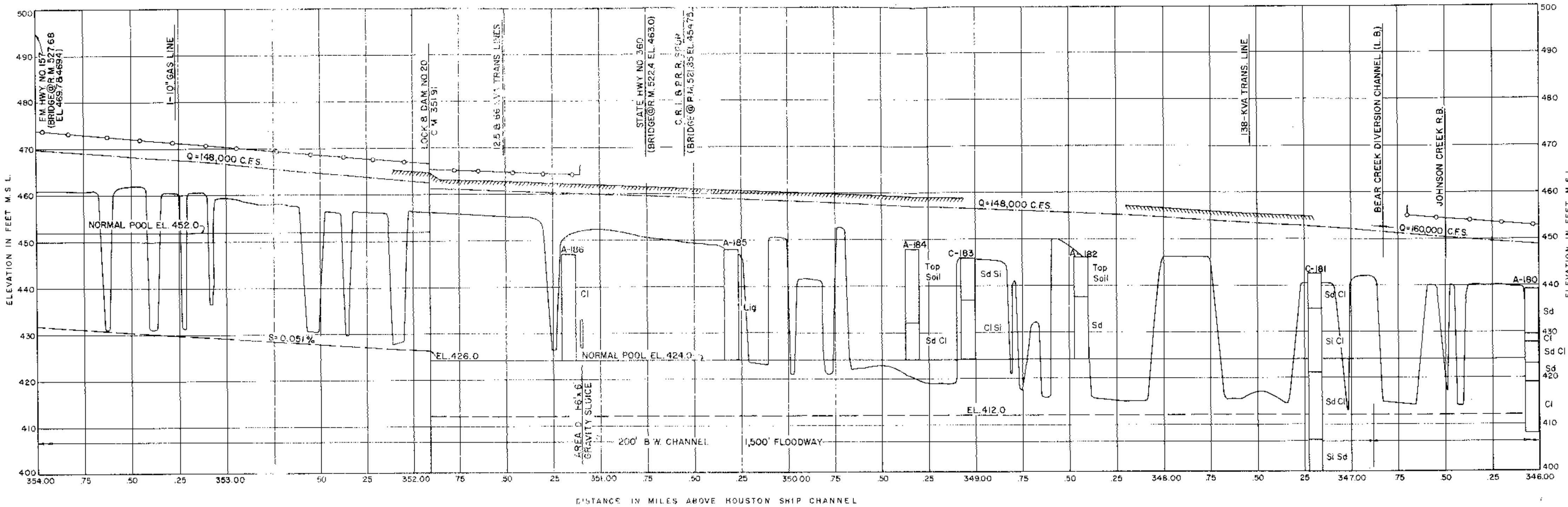
IN 2 SHEETS — SCALE OF FEET 2000 0 2000 4000 — SHEET NO. 2

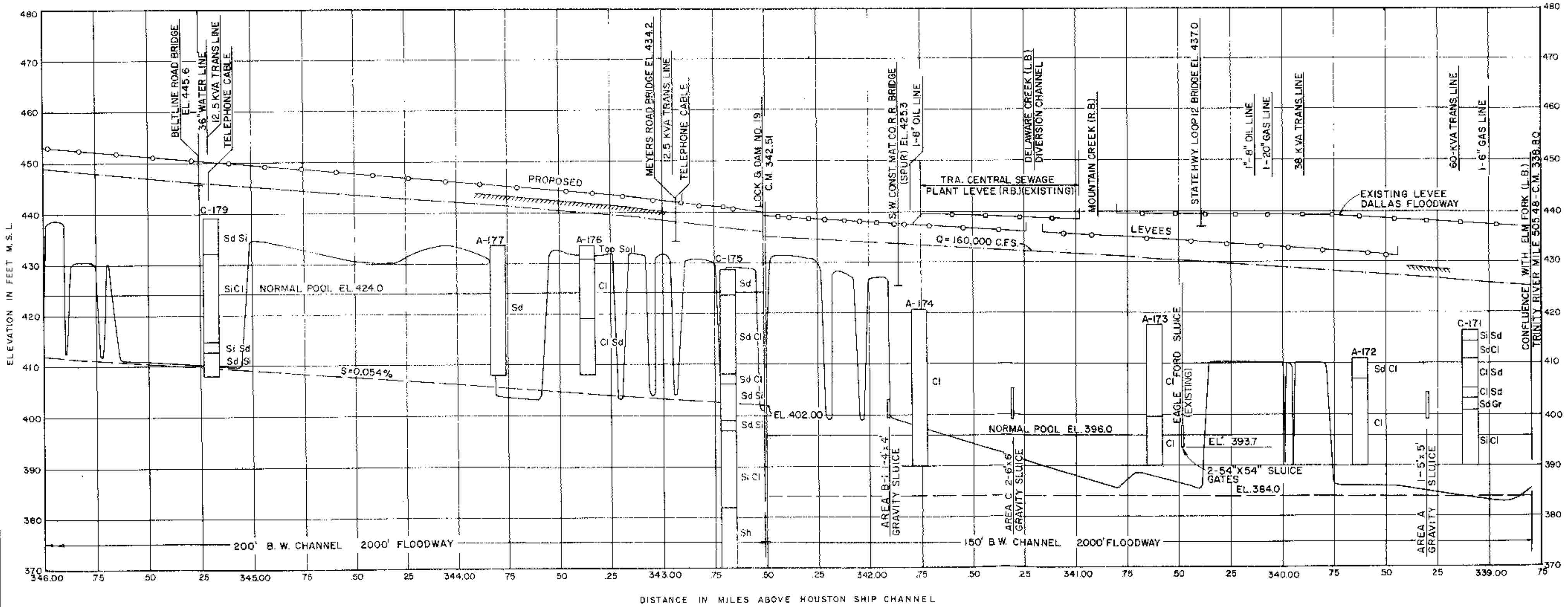
U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

SUBMITTED: W. E. Wood, ENGINEER, CHIEF PLANNING & REPORTS BRANCH
APPROVAL RECOMMENDED: C. B. Swenson, ENGINEER, CHIEF, ENGINEERING DIVISION
APPROVED: D. D. West, COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: A. W. Hawley, ENGINEER, HEAD, SPECIAL STUDIES SECTION
DRAWN BY: M.E.G.
CHECKED BY: J.H.L.
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER
FILE: TRIN 230-19

PLATE 4

92-104 O-63 Vol. II (Face p. 50) No. 2





BORING LEGEND

LABORATORY CLASSIFICATION

- SM Silty Sands, Sand-Silt mixtures
- SC Clayey Sand, Sand-Clay mixtures
- ML Inorganic Silts and very fine Sands, Rock Flour, Silty or Clayey fine Sands or Clayey Silts with slight plasticity.
- CL Inorganic Clays of low plasticity, Gravelly Clays, Sandy Clays, Silty Clays, Lean Clays
- CH Inorganic Clays of high plasticity, Fat Clays.

VISUAL CLASSIFICATION

- Gr Gravel or Gravelly
- Sd Sand or Sandy
- Si Silt or Silty
- Cl Clay or Clayey
- FE Fuller's Earth
- SS Sandstone
- SiS Siltstone
- CS Claystone
- Sh Shale or Shaly
- Lig Lignite
- Ls Limestone
- H Hard
- 8A Machine Auger Boring, 8" diameter
- 6C Core Boring, 6" diameter
- W.T. Water Table
- H.D. Texas Highway Dept. boring
- R.D. Dallas County Road District No. 1 Borings

Absence of ground water levels opposite boring logs does not mean necessarily that ground water will not be encountered at the locations or within the vertical reaches of the borings.

Figures to the right of boring logs are water contents in percent of the dry weight.

NOTES:

Floodway dimensions shown are minimum requirements measured from centerline of levees, or from centerline of levee to natural bank or fill area.

Channel side slopes are 1 vertical on 2 horizontal. Levee side slopes are 1 vertical on 2½ horizontal.

All bridges shown are existing structures. Elevations of bridges refer to existing low steel elevations.

LEGEND

- DESIGN WATER SURFACE
- LEVEE, RIGHT BANK
- LEVEE, LEFT BANK
- CENTERLINE PROFILE
- BOTTOM GRADE
- PROPOSED FILL AREAS, LEFT BANK
- PROPOSED FILL AREAS, RIGHT BANK
- B.W. BOTTOM WIDTH
- L.B. LEFT BANK
- R.B. RIGHT BANK

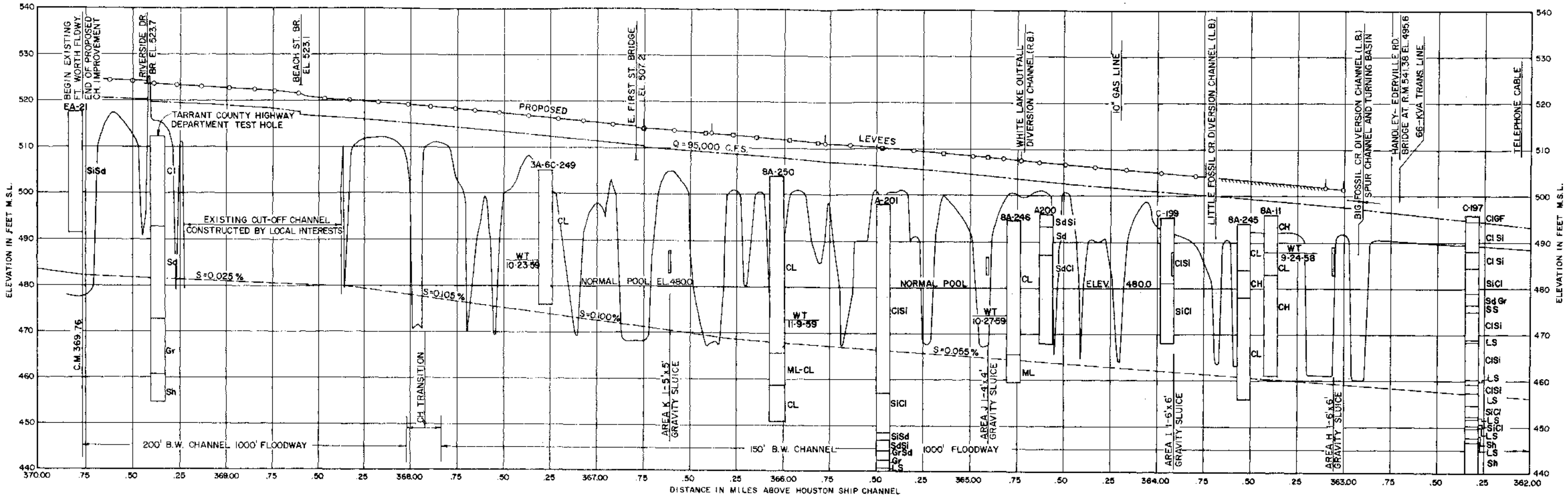
TRINITY RIVER AND TRIBUTARIES, TEXAS
WEST FORK
MULTIPLE PURPOSE CHANNEL

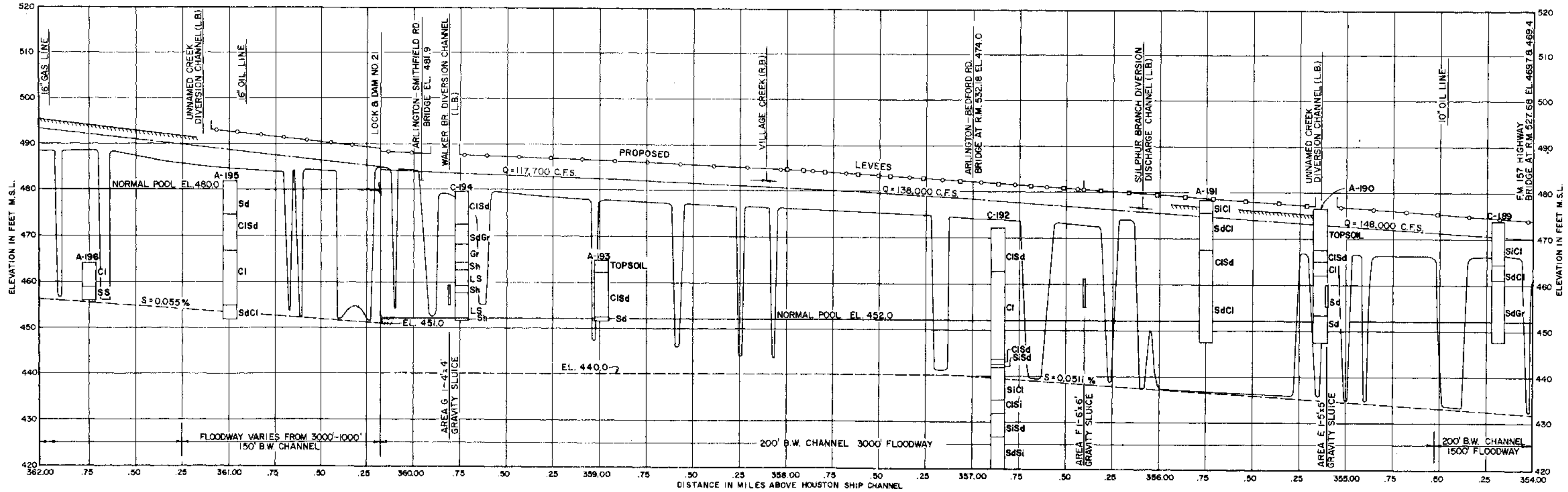
DETAILED PROFILES

IN 2 SHEETS — SCALES AS SHOWN — SHEET NO. 1

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

SUBMITTED: [signature] ENGINEER, CHIEF, PLANNING & REPORTS BRANCH
APPROVAL RECOMMENDED: [signature] ENGINEER, CHIEF, ENGINEERING DIVISION
APPROVED: [signature] COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: [signature] ENGINEER, HEAD SPECIAL STUDIES SECTION
DRAWN BY: U.J.M.
CHECKED BY: J.R.L.
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER
FILE TRIN 230-19





NOTES:

Floodway dimensions shown are minimum requirements measured from centerline of levees, or from centerline of levee to natural bank or fill area.

All channel side slopes are 1 vertical on 2 horizontal. Levee side slopes are 1 vertical on 2½ horizontal.

All bridges shown are existing structures. Elevations of bridges refer to existing low steel elevations.

LEGEND

—·—·—	DESIGN WATER SURFACE
—□—	LEVEE, RIGHT BANK
—○—	LEVEE, LEFT BANK
———	CENTERLINE PROFILE
— — —	BOTTOM GRADE
//////	FILL AREA, LEFT BANK
B.W.	BOTTOM WIDTH
L.B.	LEFT BANK
R.B.	RIGHT BANK

TRINITY RIVER AND TRIBUTARIES, TEXAS
WEST FORK
MULTIPLE PURPOSE CHANNEL

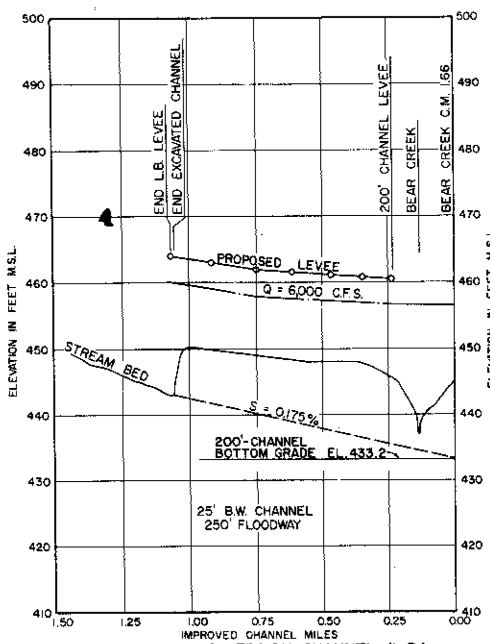
DETAILED PROFILES

IN 2 SHEETS — SCALES AS SHOWN — SHEET NO. 2

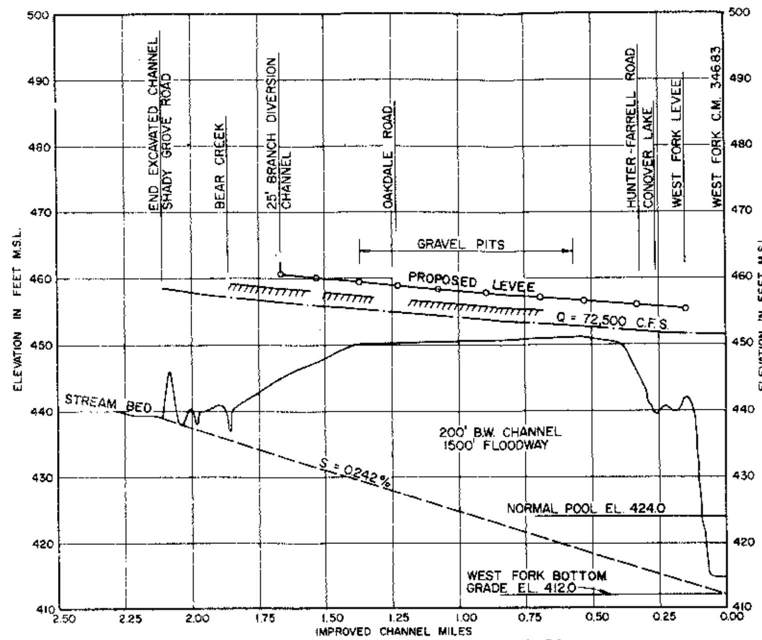
U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JAN. 1962

SUBMITTED: [signature] CHIEF, PLANNING & REPORTS BRANCH
APPROVAL RECOMMENDED: [signature] CHIEF, ENGINEERING DIVISION
APPROVED: [signature] COL., CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: [signature] HEAD, SPECIAL STUDIES SECTION
DRAWN BY: M.S.F.
CHECKED BY: A.H.L.
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER
FILE: TRIN 230-19

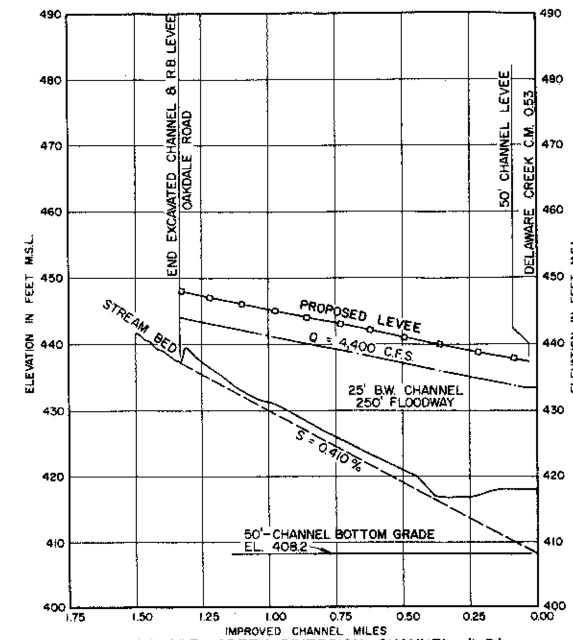
PLATE 6



BEAR CREEK DIVERSION CHANNEL (L.B.)



BEAR CREEK DIVERSION CHANNEL (L.B.)



DELAWARE CREEK DIVERSION CHANNEL (L.B.)

LEGEND

——·——	DESIGN WATER SURFACE
——□——	LEVEE, RIGHT BANK
——○——	LEVEE, LEFT BANK
————	CENTERLINE PROFILE
— — — —	BOTTOM GRADE
//////////	FILL AREA, RIGHT BANK
\\\\\\\\\\	FILL AREA, LEFT BANK
B.W.	BOTTOM WIDTH
L.B.	LEFT BANK
R.B.	RIGHT BANK

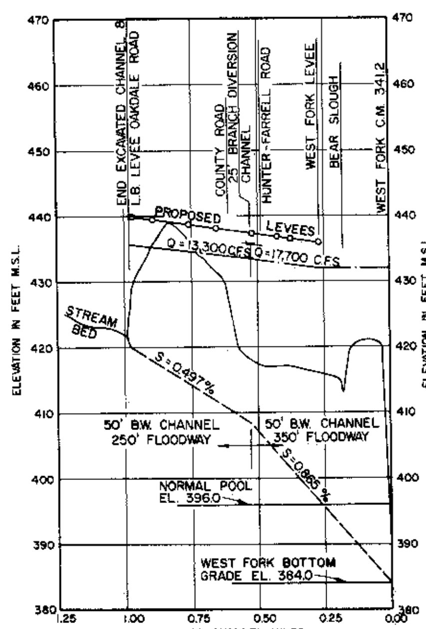
NOTES:

Floodway dimensions shown are minimum requirements measured from centerline of levees, or from centerline of levee to natural bank or fill area.

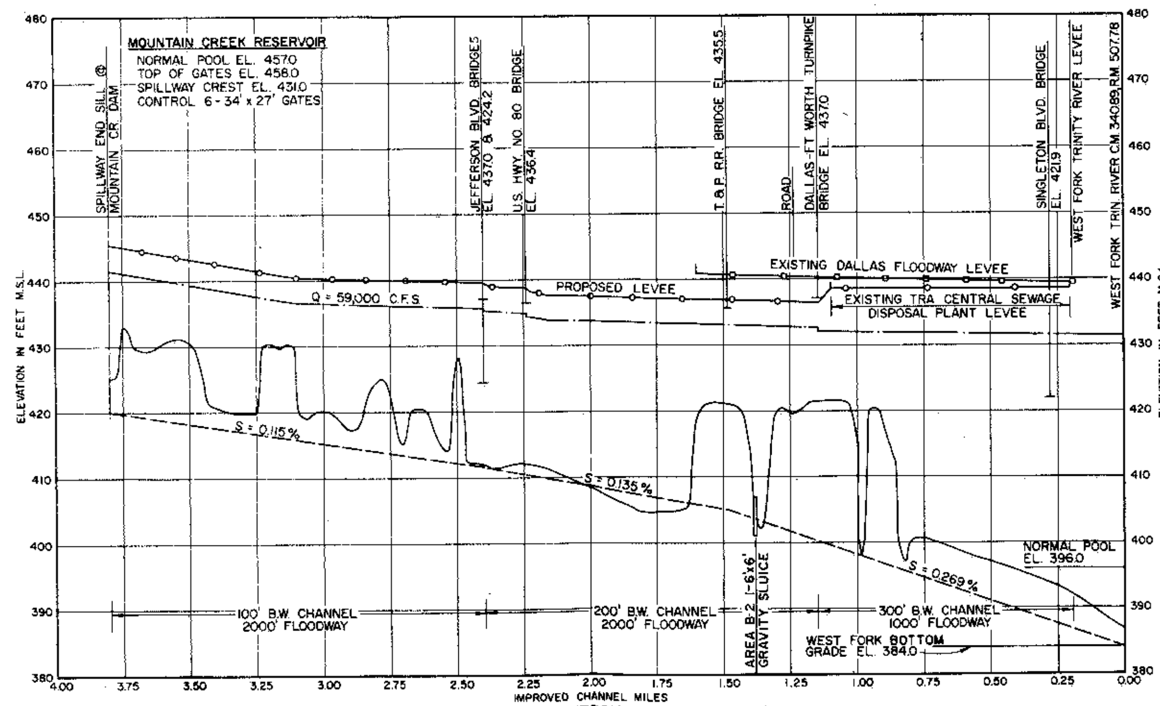
All channel side slopes are 1 vertical on 2 horizontal. Levee side slopes are 1 vertical on 2½ horizontal.

All bridges shown are existing structures. Elevations of bridges refer to existing low steel elevations.

Refer to plate 117 for typical channel and levee sections.



DELAWARE CREEK DIVERSION CHANNEL (L.B.)



MOUNTAIN CREEK DIVERSION CHANNEL (R.B.)

TRINITY RIVER AND TRIBUTARIES, TEXAS
WEST FORK TRIBUTARIES
FLOOD CONTROL CHANNELS AND FLOODWAYS

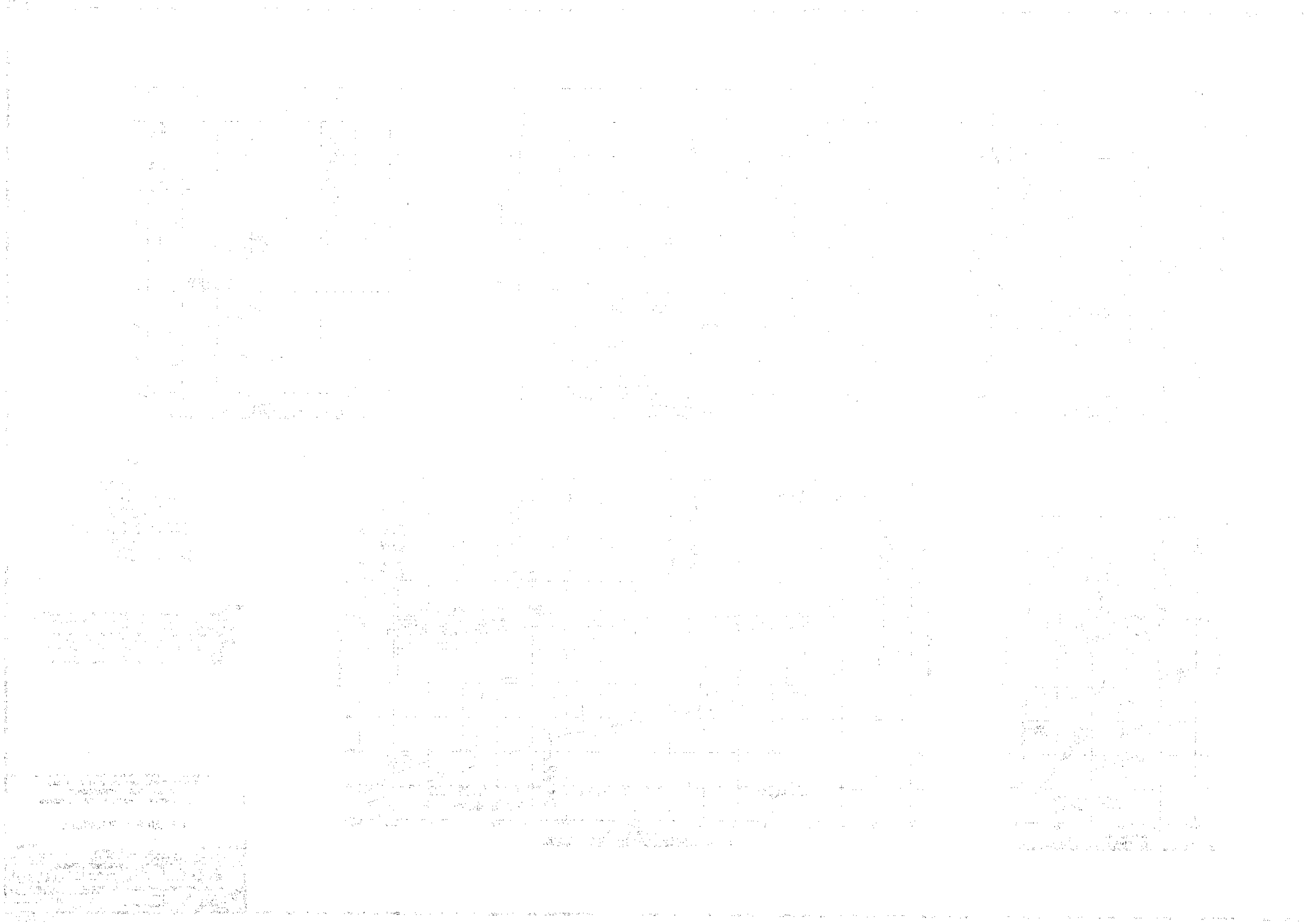
DETAILED PROFILES

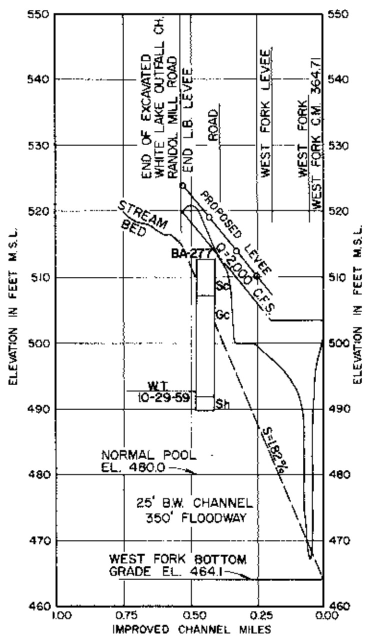
IN 2 SHEETS — SCALES AS SHOWN — SHEET NO. 1

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

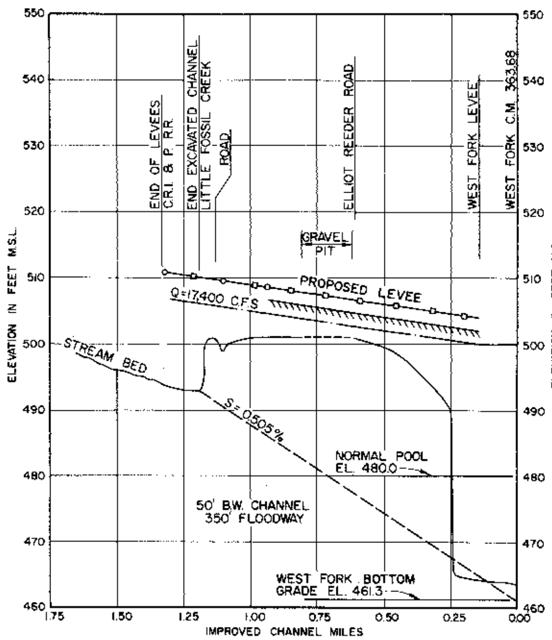
SUBMITTED: W. E. Wood, ENGINEER, CHIEF PLANNING & REPORTS BRANCH	APPROVAL RECOMMENDED: C. J. Swenson, ENGINEER, CHIEF, ENGINEERING DIVISION	APPROVED: [signature] West, COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: A. W. Hawley, ENGINEER, HEAD, SPECIAL STUDIES SECTION	DRAWN BY: O.E.C. CHECKED BY: J.H.L.	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER; FILE: TRIN 230-19

PLATE 7

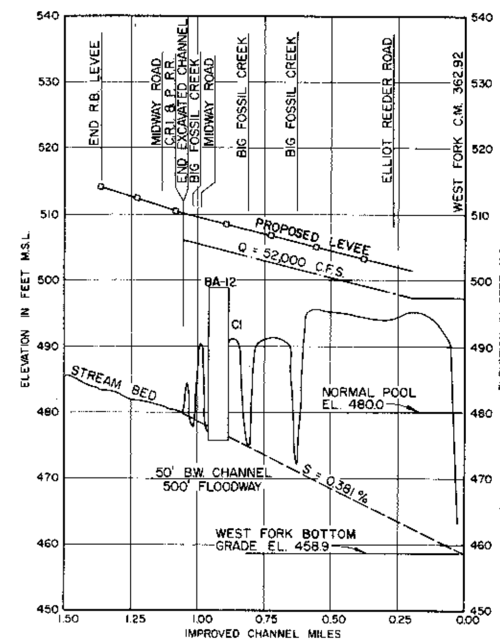




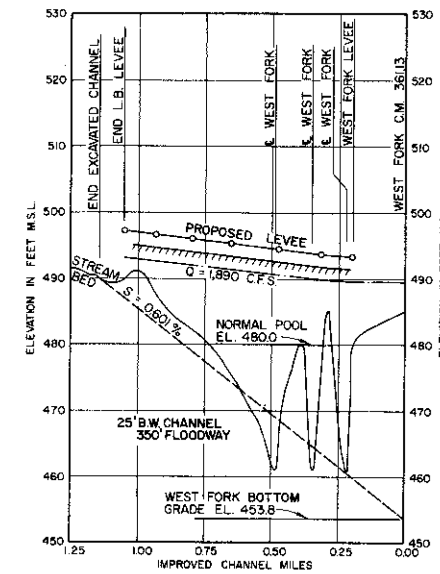
WHITE LAKE OUTFALL DIVERSION CHANNEL (R.B.)



LITTLE FOSSIL CREEK DIVERSION CHANNEL (L.B.)



BIG FOSSIL CREEK DIVERSION CHANNEL (L.B.)

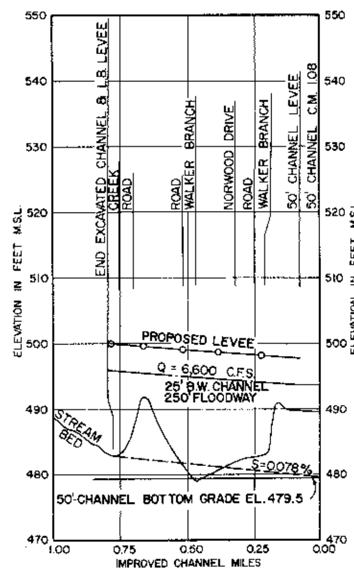


UNNAMED CREEK DIVERSION CHANNEL (L.B.)

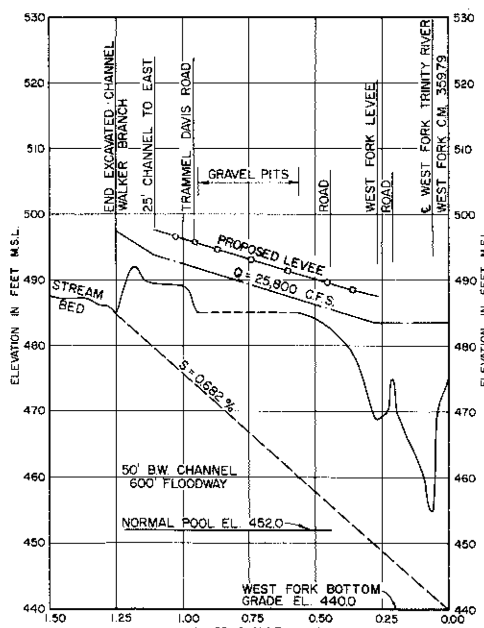
LEGEND

- DESIGN WATER SURFACE
- LEVEE, RIGHT BANK
- LEVEE, LEFT BANK
- CENTERLINE PROFILE
- BOTTOM GRADE
- FILL AREA, RIGHT BANK
- FILL AREA, LEFT BANK

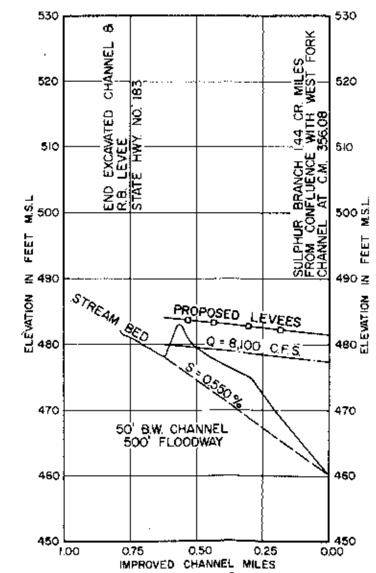
B.W. BOTTOM WIDTH
L.B. LEFT BANK
R.B. RIGHT BANK



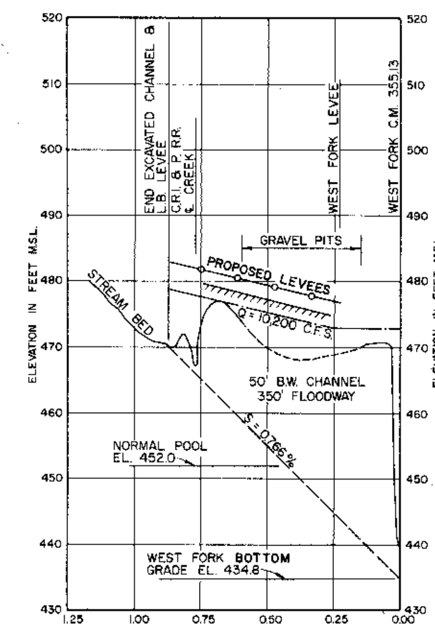
WALKER BRANCH DIVERSION CHANNEL (L.B.)



WALKER BRANCH DIVERSION CHANNEL (L.B.)



SULPHUR BRANCH DIVERSION CHANNEL (L.B.)



UNNAMED CREEK DIVERSION CHANNEL (L.B.)

NOTES:

Floodway dimensions shown are minimum requirements measured from centerline of levees, or from centerline of levee to natural bank or fill area.

All channel side slopes are 1 vertical on 2 horizontal. Levee side slopes are 1 vertical on 2½ horizontal.

All bridges shown are existing structures. Elevations of bridges refer to existing low steel elevations.

New or modified bridge openings are to provide 3 feet minimum vertical clearance above design water surface, and unobstructed horizontal clearance in dedicated floodway exclusive of bridge piers.

TRINITY RIVER AND TRIBUTARIES, TEXAS

WEST FORK TRIBUTARIES

MULTIPLE PURPOSE CHANNEL

DETAILED PROFILES

IN 2 SHEETS — SCALES AS SHOWN — SHEET NO. 2

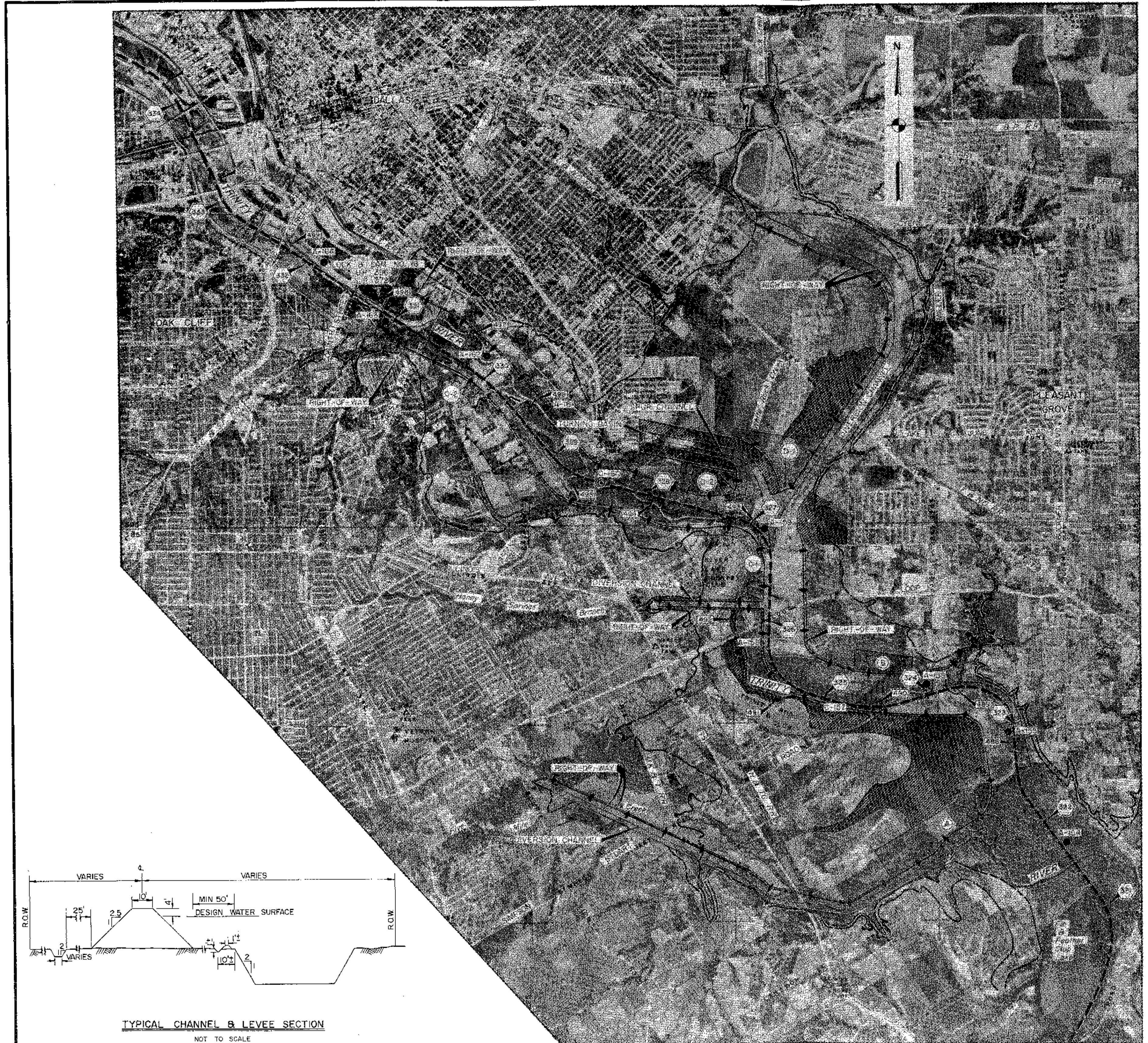
U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

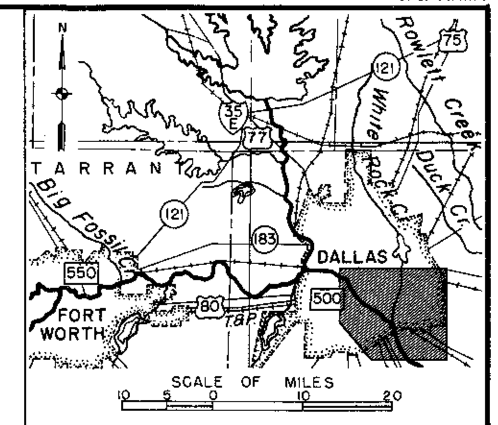
SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
W. E. Wood, ENGINEER, CHIEF PLANNING & REPORTS BRANCH	C. J. [signature], ENGINEER, CHIEF, ENGINEERING DIVISION	[signature], COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: A. W. Hawley, ENGINEER, HEAD, SPECIAL STUDIES SECTION	DRAWN BY: O.E.C. / CHECKED BY: J.H.L.	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER / FILE: TRIN 230-19

PLATE 8

44. EXTENSION OF DALLAS FLOODWAY.- In consideration of the urban area needing flood protection to the degree attained by the existing projects and the investigated channel improvements, study was made of extending the existing Dallas Floodway downstream about 9.7 miles along the Trinity River to the mouth of Five Mile Creek. The added flood control features of the project investigated include the enlargement and realignment or diversion of about 10.5 miles of tributary channels through the proposed leveed areas; the construction of a parallel levee system through the low areas consisting of about 10.2 miles of levee on the left bank, 14.6 miles of new levee and the rehabilitation of 0.6 mile of existing levee on the right bank of the proposed enlarged and realigned channel of the main stem and tributary channels. The plan provides for a dedicated floodway maintained free of encroachments. The floodway along the main stem would have a minimum width of 2,000 feet between centerline of levees and have sufficient capacity to contain the standard project flood which varies from 163,800 cubic feet per second at Dallas to 174,600 cubic feet per second in the lower reach just upstream from the mouth of Five Mile Creek. Studies showed that the cost of adding levee and appurtenant works to the proposed improved channel works was incrementally justified. It was found in other studies that with the addition of a reservoir at the Lakeview site on Mountain Creek containing flood control storage of 136,700 acre-feet, the design discharge would be lowered by about 60,000 cubic feet per second, the water surface profile would be lowered in the magnitude of 3.5 feet, and thereby Lakeview Reservoir would accrue average annual benefits of about $141,900 from the Dallas Floodway Extension area. Cost and benefit data and other information given in the following tabulation are for adding levees to the flood control channel. This cost is based on Lakeview Reservoir being operational. The plan of improvement and detailed profiles for the project are presented on plates 9 and 10. Plates 11 and 12 show the plan and profile in the existing Dallas Floodway.

Item	Amount
Annual damages with proposed channel and existing projects	$983,000
Annual damages with Dallas Floodway Extension added	0
Incremental annual benefits ($141,900 of $983,000 to Lakeview)	$841,100
Incremental Annual Cost	$684,400
Benefit-Cost Ratio	1.2





VICINITY MAP

DRAINAGE AREA AND SUMP	DRAINAGE AREA		SLUICES			SUMPS			
	ACRES	SQ.MI.	NO. REQ'D	SIZE	INVERT EL.	DAMAGING STAGE EL.	BOTTOM EL.	CAP. AT DAMAGING STAGE EL. AC-FT	DESIGN FLOOD WATER SURFACE EL.
A	5,114	7.99	5	6' X 6'	375	385	374	2,250	385.0
B	1,376	2.15	3	5' X 5'	375	385	374	620	384.5
C-1	2,411	3.77	4	5' X 5'	375	390	374	1,100	389.0
C-2	535	0.84	1	4' X 4'	375	400	374	250	393.2
D-1	3,736	5.84	3	5' X 5'	375	390	374	1,800	389.7
D-2	1,634	2.55	1	5' X 5'	375	390	374	800	388.0

LEGEND

- NAVIGATION AND FLOOD CONTROL CHANNEL
- DESIGN WATER SURFACE
- HIGH WATER LINE (MAXIMUM OF RECORD)
- NAVIGATION LOCK AND DAM
- RIVER MILEAGE
- CHANNEL MILEAGE
- CORE BORINGS
- AUGER BORINGS
- FILL AREA
- SUMP AREA
- NEW EARTH LEVEES
- EXISTING LEVEES
- STRENGTHEN EXISTING LEVEES
- FEDERAL HIGHWAY
- STATE HIGHWAY
- INTERSTATE HIGHWAY
- FARM TO MARKET ROAD
- EXISTING BRIDGE
- COUNTY LINE
- GRAVITY FLOW DRAINAGE STRUCTURE

TYPICAL CHANNEL & LEVEE SECTION

NOT TO SCALE

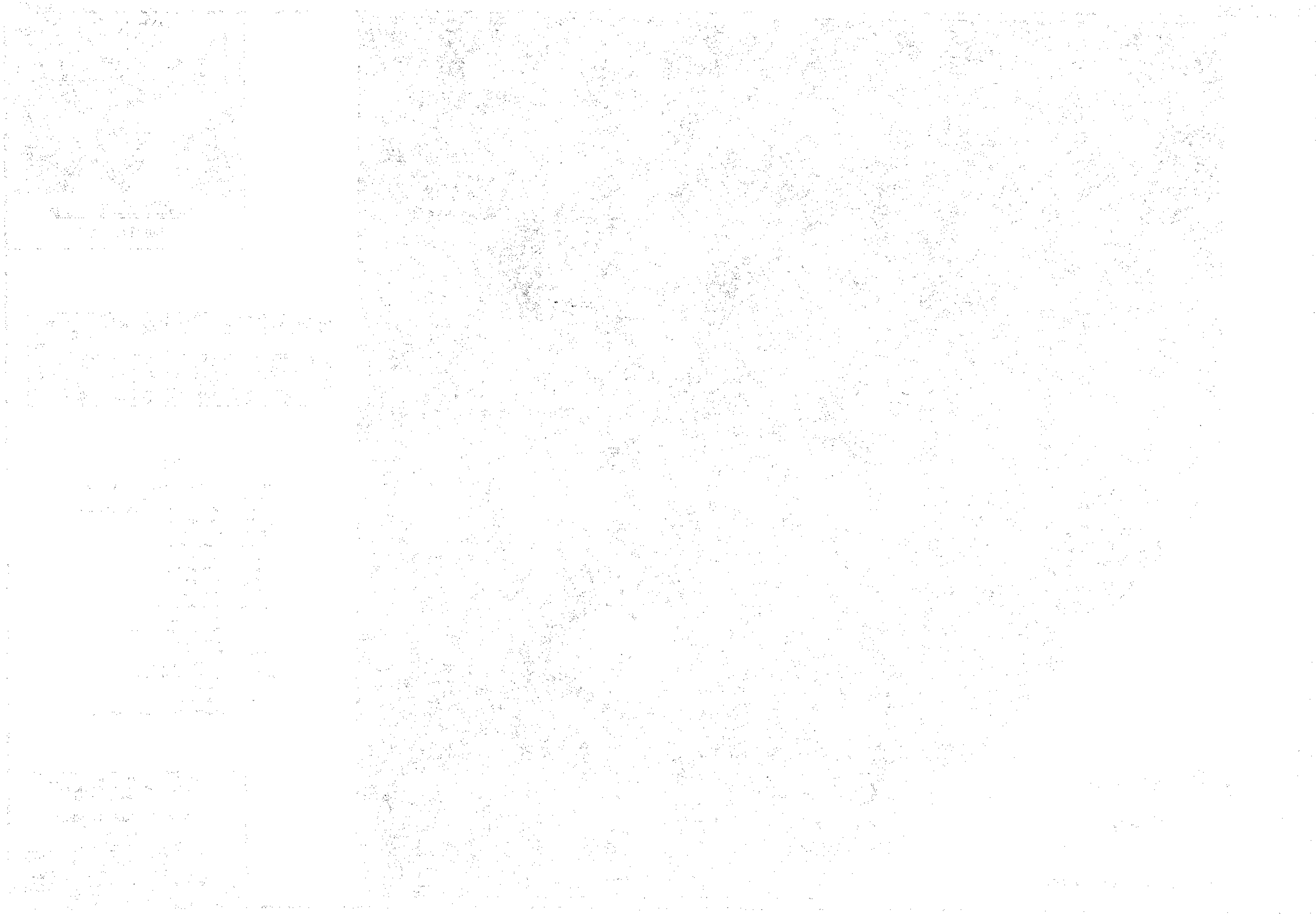
TRINITY RIVER AND TRIBUTARIES, TEXAS
DALLAS FLOODWAY EXTENSION
MULTIPLE PURPOSE CHANNEL

PLAN OF IMPROVEMENT

SCALE OF FEET
2000 0 2000 4000

U.S. ARMY ENGINEER DISTRICT, FORT WORTH JUNE 1962

SUBMITTED: W. C. Wood, ENGINEER, CHIEF PLANNING & REPORTS BRANCH
APPROVAL RECOMMENDED: C. J. Swenson, ENGINEER, CHIEF, ENGINEERING DIVISION
APPROVED: West, COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: A. W. Hawley, ENGINEER, HEAD, SPECIAL STUDIES SECTION
DRAWN BY G.E.C.
CHECKED BY J.H.L.
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER
FILE TRIN 230-19



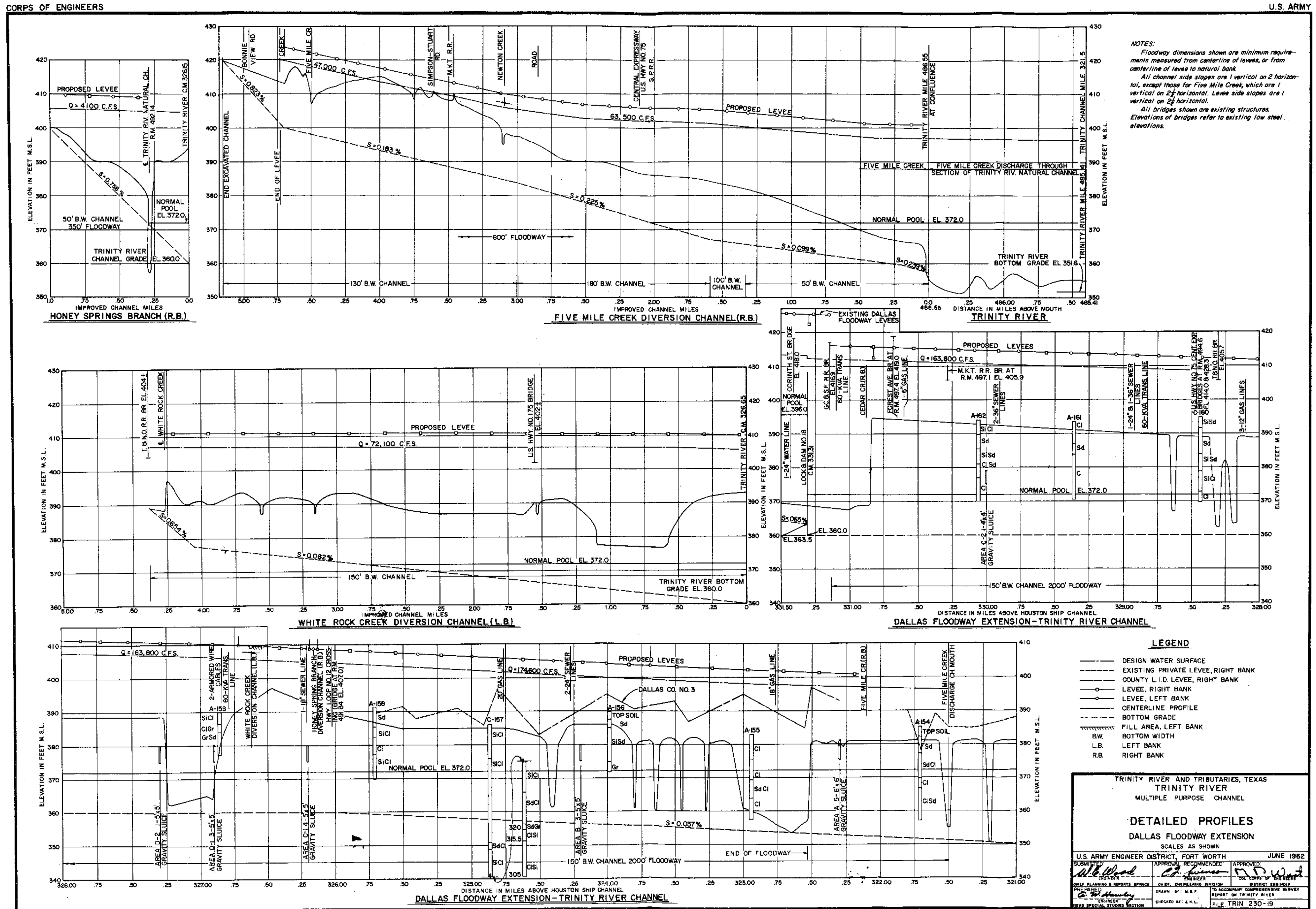
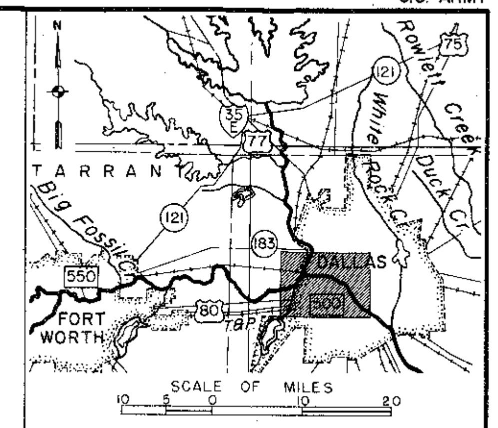


PLATE 10

52-704 O-65 Vol. II (Face blank p. 32) No. 2



VICINITY MAP

LEGEND

- NAVIGATION AND FLOOD CONTROL CHANNEL
- DESIGN WATER SURFACE
- HIGH WATER LINE (MAXIMUM OF RECORD)
- NAVIGATION LOCK AND DAM
- RIVER MILEAGE
- CHANNEL MILEAGE
- CORE BORINGS
- AUGER BORINGS
- FILL AREA
- SUMP AREA
- NEW EARTH LEVEES
- EXISTING LEVEES
- STRENGTHEN EXISTING LEVEES
- FEDERAL HIGHWAY
- STATE HIGHWAY
- INTERSTATE HIGHWAY
- FARM TO MARKET ROAD
- EXISTING BRIDGE
- COUNTY LINE
- GRAVITY FLOW DRAINAGE STRUCTURE

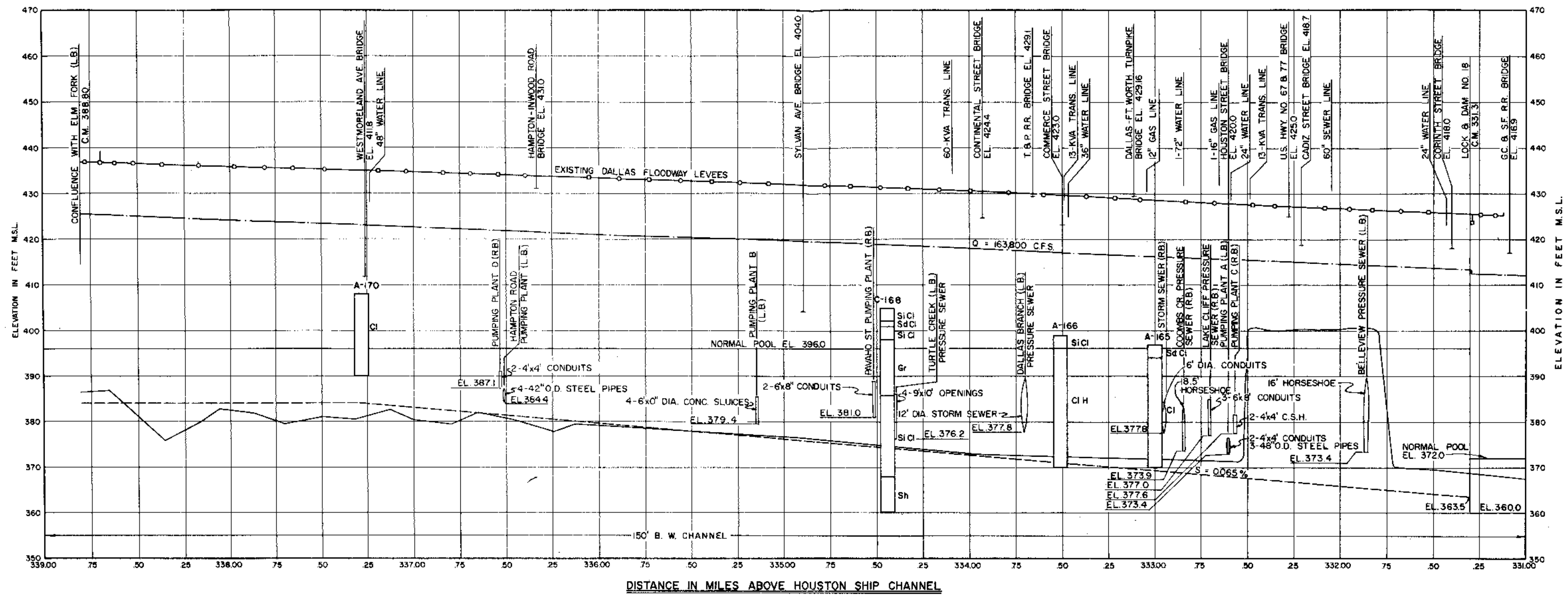
TRINITY RIVER AND TRIBUTARIES, TEXAS
DALLAS FLOODWAY
MULTIPLE PURPOSE CHANNEL

PLAN OF IMPROVEMENT

SCALE OF FEET
2000 0 2000 4000

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
ENGINEER, CHIEF PLANNING & REPORTS BRANCH	ENGINEER, CHIEF, ENGINEERING DIVISION	COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ENGINEER, HEAD, SPECIAL STUDIES SECTION	DRAWN BY: DEC. CHECKED BY: J.H.L.	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER. FILE TRIN 230-19



LEGEND

— · —	DESIGN WATER SURFACE
—o—	LEVEE, RIGHT BANK
—o—	LEVEE, LEFT BANK
———	CENTERLINE PROFILE
— — —	BOTTOM GRADE
L.B.	LEFT BANK
B.W.	BOTTOM WIDTH
R.B.	RIGHT BANK

NOTES:
All channel side slopes are 1 vertical on 2 horizontal.
All bridges shown are existing structures. Elevations of bridges refer to existing low steel elevations.
Pumping plants and drainage structures shown are those of the existing Dallas Floodway.

TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER
MULTIPLE PURPOSE CHANNEL

DETAILED PROFILE

DALLAS FLOODWAY

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
ENGINEER, CHIEF PLANNING & REPORTS BRANCH	ENGINEER, CHIEF, ENGINEERING DIVISION	COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ENGINEER, HEAD SPECIAL STUDIES SECTION	DRAWN BY: D.E.C. / CHECKED BY: J.R.L.	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER / FILE: TRIN 230-19

45. LIBERTY LOCAL PROTECTION PROJECT.- An area subject to flooding along the left bank of the lower Trinity River in the vicinity of Liberty consists of about 50 percent of the highly urbanized portion of the town, oil fields, and pasture lands. Some floods have affected the oil field production for as long a period as 75 days. The degree of protection that would be provided at Liberty by the Tennessee Colony Reservoir and channel ranges in magnitude up to those occurring once in 60 years. A higher degree of protection was considered desirable because of the urban nature of the area. A levee project to provide standard project flood protection would consist of about 53,500 feet of levee and appurtenant works. Incremental costs and benefits of the addition of the Liberty levees to the flood control channel to provide standard project flood protection are $79,200 and $151,500 respectively. This cost is based on the Tennessee Colony Reservoir being operational. The benefit-cost ratio is 1.9. The plan and profile of the proposed plan of improvement are shown on plates 13 and 14.

46. ELM FORK FLOODWAY.- As previously covered in the channel only plan presentation, increasing channel capacities downstream from Grapevine and Lewisville Dams would considerably increase the effectiveness of the Elm Fork project operation, particularly with respect to the evacuation of the flood control storage space in these reservoirs. For more effective reservoir operation, it is proposed to increase the channel capacity of Denton Creek from Grapevine Dam downstream to the Elm Fork to 7,000 cubic feet per second, the Elm Fork from Lewisville Dam downstream to the mouth of Denton Creek to 10,000 cubic feet per second and 15,000 cubic feet per second downstream to its confluence with the West Fork. Annual charges for channel improvement work along Denton Creek below the Grapevine Reservoir are $3,600 and the annual damages prevented are $6,100. This gives a benefit-cost ratio of 1.7 and the frequency of flooding is reduced from once in 17 years to once in 25 years. The channel project along Denton Creek consists of clearing the natural river channel which increases bankfull capacity from 6,000 to 7,000 cubic feet per second. Figure 4 indicates that this project would return the most excess benefits over costs. The annual charges for channel work along the Elm Fork from the Lewisville Damsite to the mouth is $203,000 and the flood damages prevented in this reach total $1,342,900. The channel requirements used in this analysis were established primarily for the purpose of insuring efficient reservoir operation.

47. The flood plain along the lower reaches of the Elm Fork, from the mouth of Denton Creek downstream, is developing rapidly and has great potential as an industrial area partly because of its proximity to Dallas, Irving, Farmers Branch and Carrollton. Extensive flood damages occur along the lower reaches of the Elm Fork below the mouth of Denton Creek. As previously pointed out, with the flood control capabilities of the existing reservoirs augmented by increased channel capacities, a higher degree of control over floods originating on the Elm Fork

CORPS OF ENGINEERS — U. S. ARMY

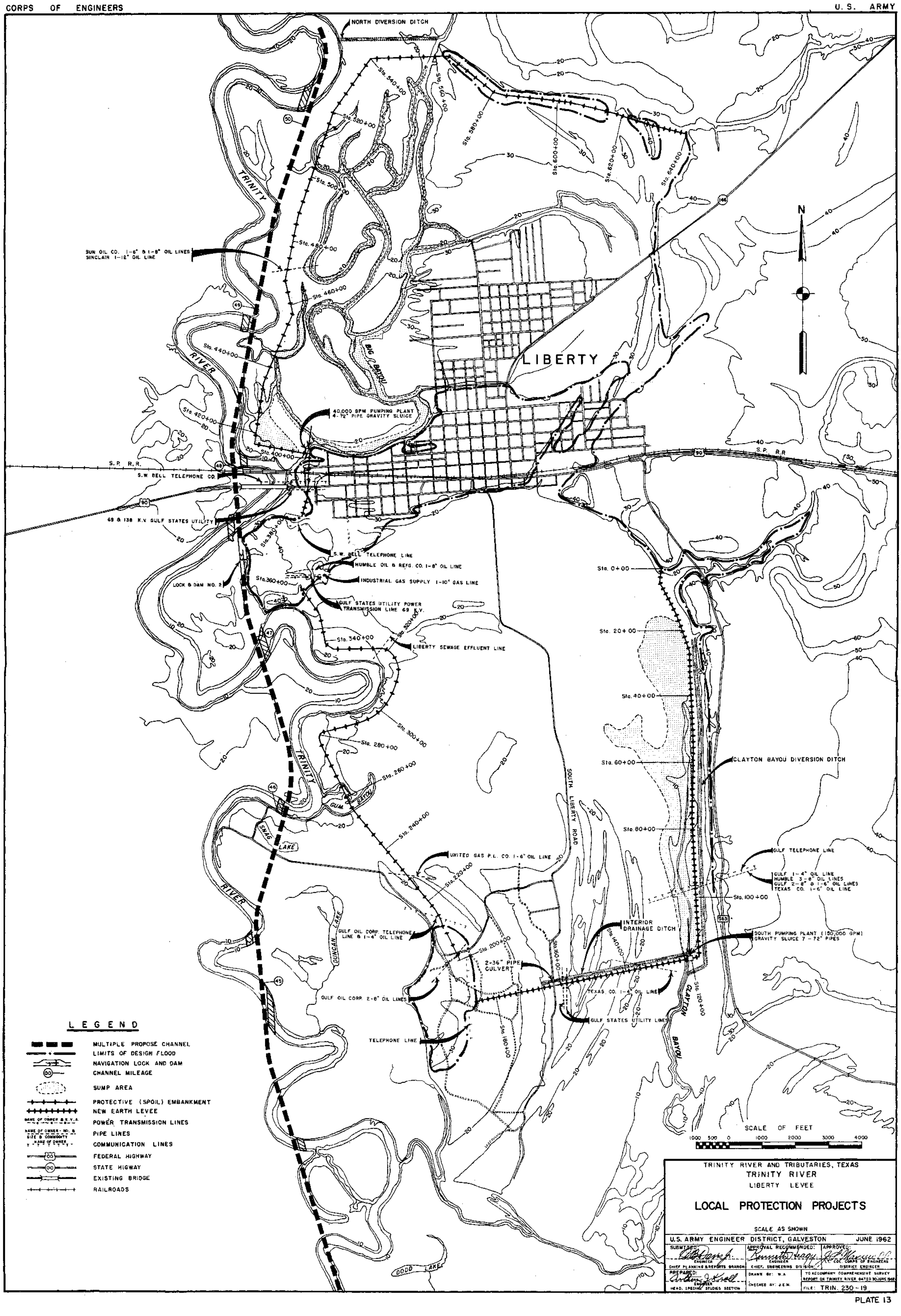
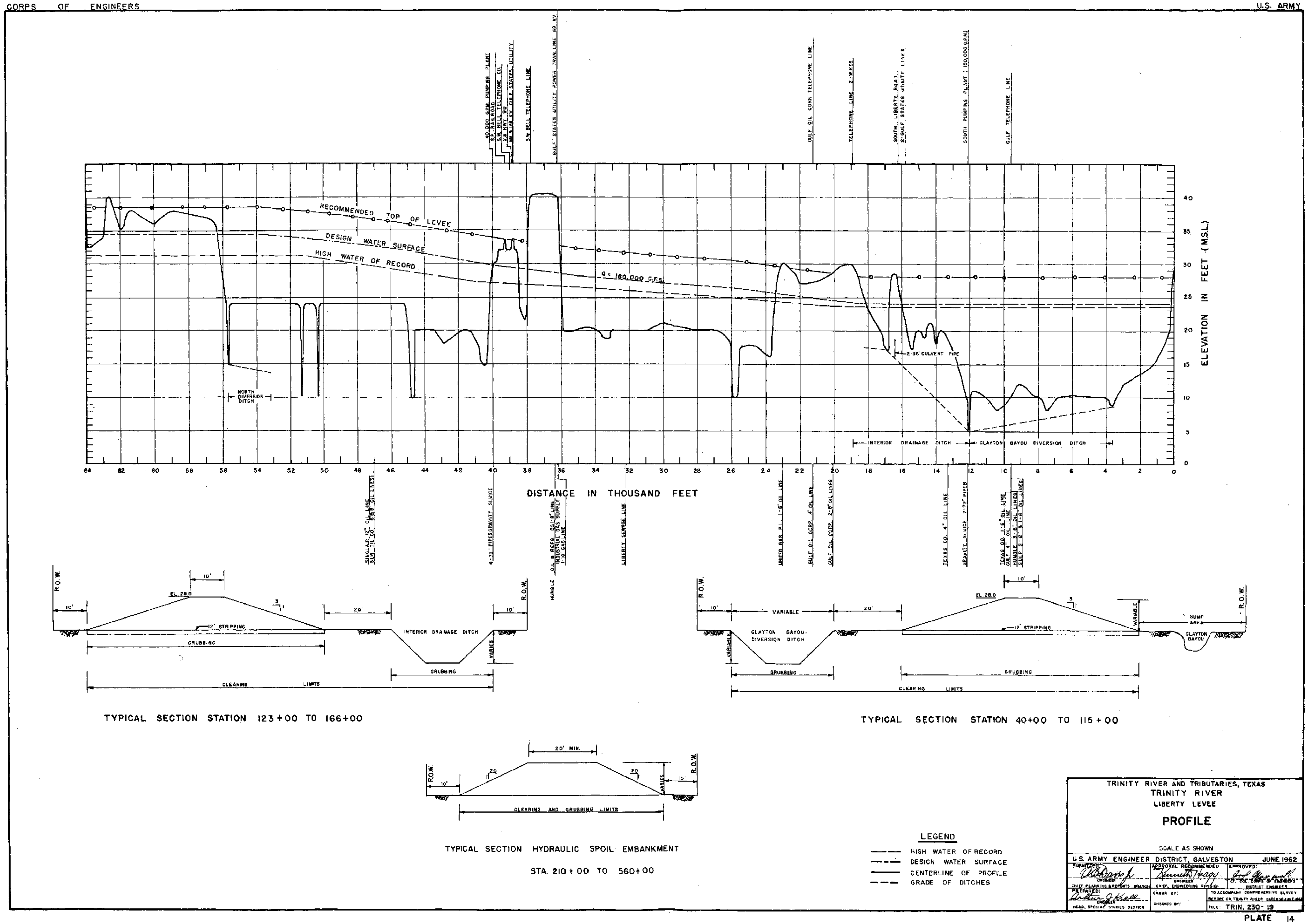


PLATE 13

PLATE 13



CORPS OF ENGINEERS
U.S. ARMY
RECOMMENDED TOP OF LEVEE
DESIGN WATER SURFACE
HIGH WATER OF RECORD
Q = 180,000 C.F.S.
NORTH DIVERSION DITCH
2-36" CULVERT PIPE
INTERIOR DRAINAGE DITCH
CLAYTON BAYOU DIVERSION DITCH
DISTANCE IN THOUSAND FEET
ELEVATION IN FEET (MSL)
40,000 G.P.M. PUMPING PLANT
S.P. RAILROAD
S.W. BELL TELEPHONE CO.
U.S. HWY. 90
GULF STATES UTILITY
S.W. BELL TELEPHONE LINE
GULF STATES UTILITY POWER TRAN. LINE 60 KV
GULF OIL CORP. TELEPHONE LINE
TELEPHONE LINE 2-WIRES
SOUTH LIBERTY ROAD
2-GULF STATES UTILITY LINES
SOUTH PUMPING PLANT (150,000 G.P.M.)
GULF TELEPHONE LINE
SINCLAIR 12" OIL LINE
SUN OIL CO. 6 5/8" OIL LINE
4-72" PIPES GRAVITY SLUICE
HUMBLE OIL & REFG. CO. 8" LINE
INDUSTRIAL GAS SUPPLY
GAS LINE
LIBERTY SEWAGE LINE
UNITED GAS P.L. 1-6" OIL LINE
GULF OIL CORP. 4" OIL LINE
GULF OIL CORP. 2-8" OIL LINES
TEXAS CO. 4" OIL LINE
GRAVITY SLUICE 7-72" PIPES
TEXAS CO. 1-6" OIL LINE
GULF 4" OIL LINE
HUMBLE 3-6" OIL LINES
GULF 2-8" OIL LINES
R.O.W.
EL. 28.0
12" STRIPPING
GRUBBING
INTERIOR DRAINAGE DITCH
VARIES
CLEARING LIMITS
TYPICAL SECTION STATION 123+00 TO 166+00
VARIABLE
CLAYTON BAYOU-DIVERSION DITCH
SUMP AREA
CLAYTON BAYOU
TYPICAL SECTION STATION 40+00 TO 115+00
20' MIN.
CLEARING AND GRUBBING LIMITS
TYPICAL SECTION HYDRAULIC SPOIL EMBANKMENT
STA. 210+00 TO 560+00
LEGEND
HIGH WATER OF RECORD
DESIGN WATER SURFACE
CENTERLINE OF PROFILE
GRADE OF DITCHES
TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER
LIBERTY LEVEE
PROFILE
SCALE AS SHOWN
U.S. ARMY ENGINEER DISTRICT, GALVESTON
JUNE 1962
SUBMITTED:
APPROVAL RECOMMENDED
APPROVED:
CHIEF, PLANNING & REPORTS BRANCH
CHIEF, ENGINEERING DIVISION
DISTRICT ENGINEER
PREPARED:
HEAD, SPECIAL STUDIES SECTION
DRAWN BY:
CHECKED BY:
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER
FILE: TRIN. 230-19
PLATE 14

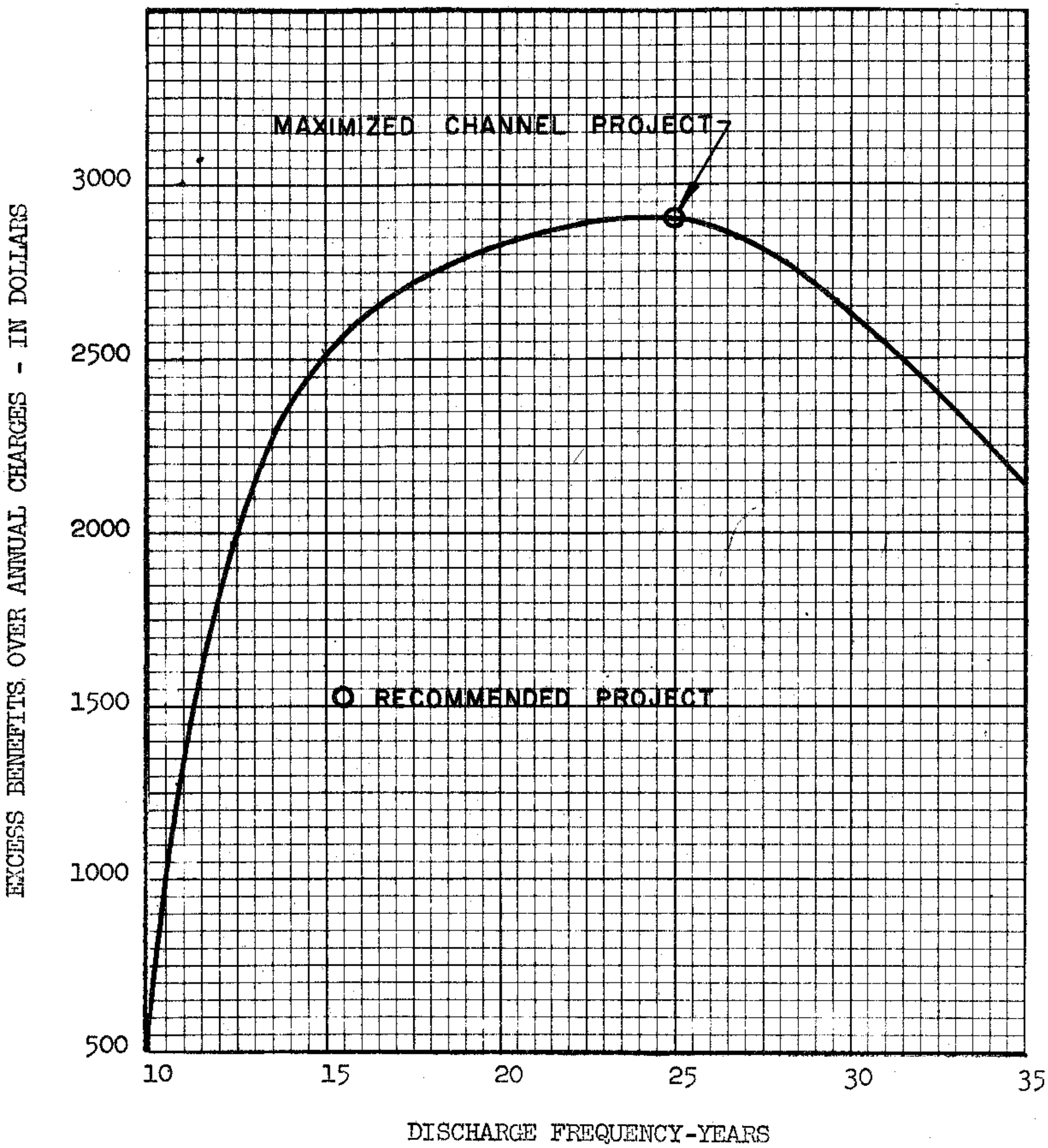
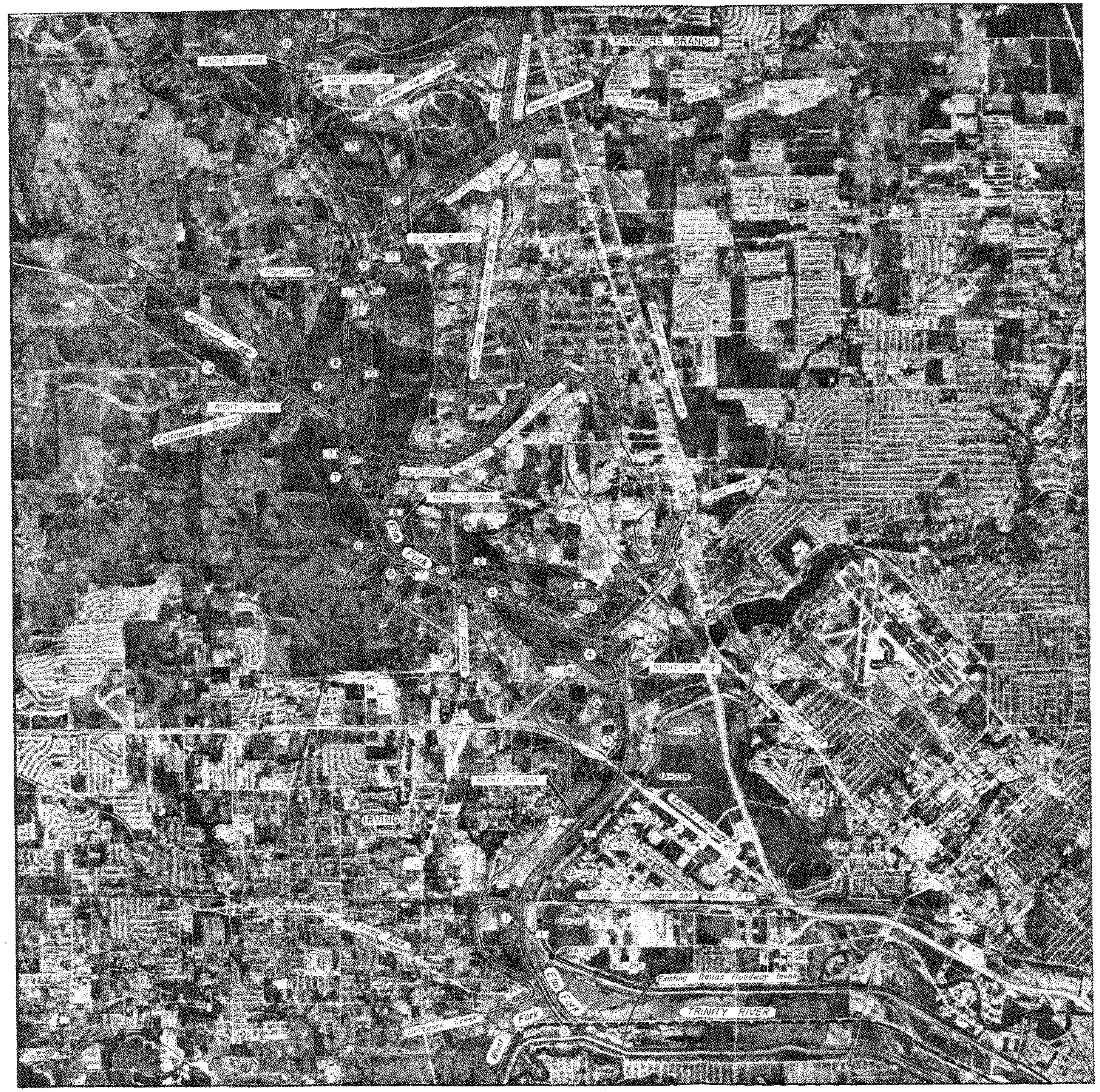
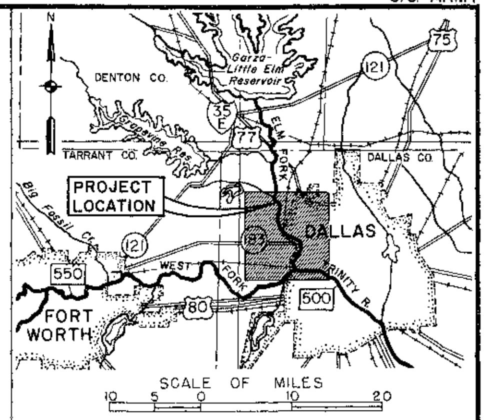


FIGURE 4
DENTON CREEK
CLEARED CHANNEL
MAXIMIZATION OF EXCESS BENEFITS OVER COSTS

watershed would result. However, local flood protection works would still be required to provide adequate protection from the backwater effects of major floods originating on the West Fork of the Trinity River and from damages caused by excessive local flood runoff. Further investigations of the reach downstream from Denton Creek were made of the addition of levees to protect the area from the standard project flood. A floodway having a channel with a bottom width of 100 feet and 1,100 feet between centerline of levees was compared with a floodway having a channel with a bottom width of 200 feet and 800 feet between centerline of levees. This study indicated that either project would be justified. However, the maximum excess of benefits over costs would be realized by using the 1100-foot floodway and 100-foot bottom width channel. The 100-foot bottom width channel would be of sufficient size to contain the desired channel capacity of 15,000 cubic feet per second. The major levee improvement elements added to the previously discussed channel only plan for reservoir regulation in the lower 14.3-mile channel of the Elm Fork include the construction of a parallel levee system through the low areas consisting of about 24.8 miles of levee along the left bank and 14.1 miles of new levee and the rehabilitation of 1.8 miles of existing levee on the right bank of the proposed enlarged and realigned channel of the Elm Fork and tributary channels between channel miles 2.7 and 15.2. The floodway along the main stem would be a dedicated floodway maintained free of encroachments and would have a minimum width of 1,100 feet between centerline of levees and have sufficient capacity to contain the standard project flood which varies from 58,000 cubic feet per second at the Carrollton gage to 61,000 cubic feet per second at the mouth of Elm Fork. Cost and benefit data for adding levees to the flood control channel are given in the following tabulation. The plan of improvement and detailed profiles for the Elm Fork and Tributaries are shown on plates 15 through 19.

Incremental annual charges	$516,800
Incremental annual benefits	$517,700
Benefit-Cost Ratio	1.0





VICINITY MAP

DRAINAGE AREA AND SUMP	DRAINAGE AREA		SLUICES			SUMPS			
	ACRES	SQ. MI.	NO. REQ'D	SIZE	INVERT EL.	DAMAGING STAGE EL.	BOTTOM EL.	CAP. AT DAMAGING STAGE EL. AC.-FT.	DESIGN FLOOD WATER SURFACE EL.
A	905	1.41	3	5'X5'	401	415	400	250	414.2
B	2,952	4.61	6	5'X5'	401	416	400	800	415.9
C	1,273	1.99	3	5'X5'	405	421	404	350	421.0
D	2,381	3.72	3	6'X6'	406	423	405	650	422.8
E	3,738	5.84	5	6'X6'	408	425	407	1000	424.4
F	3,724	5.82	5	6'X6'	411	430	410	1000	428.6
G	2,720	4.25	5	5'X5'	417	435	416	750	434.8
H	1,700	2.66	3	6'X6'	418	437	417	460	435.2

LEGEND

- NAVIGATION AND FLOOD CONTROL CHANNEL
- DESIGN WATER SURFACE
- HIGH WATER LINE (MAXIMUM OF RECORD)
- NAVIGATION LOCK AND DAM
- RIVER MILEAGE
- CHANNEL MILEAGE
- CORE BORINGS
- AUGER BORINGS
- FILL AREA
- SUMP AREA
- NEW EARTH LEVEES
- EXISTING LEVEES
- STRENGTHEN EXISTING LEVEES
- FEDERAL HIGHWAY
- STATE HIGHWAY
- INTERSTATE HIGHWAY
- FARM TO MARKET ROAD
- EXISTING BRIDGE
- COUNTY LINE
- GRAVITY FLOW DRAINAGE STRUCTURE

TRINITY RIVER AND TRIBUTARIES, TEXAS
ELM FORK AND TRIBUTARIES
FLOOD CONTROL CHANNEL
AND FLOODWAY

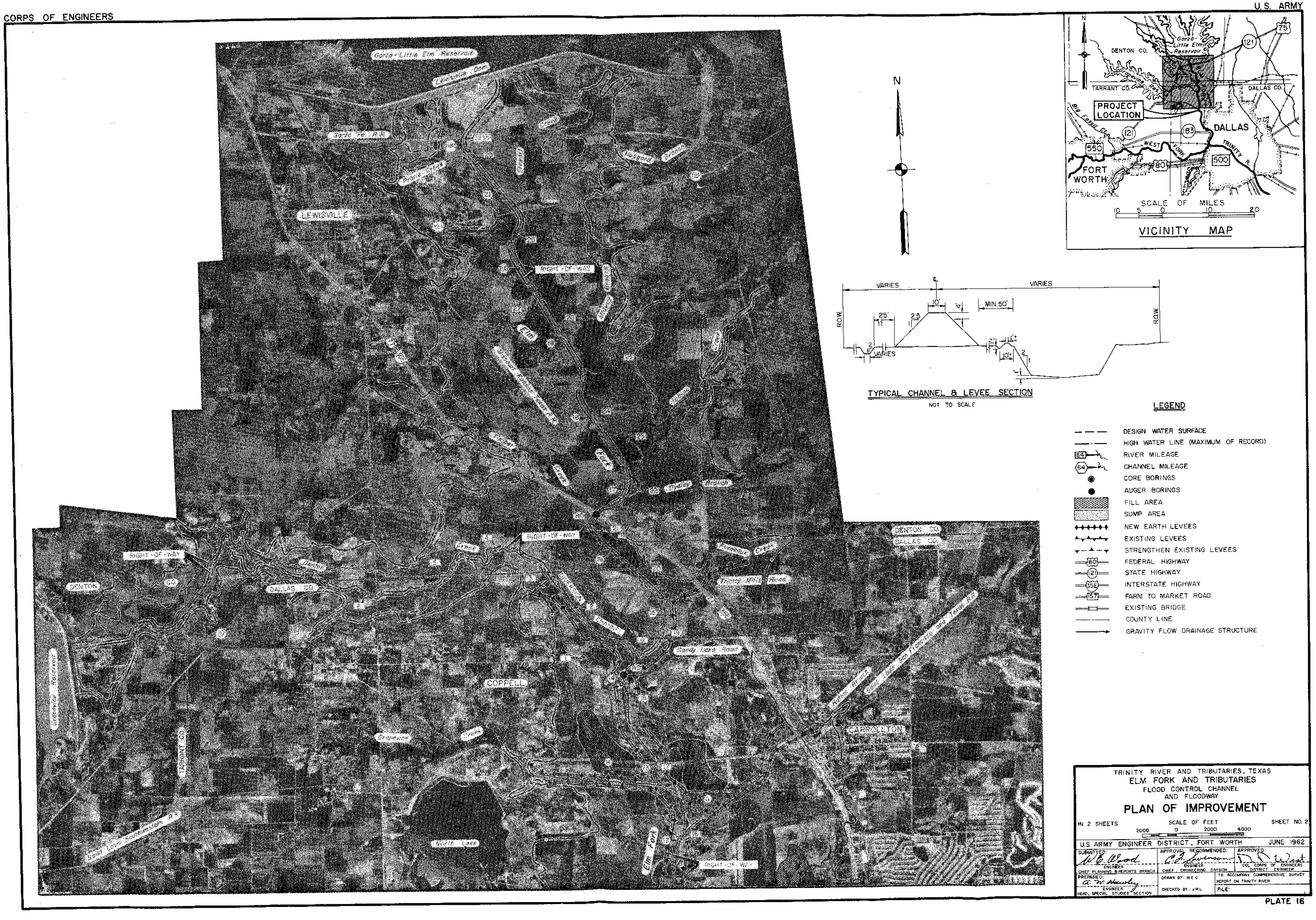
PLAN OF IMPROVEMENT

IN 2 SHEETS — SCALE OF FEET 2000 0 2000 4000 — SHEET NO. 1

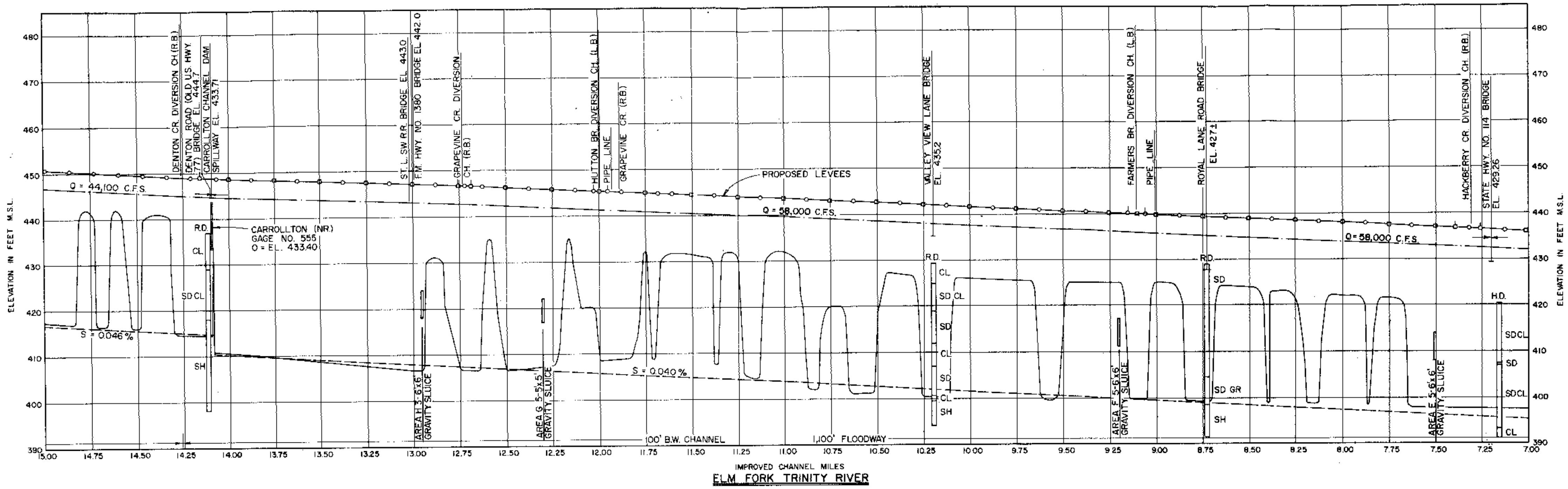
U.S. ARMY ENGINEER DISTRICT, FORT WORTH JUNE 1962

SUBMITTED: W. E. Wood, ENGINEER, CHIEF PLANNING & REPORTS BRANCH
APPROVAL RECOMMENDED: C. R. Swenson, ENGINEER, CHIEF, ENGINEERING DIVISION
APPROVED: [signature] West, COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: A. W. Hawley, ENGINEER, HEAD, SPECIAL STUDIES SECTION
DRAWN BY G.E.C.
CHECKED BY J.H.L.
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER
FILE: TRIN. 230-19

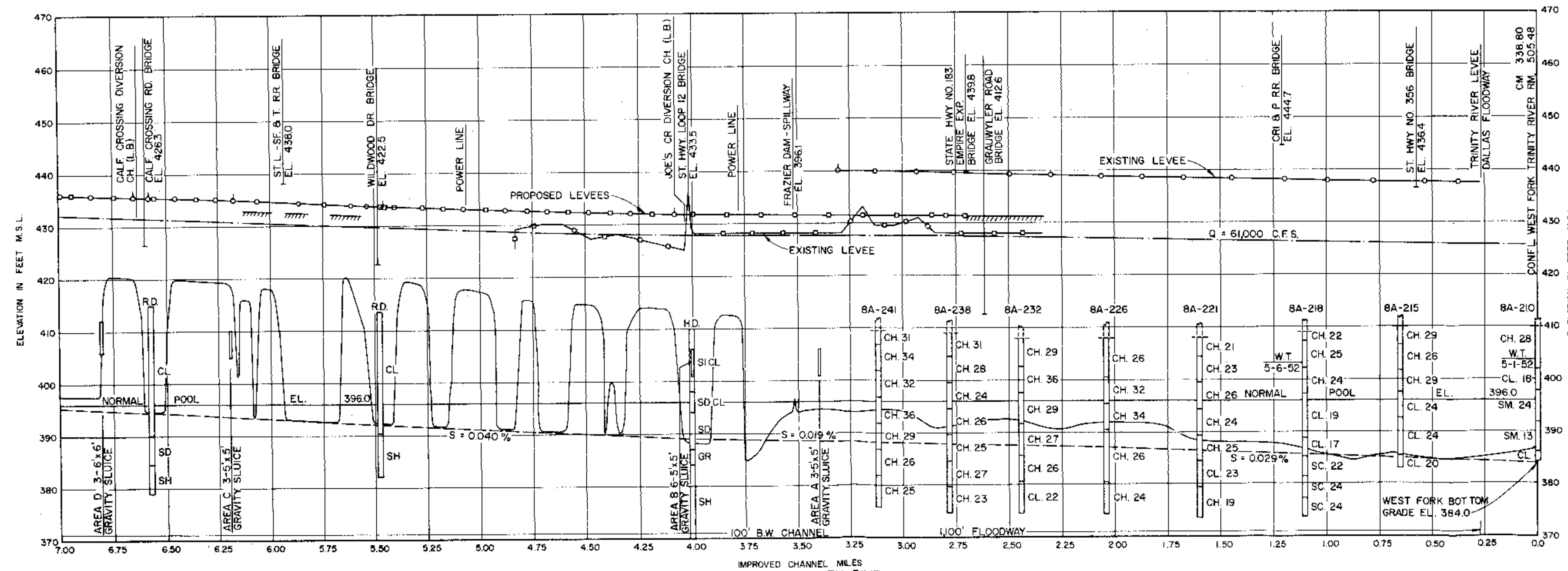
PLATE 15



52-704 O-65 Vol. II (Face p. 36) No. 2



ELM FORK TRINITY RIVER



ELM FORK TRINITY RIVER

LEGEND

—·—	DESIGN WATER SURFACE
—o—	LEVEE, RIGHT BANK
—o—	LEVEE, LEFT BANK
——	CENTERLINE PROFILE
— —	BOTTOM GRADE
//////	FILL AREA, RIGHT BANK
B.W.	BOTTOM WIDTH
L.B.	LEFT BANK
R.B.	RIGHT BANK

NOTES:

Floodway dimensions shown are minimum requirments measured from centerline of levees, or from centerline of levee to natural bank or fill area.

All channel side slopes are 1 vertical on 2 horizontal. Levee side slopes are 1 vertical on 2½ horizontal.

All bridges shown are existing structures. Elevations of bridges refer to existing low steel elevations.

New or modified bridge openings are to provide 3 feet minimum vertical clearance above design water surface, and unobstructed horizontal clearance in dedicated floodway exclusive of bridge piers.

TRINITY RIVER AND TRIBUTARIES, TEXAS
ELM FORK AND TRIBUTARIES
FLOOD CONTROL CHANNELS AND FLOODWAYS

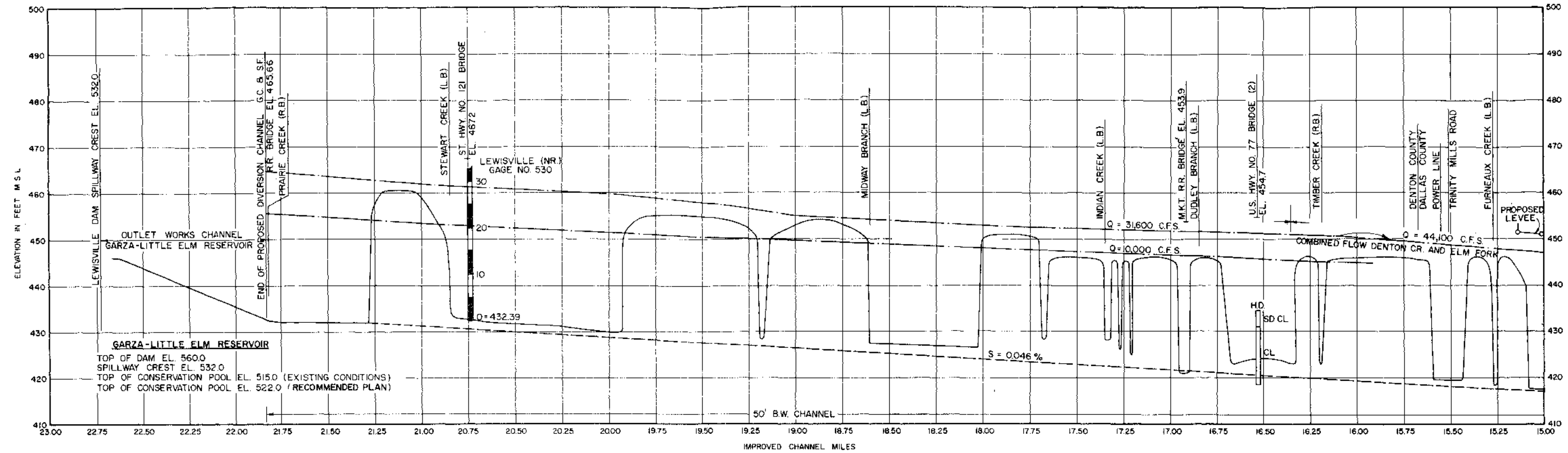
DETAILED PROFILES

IN 3 SHEETS — SCALES: AS SHOWN — SHEET NO. 1

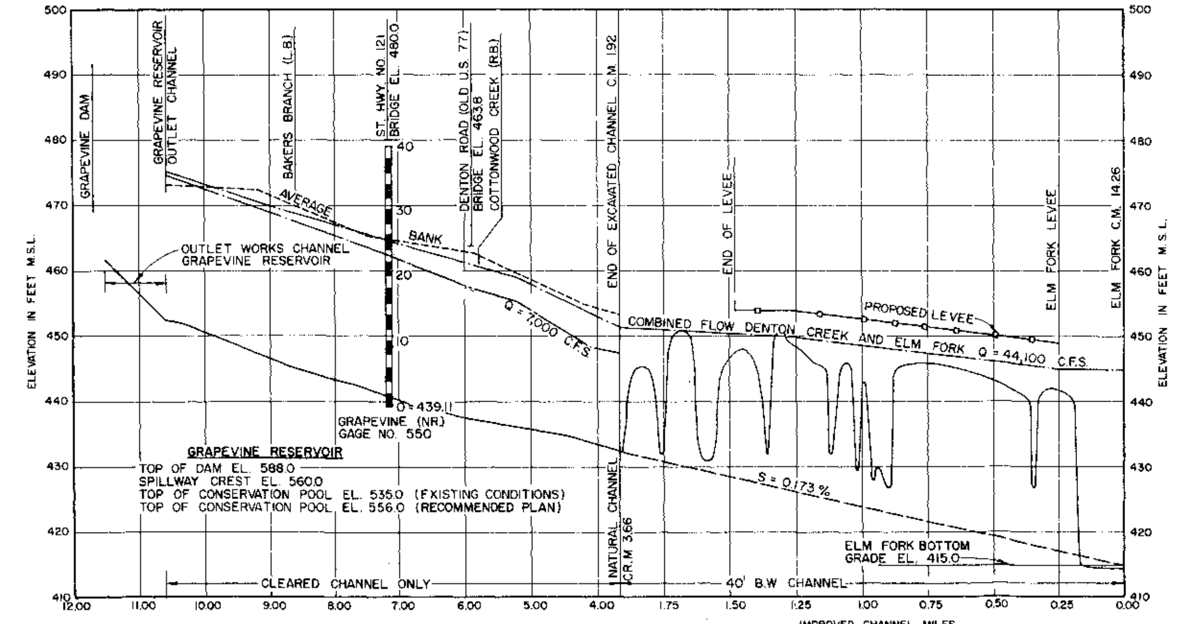
U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

SUBMITTED: [signature] ENGINEER CHIEF, PLANNING & REPORTS BRANCH
APPROVAL RECOMMENDED: [signature] ENGINEER CHIEF, ENGINEERING DIVISION
APPROVED: [signature] COL., CORPS OF ENGINEERS DISTRICT ENGINEER
PREPARED: [signature] ENGINEER HEAD, SPECIAL STUDIES SECTION
DRAWN BY: D.E.C. CHECKED BY: J.W.L.
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER
FILE: TRIN 230-19

PLATE 17



ELM FORK TRINITY RIVER



DENTON CREEK NATURAL MILES

DENTON CREEK DIVERSION CHANNEL (R.B.)

LEGEND

- DESIGN WATER SURFACE
- LEVEE, RIGHT BANK
- LEVEE, LEFT BANK
- CENTERLINE PROFILE
- BOTTOM GRADE
- FILL AREA, RIGHT BANK
- B.W. BOTTOM WIDTH
- L.B. LEFT BANK
- R.B. RIGHT BANK

NOTES:

Floodway dimensions shown are minimum requirments measured from centerline of levees, or from centerline of levee to natural bank or fill area.

All channel side slopes are 1 vertical on 2 horizontal. Levee side slopes are 1 vertical on $2\frac{1}{2}$ horizontal.

All bridges shown are existing structures. Elevations of bridges refer to existing low steel elevations.

New or modified bridge openings are to provide 3 feet minimum vertical clearance above design water surface, and unobstructed horizontal clearance in dedicated floodway exclusive of bridge piers.

TRINITY RIVER AND TRIBUTARIES, TEXAS
ELM FORK AND TRIBUTARIES
FLOOD CONTROL CHANNELS AND FLOODWAYS

DETAILED PROFILES

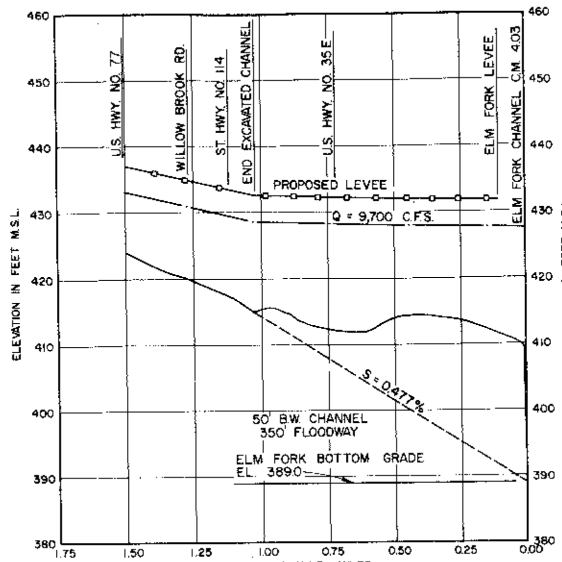
IN 3 SHEETS — SCALES AS SHOWN — SHEET NO. 2

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

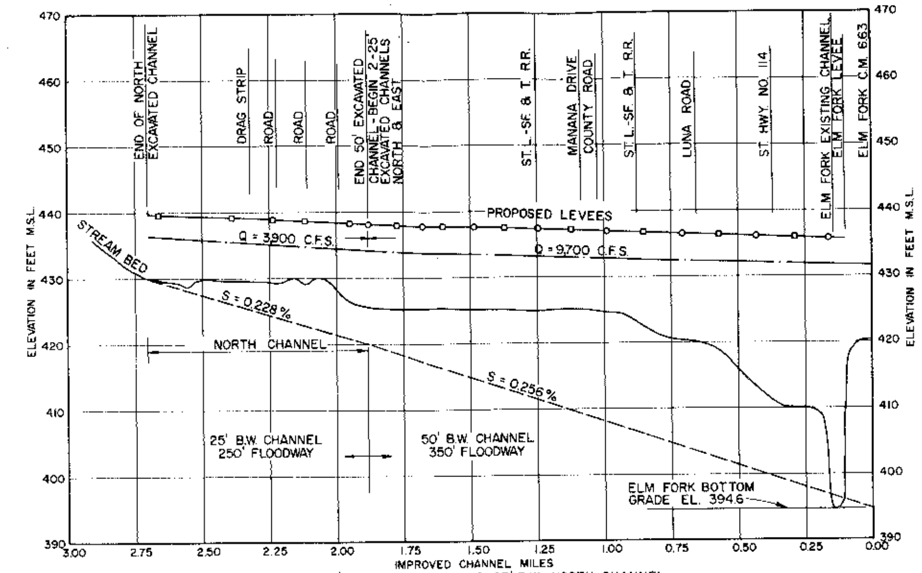
SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
ENGINEER, CHIEF, PLANNING & REPORTS BRANCH	ENGINEER, CHIEF ENGINEERING DIVISION	COL., CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ENGINEER, HEAD, SPECIAL STUDIES SECTION	DRAWN BY: O.E.C. CHECKED BY: J.H.L.	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER. FILE: TRIN. 230-19

PLATE 18

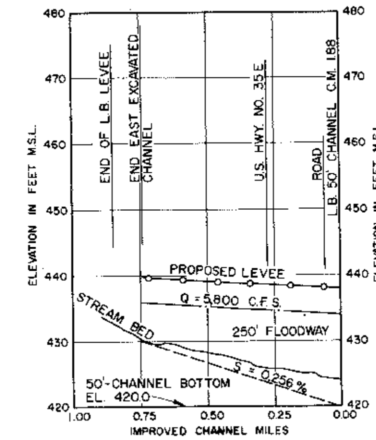
52-704 O-65 Vol. II (Face p. 36) No. 4



JOE'S CREEK DIVERSION CHANNEL (L.B.)

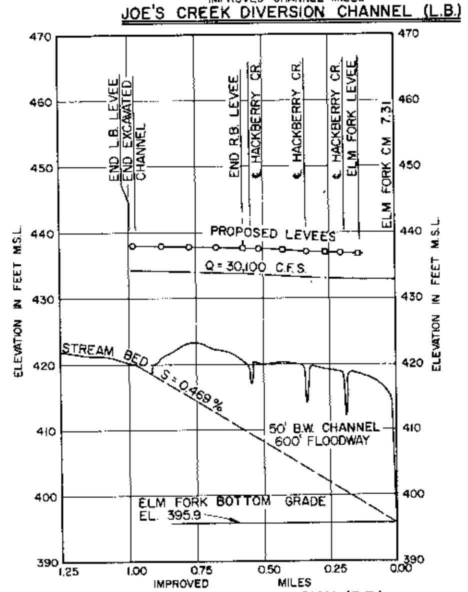


50' B.W. CHANNEL AND 25' B.W. NORTH CHANNEL

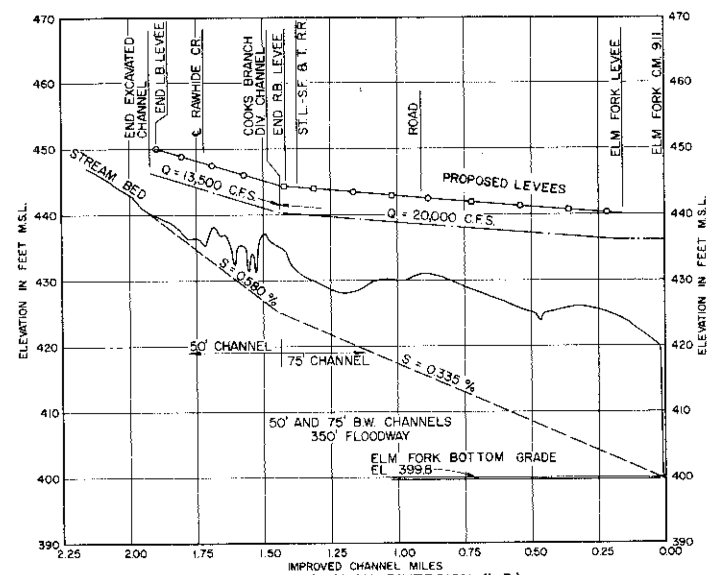


25' B.W. EAST CHANNEL

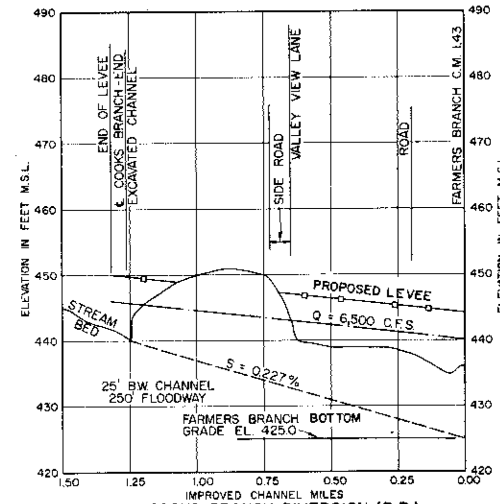
CALIFORNIA CROSSING DIVERSION CHANNEL L. B.



HACKBERRY CREEK DIVERSION (R.B.)



FARMERS BRANCH DIVERSION (L.B.)



COOKS BRANCH DIVERSION (R.B.)

LEGEND

- DESIGN WATER SURFACE
- LEVEE, RIGHT BANK
- LEVEE, LEFT BANK
- CENTERLINE PROFILE
- BOTTOM GRADE
- FILL AREA, RIGHT BANK
- B.W. BOTTOM WIDTH
- L.B. LEFT BANK
- R.B. RIGHT BANK

NOTES:

Floodway dimensions shown are minimum requirments measured from centerline of levees, or from centerline of levee to natural bank or fill area.

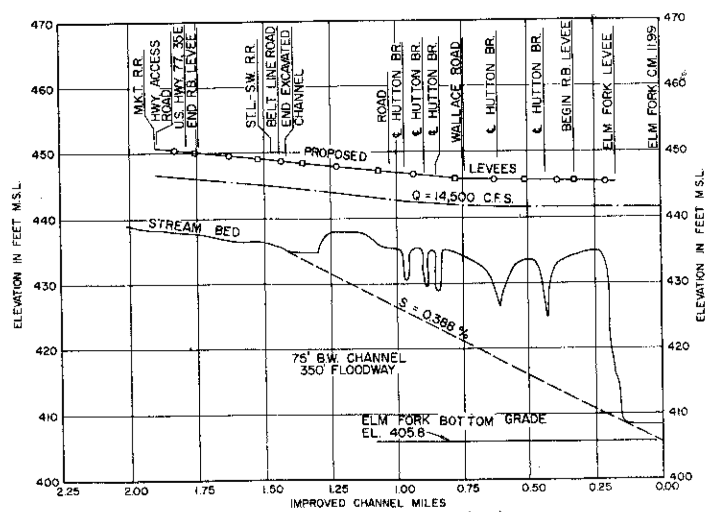
All channel side slopes are 1 vertical on 2 horizontal. Levee side slopes are 1 vertical on 2½ horizontal.

All bridges shown are existing structures. Elevations of bridges refer to existing low steel elevations.

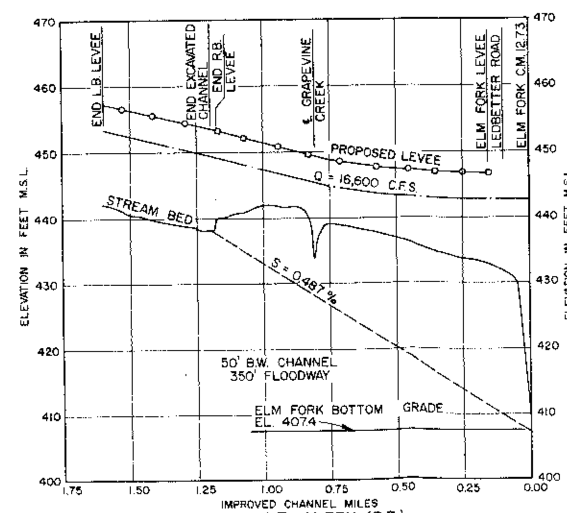
New or modified bridge openings are to provide 3 feet minimum vertical clearance above design water surface, and unobstructed horizontal clearance in dedicated floodway exclusive of bridge piers.

Refer to plate 106 for boring legend.

Refer to plate 111 for typical channel and levee sections.



HUTTON BRANCH DIVERSION (L.B.)



GRAPEVINE CREEK (R.B.)

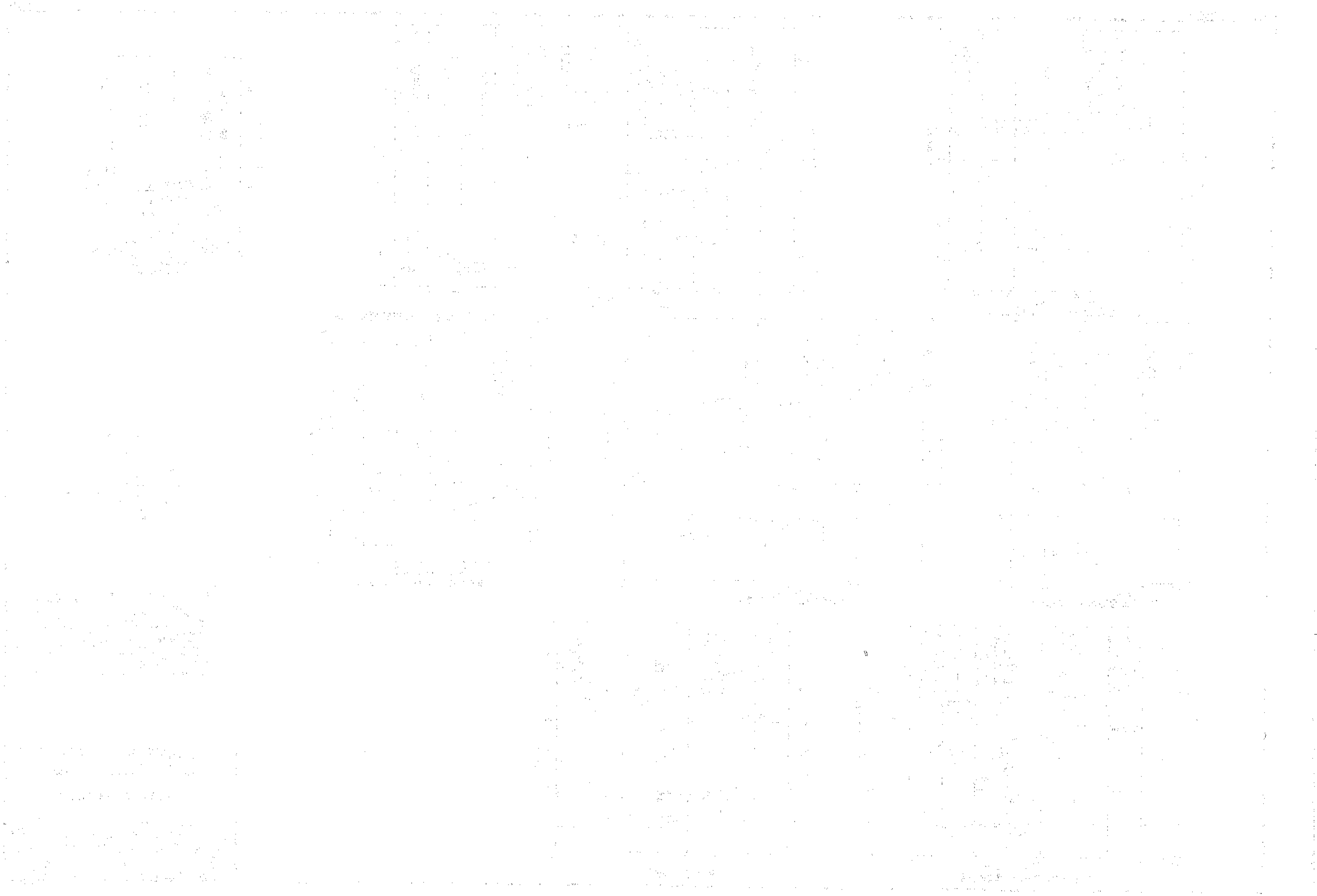
TRINITY RIVER AND TRIBUTARIES, TEXAS
ELM FORK AND TRIBUTARIES
FLOOD CONTROL CHANNELS AND FLOODWAYS

DETAILED PROFILES

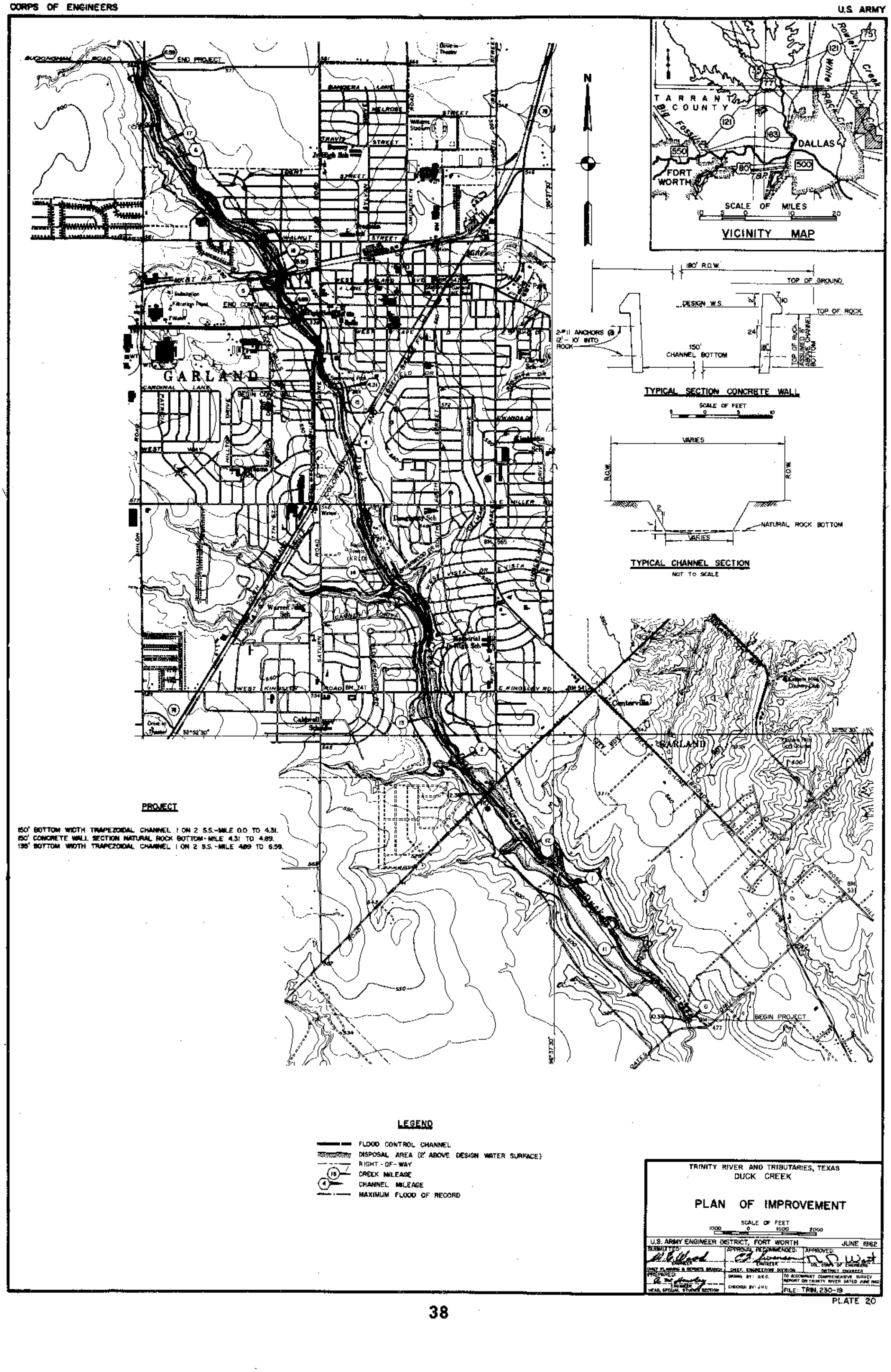
IN 3 SHEETS — SCALES AS SHOWN — SHEET NO. 3

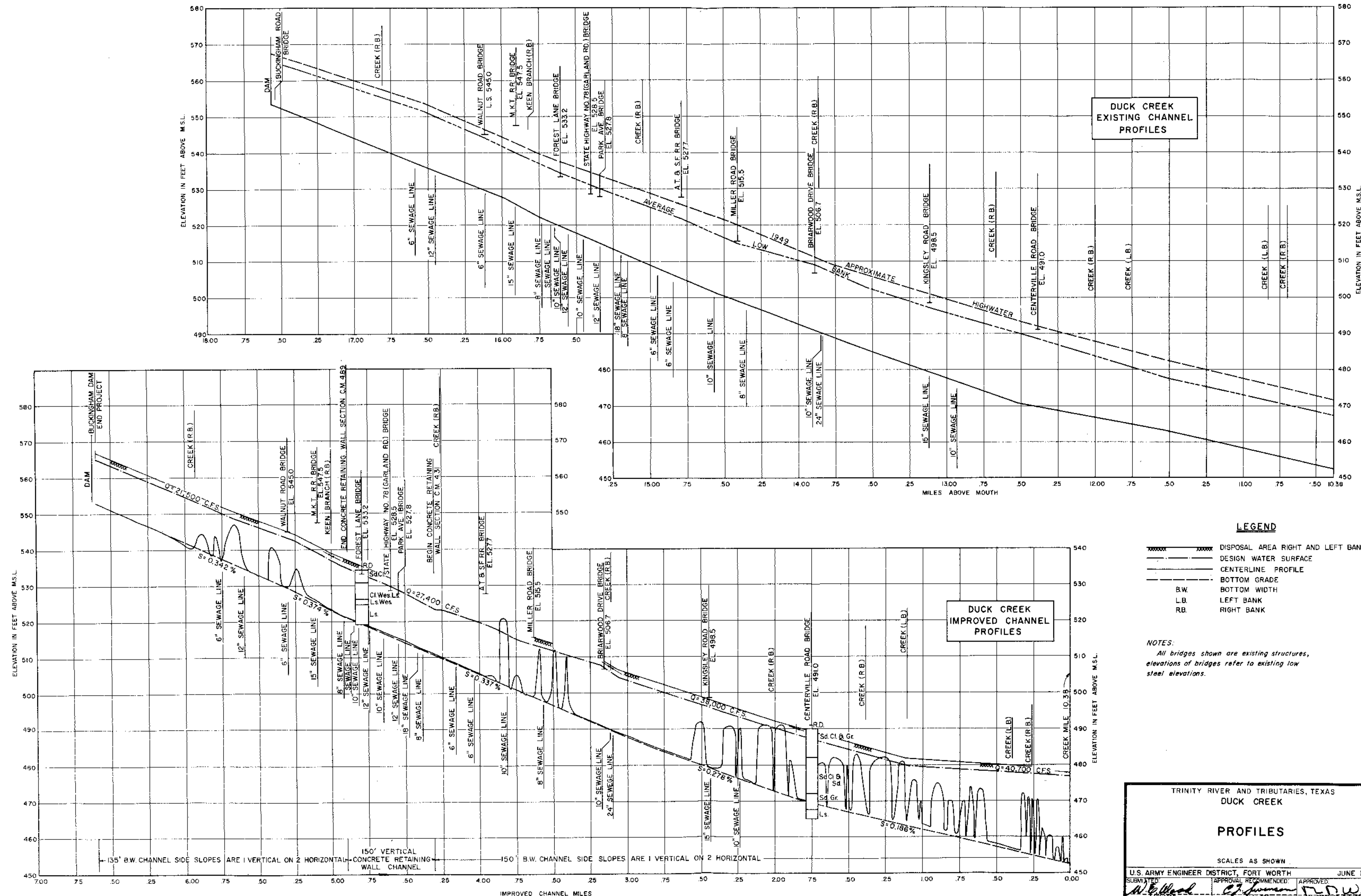
U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
W. E. Wood, ENGINEER, CHIEF PLANNING & REPORTS BRANCH	C. J. Swenson, ENGINEER, CHIEF, ENGINEERING DIVISION	COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: G. W. Hawley, ENGINEER, HEAD SPECIAL STUDIES SECTION	DRAWN BY: O.E.C. CHECKED BY: J.H.L.	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER; FILE TRIN 230-19



48. DUCK CREEK.- The phenomenal growth of Garland during the past decade has witnessed considerable urban development in the watershed of Duck Creek and also in its flood plain. Preliminary investigation of the flood problem area along Duck Creek in the City of Garland indicated the need for a local flood protection project. This stream, with a drainage area of 45 square miles, rises near U. S. Highway 75 at the north line of Dallas County and flows about 20 miles in a southeasterly direction through the City of Garland to its junction with the East Fork of the Trinity River. The Duck Creek channel has a width of about 60 feet, a depth of about 15 feet, and falls about ten feet per mile along its entire water course. Through the City of Garland, the channel has an average slope of about 14 feet per mile and an estimated discharge capacity of 5,700 cubic feet per second. As a result of preliminary design, cost and economic studies of a flood control reservoir project versus a channel enlargement project to protect the area from the flood of record, it was determined that a channel project would return the most excess benefits over costs. About 65 percent of the project area lies within Garland's city boundary, and the remaining 35 percent is dominated by the city's growth pattern. Because of this accelerated urbanization of the area with its attendant ability to produce higher rates of runoff and shorter periods of concentration, flood hazards are becoming more intensified. Levees and their necessary interior drainage facilities were not considered practical because of the physical limitations imposed by existing developments. Deprived of the feasibility of constructing levees in combination with a channel, the solution to Garland's flood problem remained in an independent channel of sufficient capacity to provide urban protection. Design, cost, and economic studies determined that the channel to contain standard project flood discharges would be fully justified. The plan of improvement for Duck Creek consists of a channel improvement project along the main channel from river mile 10.4 upstream to river mile 17.5. The project includes the realignment and enlargement of 6.6 miles of Duck Creek channel including 0.6 mile of concrete gravity wall section, to provide sufficient within-banks capacity to contain the standard project flood which varies from about 21,500 cubic feet per second at the upstream end near Buckingham Road to 40,700 cubic feet per second at the downstream end near Oates Drive, and the modification of 10 bridges. The project cost is $5,024,000; the annual charges are $160,400 and the annual benefits are $224,400. The project has a benefit-cost ratio of 1.4. The plan of improvement and profiles of the existing and improved channel are shown on plates 20 and 21.


CORPS OF ENGINEERS
U.S. ARMY
VICINITY MAP
TARRANT COUNTY
DALLAS
FORT WORTH
SCALE OF MILES
TYPICAL SECTION CONCRETE WALL
SCALE OF FEET
TYPICAL CHANNEL SECTION
NOT TO SCALE
GARLAND
PROJECT
150' BOTTOM WIDTH TRAPEZOIDAL CHANNEL 1 ON 2 S.S.-MILE 0.0 TO 4.31.
150' CONCRETE WALL SECTION NATURAL ROCK BOTTOM-MILE 4.31 TO 4.89.
135' BOTTOM WIDTH TRAPEZOIDAL CHANNEL 1 ON 2 S.S.-MILE 4.89 TO 6.59.
END PROJECT
BEGIN PROJECT
LEGEND
FLOOD CONTROL CHANNEL
DISPOSAL AREA (2' ABOVE DESIGN WATER SURFACE)
RIGHT-OF-WAY
CREEK MILEAGE
CHANNEL MILEAGE
MAXIMUM FLOOD OF RECORD
TRINITY RIVER AND TRIBUTARIES, TEXAS
DUCK CREEK
PLAN OF IMPROVEMENT
SCALE OF FEET
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
JUNE 1962
SUBMITTED:
APPROVAL RECOMMENDED:
APPROVED:
PREPARED:
DRAWN BY: D.E.C.
CHECKED BY: J.H.L.
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER DATED JUNE 1962
FILE: TRIN. 230-19
PLATE 20



NOTES:
All bridges shown are existing structures, elevations of bridges refer to existing low steel elevations.

TRINITY RIVER AND TRIBUTARIES, TEXAS
DUCK CREEK

PROFILES

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
W. E. Wood, ENGINEER, CHIEF, PLANNING & REPORTS BRANCH	C. J. Swenson, ENGINEER, CHIEF, ENGINEERING DIVISION	COL., CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: G. W. Hawley, ENGINEER, HEAD, SPECIAL STUDIES SECTION	DRAWN BY: M.E.G. CHECKED BY: J.H.L.	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER DATED JUNE 1962. FILE: TRIN 230-19

49. LAKEVIEW RESERVOIR.- Of primary importance in the development of a plan to aid in solving the flood problem of the Trinity Basin was the consideration of reservoirs containing flood control storage. Mountain Creek was investigated for a reservoir site because of its substantial contribution to flood flows along the Trinity River, and more specifically because of its possible contribution to reach the goal of providing standard project flood protection in the unprotected urban area below the existing Dallas Floodway. Mountain Creek was one of the major contributors to flooding along the Trinity River in Dallas and downstream from Dallas during the 1957 flood. The peak outflow from Mountain Creek reached 37,000 cubic feet per second on April 26 and the peak discharge in Dallas reached 49,300 cubic feet per second on April 27. Although this was not the peak discharge for the entire flood period in Dallas, which was 75,300 cubic feet per second on May 26, it does demonstrate that Mountain Creek is a major contributor to floods along the Trinity River. Flood control storage on Mountain Creek would have a pronounced effect in reducing flood damages in the Dallas area. Preliminary studies showed that a reservoir in the lower reaches of Mountain Creek with capacity to contain a flood of 50-year frequency would reduce the standard project flood in Dallas from 226,000 cubic feet per second to 163,800 cubic feet per second or would reduce the flood stage about 3.8 feet at the Dallas Gage and 3.4 feet at South Loop 12 Bridge. Further studies showed that a reservoir on Mountain Creek would provide a high degree of protection in the urban complex below the existing Dallas Floodway but could not be physically or economically developed with sufficient storage to provide standard project flood protection to the area. Levees would be required to provide the degree of flood protection needed in this area. The average annual benefits from the leveed Dallas Floodway Extension area that would accrue to the Lakeview Reservoir would total $141,900.

50. Preliminary design, costs and benefit determinations were made for three single purpose reservoirs covering the full range of probable storage requirements at the Lakeview site. On the basis of capacity-cost and capacity-benefit curves, the maximum excess benefits over cost indicated that for flood control only the optimum project should have sufficient storage space to contain a flood of 40-year frequency or at least 175,400 acre-feet including sediment reserve. Using the same capacity cost curve, a dual purpose reservoir was investigated and it was determined that the 175,400 acre-feet of flood control and sediment storage would also result in optimum development. However, to make this reservoir compatible with other reservoirs in the system, it was considered advisable to increase the flood control storage space to contain floods of 50-year frequency. Increasing the flood control storage space to 182,300 acre-feet, including the reserve for sediment, results in a reduction of excess flood control benefits over costs by $7,500 or less than two percent, which is insignificant considering the added degree of protection afforded. The flood control storage space is more than adequate to control the flood of record on Mountain Creek. The results

of the maximization tests for a dual purpose project at the Lakeview site is shown in figure 5. Benefit and cost data relative to Lakeview Reservoir as the next added project to the flood control channel and levees are shown in the following tabulation. The location and area of Lakeview Reservoir are shown on plate 22.

Item	Cost
Annual charges for single-purpose flood control project	$527 700
Annual benefits for single-purpose flood control project	$909,200
Benefit-Cost Ratio single-purpose flood control project	1.7
Annual charges for flood control - water supply project	$984,700
Annual charges for water supply only project	$735,900
Flood control cost incremental to water supply	$248,800
Benefit-Cost Ratio	3.7

51. TENNESSEE COLONY RESERVOIR.- Since a reasonable degree of flood protection could not be developed by increasing the channel capacity downstream from the Tennessee Colony Damsite, alternative solutions were investigated. Consideration of alternatives readily showed that a reservoir at the Tennessee Colony site would be highly efficient in the control and reduction of floods. Numerous reservoirs on the tributary streams were also considered. However, reservoir sites on the tributary streams are limited, and it would be necessary to construct some of these reservoirs on tributaries far down the basin to obtain protection comparable to a single main stem reservoir more favorably located near the Fort Worth-Dallas complex. A reservoir at the Tennessee Colony site would control the major tributaries, including Cedar and Richland Creeks. Another consideration for selection of a site in this area was dictated by the urgent need for a reservoir that could also provide storage for water conservation. A site in this area is strategically located to produce a high yield that could serve the Fort Worth-Dallas complex.

52. With the general location of a reservoir thus determined, further investigation for a specific site was made by the use of topographic maps, aerial mosaics, and by field reconnaissance. The relatively narrow flood plain in the vicinity of river mile 339 offered the best possibility for a damsite and a reservoir that would satisfy storage requirements. The Trinity River Authority had selected a damsite at river mile 340.2 which had multiple crossings of Catfish Creek. In order to avoid these crossings, a site was selected at

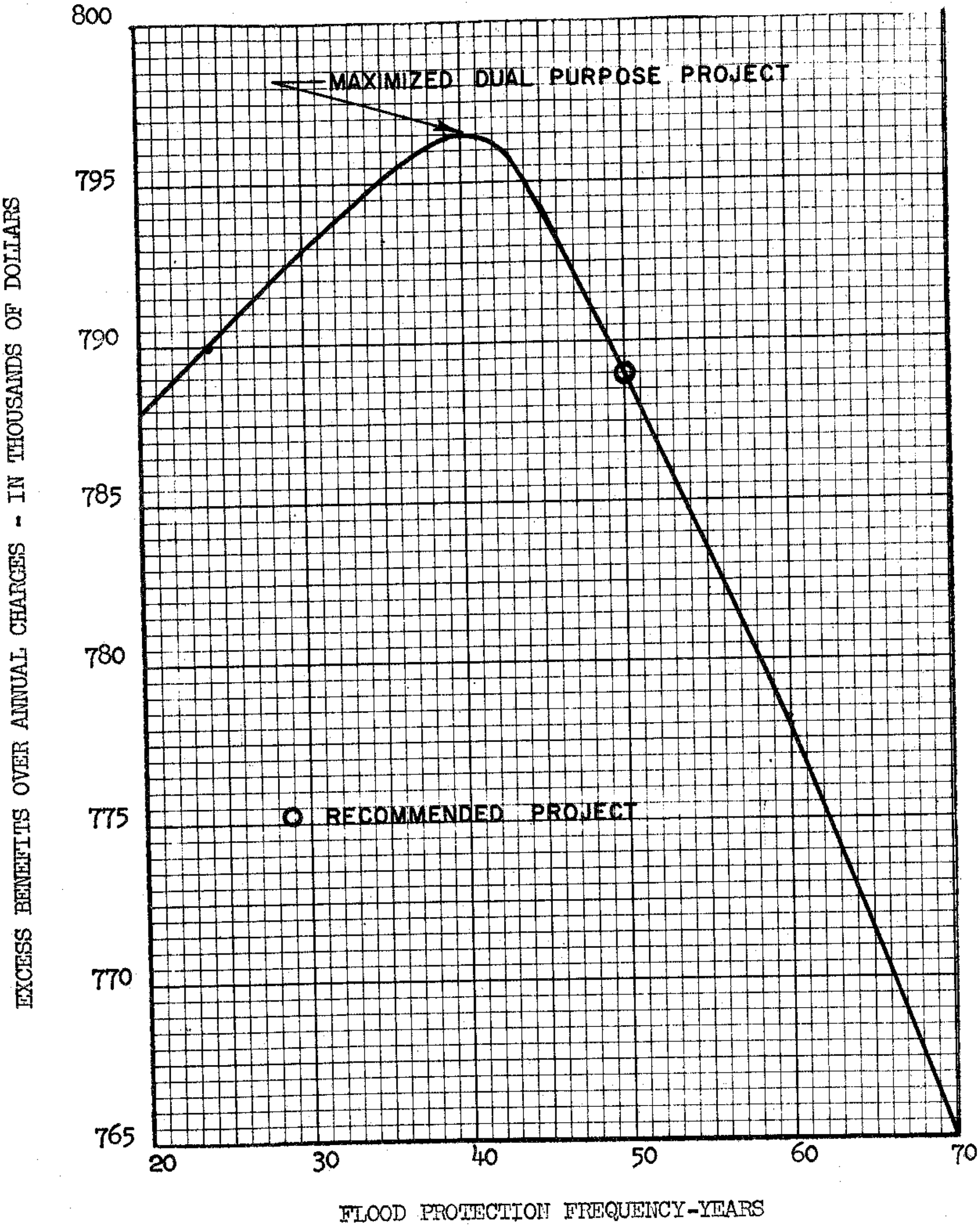


FIGURE 5
LAKEVIEW RESERVOIR
MAXIMIZATION OF EXCESS BENEFITS OVER COSTS

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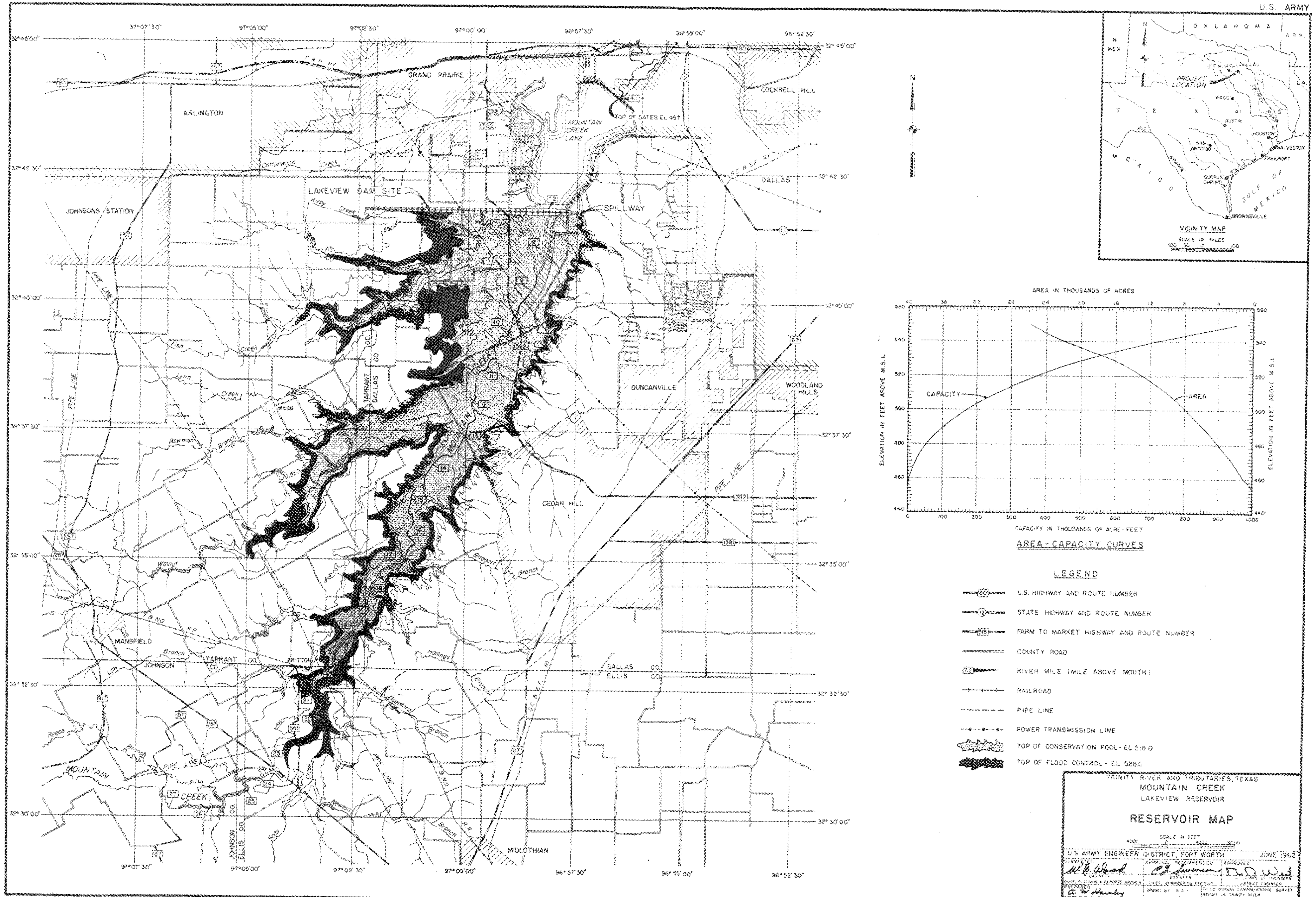

PLATE 22

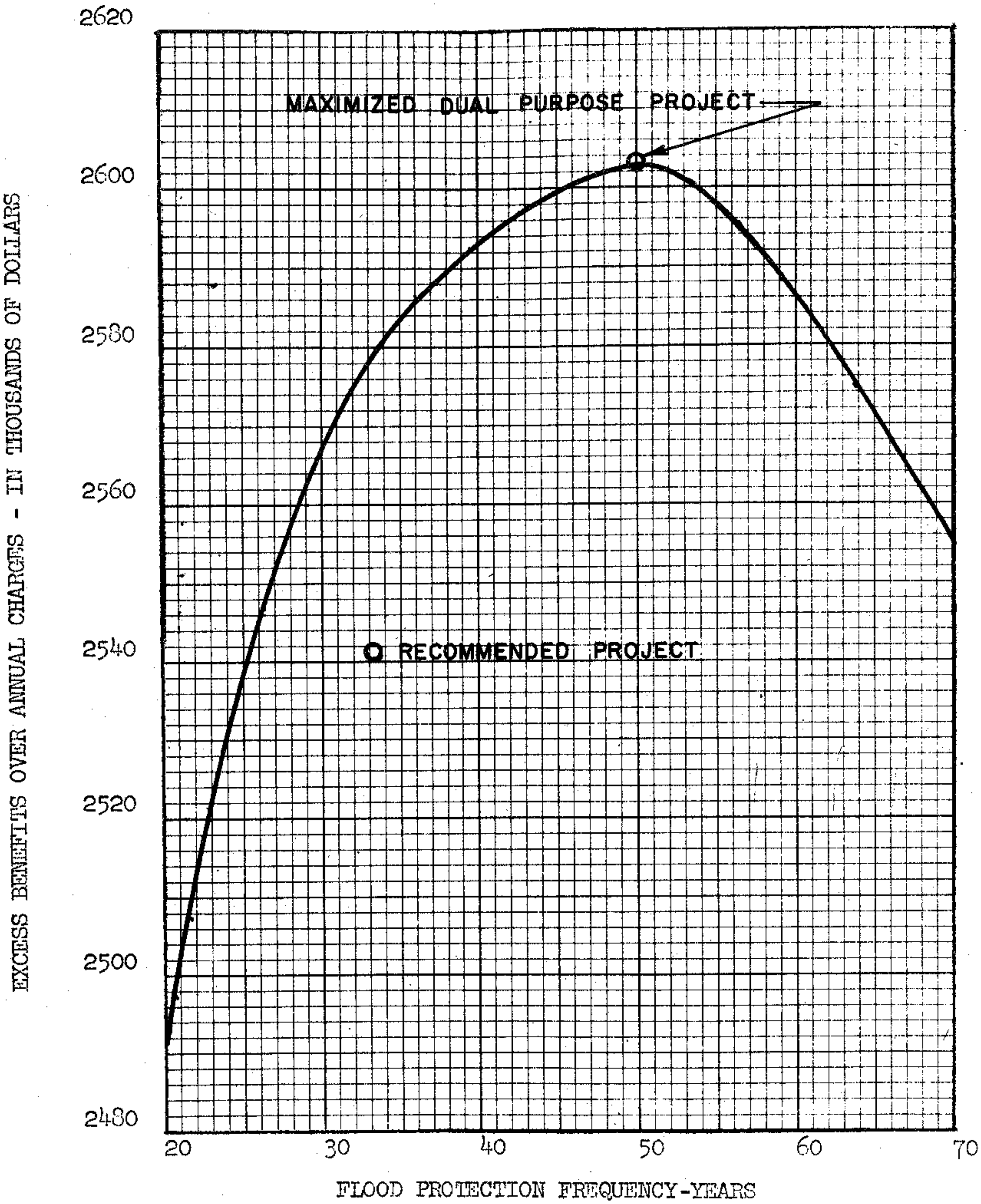

FIGURE 6
TENNESSEE COLONY RESERVOIR
MAXIMIZATION OF EXCESS BENEFITS OVER COSTS

river mile 339.2, known as the Tennessee Colony site. The next step was to determine the amount of storage space to be included in the reservoir. A capacity-cost curve for a dam and reservoir at this site, together with preliminary estimates of benefits, were used in the maximization studies. In determining the project dimensions, the Cedar Creek Reservoir, presently under construction, the Richland Creek Reservoir, for which an application for a permit has been made, and Tehuacana Creek Reservoir are considered in place. The area and capacity curves were developed from the incremental area between the above-mentioned sites and the Tennessee Colony damsite. However, project cost includes real estate and relocation costs in the Richland and Tehuacana Creek Reservoir areas that are below the Tennessee Colony project taking line since these reservoirs are not presently under construction. Inasmuch as local interests will require a portion of the Tennessee Colony Reservoir lands for the Richland and Tehuacana Creek reservoirs, it is considered in the best interests of the Government and local interests for local interests to acquire the land and grant the Government a flowage easement. It is proposed to negotiate with local interests during the preconstruction planning stage of the Tennessee Colony Reservoir project and reach an agreement of this nature. Also included in the project cost is an item for the downstream slope protection of Richland Creek, Cedar Creek and Tehuacana Dams. On the basis of these data, it was found that the greatest excess of benefits over costs would be attained by a reservoir having sufficient capacity to contain a flood of about 50-year frequency of about 2,144,300 acre-feet. The results of the maximization studies for the Tennessee Colony Reservoir is shown in figure 6. A single purpose flood control project at the Tennessee Colony site comparable in design and cost detail to the recommended multiple purpose Tennessee Colony Reservoir would cost in the magnitude of $56,380,000. The incremental annual charges of adding a flood control only reservoir project at the Tennessee Colony site to the flood control channel and levee projects would be $1,989,800. The incremental benefits would be $2,268,100 and the benefit-cost ratio would be 1.1. The location and area of the proposed reservoir are shown on plate 23.

53. OTHER FLOOD PROBLEM AREAS.- The study of the flood problems in the basin revealed that in addition to the areas discussed above, there are other areas with flood problems. The U. S. Soil Conservation Service has developed a channel project along Town Branch in Madisonville to relieve the flood problem in that area. The minor tributaries along the east bank of the Elm Fork in the vicinity of Carrollton and Farmers Branch have created some flood problems along their flood plains. In the area along the downstream reaches of these tributaries, flood problems would be eliminated by the floodway plan of improvement along the Elm Fork as previously discussed. The remaining flood damages along the upstream reaches of these streams are relatively small. Should the economic development occur in a pattern considerably

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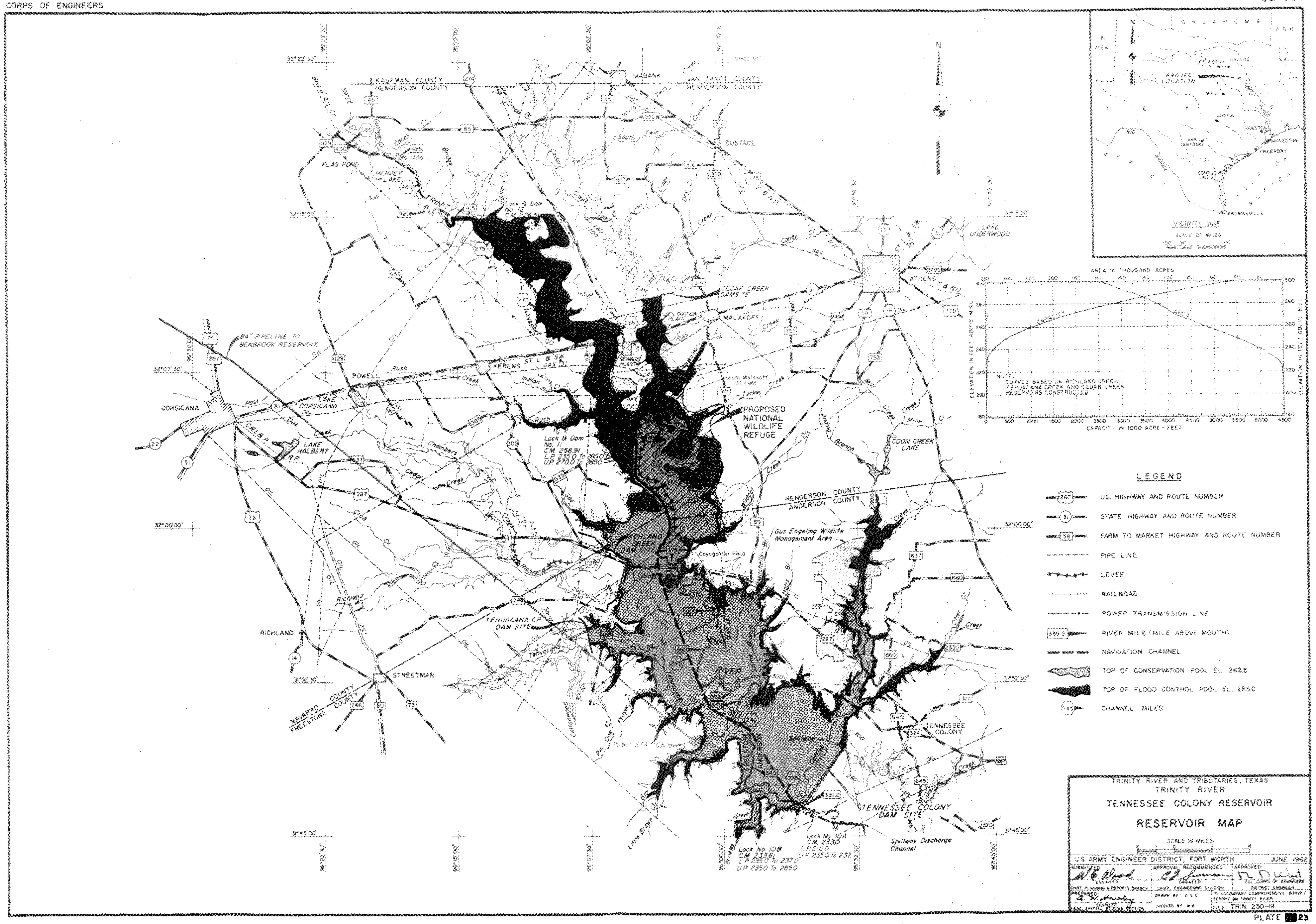

PLATE 23

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different from that now expected, projects in these areas may become justifiable in the future and could be added to the basin plan of development.

54. The Richland Creek and Chambers Creek watersheds have experienced damage from past floods. The authorized Bardwell Reservoir on Waxahachie Creek, a Chambers Creek tributary, and the Navarro Mills Reservoir, presently under construction on Richland Creek, were designed to reduce these damages. The Soil Conservation Service has initiated a floodwater retardation program through land treatment measures, floodwater retarding structures, and stream channel improvements. This program included 153 flood-water retarding structures and 65.5 miles of channel improvement for the Richland Creek watershed, and 138 structures and 78.5 miles of channel for the Chambers Creek watershed. Data as of January 1, 1961 indicated that 16 flood-water structures have been completed in the Richland Creek watershed, and 67 structures and 11 miles of channel improvement completed in the Chambers watershed. With these planned and completed improvements, residual damages, while serious to individuals, are relatively minor collectively when used as a basis for comparison of costs and benefits.

55. The plan of improvement, of which local flood protection is a part, on the East Fork has been formulated in the interim report entitled East Fork Watershed. In response to a resolution by the Committee on Rivers and Harbors of the House of Representatives, adopted November 30, 1945, an investigation was made of the Elm Fork above the Garza-Little Elm Reservoir to ascertain the extent of existing flood problems. It was found that there were insufficient benefits to justify a project in this area at the present time.

56. ALTERNATIVE SOLUTIONS CONSIDERED.- To meet the existing and potential water needs in the Trinity River Basin it was necessary to analyze the physical possibilities for improvement or development of the water resources of the basin. Preliminary studies were made of various local protection projects consisting of channel improvements only and channel improvements with levees. Various plans were investigated in the development of single-purpose waterway projects to the Dallas-Fort Worth area. All of these projects were considered singly, in functional segments, and in combinations with the reservoirs investigated, and with other local works to determine the most practical solution to the basin's water problems. More than forty potential reservoir sites throughout the basin were investigated for various project purposes. In some cases, two or three sites were selected on the same stream where only one reservoir could possibly be warranted. In these cases, the final site selection was made on the basis of which would be most effective and feasible. Twenty-two of the reservoir sites on the main stem of the Trinity River and major tributaries were

selected as having favorable locations, topography, and effectiveness for this study. Further consideration was made of these reservoirs on the basis of preliminary design, cost, and economic studies with each being considered with and without channel improvements and tested in turn as the next added project to the existing and authorized plan for the basin. Of the twenty-two reservoirs, it was found that (1) Lakeview, Aubrey, Roanoke, and Tennessee Colony Reservoirs were sufficiently effective and needed in the immediate future to warrant further studies; and (2) that a system of thirteen reservoirs in the basin (see table 1) should be included in the long-range plan to meet the projected water development needs of the basin and for possible additional flood protection in localized areas. The extent of consideration given to these thirteen projects varied but studies were sufficiently thorough in each case to provide a sound conclusion concerning their suitability primarily for water supply purposes and with a definite possibility that storage for flood control may be desirable at some future time for protection of localized areas.

57. One of the reservoir projects investigated was at the Boyd site on the West Fork of the Trinity above Fort Worth. The Boyd Reservoir site was investigated for flood control purposes in studies for the upstream extension of the Fort Worth Floodway. As discussed in the interim report covering that problem area (West Fork Watershed Flood Protection - Fort Worth Area Part I), a reservoir at this site would not reduce the design flood discharges in the problem area sufficiently to eliminate the requirement for floodway improvements. The reduction in first costs for the floodway extension plus the incremental benefits which would accrue by construction of the reservoir was not sufficient to justify the added cost of including the reservoir in the plan. In connection with this study, the Boyd Reservoir site was investigated to ascertain if a reservoir at this site would relieve the flood problem along the West Fork between Fort Worth and Dallas. Preliminary studies indicated that to economically provide the desirable degree of flood protection for this area would require floodway improvements consisting of an improved channel and levees. Further investigations disclosed that no material reduction in floodway capacity and cost of floodway improvements would be realized by inclusion of a reservoir at Boyd site and that the incremental flood control benefits afforded by a reservoir at this site would be insufficient to justify the additional costs required for its construction and operation. On the basis of the foregoing, the Boyd Reservoir as a flood control element in a comprehensive basin plan was eliminated from further consideration at this time. However, in view of the interest in this project as a source of future water supply and because of its potential use as a flood control project at some future time for flood protecton between Boyd and Eagle Mountain Reservoir, it has been included in the long-range plan for the basin. (See table 1).

58. Bridgeport and Eagle Mountain Reservoirs located above Fort Worth were studied in conjunction with the studies undertaken for the Boyd Reservoir site. These two reservoirs were constructed by local interests for water supply purposes. (See table 1 for pertinent data.) However, they provide some degree of protection for the area below the reservoirs because the comparatively narrow spillways of these two structures induce surcharge storage that will reduce flood peaks. The standard project flood routings through these reservoirs indicate that both reservoirs could control this flood and afford freeboards of 10.4 feet at Bridgeport and 12.0 feet at Eagle Mountain. Also, under Corps of Engineers spillway design storm criteria, flood routings studies show that both dams would be overtopped by the spillway design flood. Investigations indicate that Bridgeport Reservoir could control 64 percent of the spillway design flood below the top of the dam. Likewise, Eagle Mountain Reservoir would control about 60 percent of this flood below the top of the dam. It is understood that local interests are currently considering remedial works by the addition of emergency spillways.

59. RECAPITULATION-SOLUTIONS CONSIDERED TO THE EXISTING FLOOD PROBLEM IN THE BASIN.- Presentation in preceding paragraphs and examination of table 8, shows that the serious flood problem in the Trinity River Basin can be solved by various remedial works with costs considerably less than the benefits. Functional segments of the plan considered clearly demonstrate that benefits would accrue immediately upon completion of many self-contained units of an overall plan that is urgently needed to solve the Trinity River flood problem. As will be developed later, the remedial works discussed herein will be greatly enhanced and become even more efficient with the joint use of other project purposes such as additional storage in the Tennessee Colony Reservoir and the Lakeview Reservoir for water supply and other conservation purposes. Also, the merits of the channel improvement project for flood control can be significantly enhanced by joint use as a waterway for barge transportation which is presented in subsequent paragraphs.

60. DETERMINATION OF FAIR SHARE BENEFITS.- The flood control benefits creditable to the multiple-purpose channel, the local protection projects, and the reservoirs in the proposed plan of improvement of the Trinity River Basin have been assigned to the individual projects in an equitable manner and separate benefit-cost ratios have been determined for each project in the system. In connection with determining a reasonable distribution of system flood control benefits to the interrelated projects, flood routing studies were made to determine the effect each individual project would have on system benefits for river reaches where more than one project will be effective. The benefits for each project in a given reach was determined, assuming that the project was the first-added modification in that reach. The ratio of the project benefits so determined to the sum of all individual project benefits in the reach was used to determine the equitable fair-share benefits each project would be credited with in a given reach.

TABLE 8

ANALYSIS OF FLOOD CONTROL PROJECTS

Reach	Stream miles	Rural or urban property	Average annual damages	Frequency of flooding under existing conditions (years)	Average minimum bankfull capacity (cfs)	Channel requirements for reservoir regulation: Channel design discharge (cfs)	Flood frequency of design discharge (years)	Channel bottom width (feet)	Annual charges	Annual benefits	Residual annual damages	Channel requirements plus standard project flood protection to urban areas by use of local protection project: Design discharge: Channel (cfs)	Design discharge: Floodway (cfs)	Flood frequency with design discharge: Channel (years)	Flood frequency with design discharge: Floodway (years)	Channel bottom width (feet)	Incremental: Annual charges (1)	Incremental: Annual benefits	Residual annual damages	Added protection by reservoirs: Lakeview: Annual benefits	Lakeview: Residual annual damages	Tennessee Colony: Annual benefits	Tennessee Colony: Residual annual damages
I. West Fork of Trinity River																							
a. Fort Worth Floodway to Dallas Floodway	551.5-505.5	Urban	$3,624,400	2.4	7,000	15,000	7.7	30	$336,900(2)	$944,200	$2,680,200	30,000	95,-160,000	16.7	400±	150-200	$2,118,400(3)	$2,359,400	$320,800	-	$320,800	-	$320,800
b. Mountain Creek	7.2-2.4	Urban	481,800	1.0	4,000	-	-	-	-	0	481,800	-	-	-	-	-	-	0	481,800	$457,800	24,000	-	24,000
II. Trinity River - Main Stem																							
a. Through existing Dallas Floodway	505.5-497.9	Urban	(4)	2.7	13,000	25,000	5.9	125	-	-	-	35,000	163,800	9.0	400±	150	-	-	-	-	-	-	0
b. Extension of Floodway to Five Mile Creek	497.9-486.6	Urban	1,216,500	2.7	13,000	25,-27,000	5.9-6.6	125	180,000	233,500	983,000	35,000	163,800-174,600	9.0	400±	150	684,400	841,100	141,900	141,900	0	-	0
c. Five Mile Creek to head of Tennessee Colony Reservoir	486.6-407.0	Rural	2,501,200(5)	1.0	9,000	27,-35,000	4.0-7.4	125-200	935,200	1,639,900	861,300	-	-	-	-	-	-	-	861,300	250,000	611,300	-	611,300
d. Tennessee Colony Dam to head of Livingston Reservoir	339.2-183.0	Rural	3,038,400	1.0-4.0	24,-53,000	45,000	3.0	200-75(6)	1,082,300	1,382,900(7)	1,655,500	-	-	-	-	-	-	-	1,655,500	38,400	1,617,100	1,561,500	55,600
e. Livingston Dam to head of Wallisville Reservoir	129.2-12.0	Rural	2,447,700	4.0-1.0	53,-20,000	45,000	3.6	150-300(6)	1,027,200	1,549,500(8)	898,200	-	-	-	-	-	-	151,500	746,700	21,100	725,600	706,600	19,000
(1) Liberty levee area	45-33	Urban	(651,000)(9)	1.0	20,000	45,000	3.6	-	-	(474,400)(9)	(176,600)(9)	45,000	180,000	60.0	800±	250	79,200	(151,500)(9)	(25,100)(9)	(4,200)(9)	(20,900)(9)	(20,900)(9)	(0)
Sub-total I and II			13,310,000						3,561,600	5,750,000	7,560,000						2,882,000	3,352,000	4,208,000	909,200	3,298,800	2,268,100	1,030,700
III. Elm Fork																							
a. Lewisville Dam to mouth	30.0-0	Rural-Urban	1,884,200	9.0-3.3	8,000	10,-15,000	14.0-12.5	50-100	203,000	1,342,900	541,300	15,000	58,-61,000	12.5	400±	100	516,800	517,700	23,600	-	23,600	-	23,600
b. Denton Creek - Grapevine Dam to mouth	11.7-0	Rural	11,000	17.0	6,000	7,000	25.0	(10)	3,600	6,100	4,900	-	-	-	-	-	-	-	4,900	-	4,900	-	4,900
Sub-total Elm Fork			1,895,200						206,600	1,349,000	546,200						516,800	517,700	28,500		28,500		28,500
IV. Duck Creek																							
a. Channel only project	17.5-10.4	Urban	224,400	5.0	6,000	-	-	-	-	-	224,400	21,500-40,700	-	400+	-	135-150	160,400	224,400	0	-	-	-	0
Grand total			15,429,600						3,768,200	7,099,000	8,330,600						3,559,200	4,094,100	4,236,500	909,200	3,327,300	2,268,100	1,059,200
Annual charges for reservoir project																				527,700		1,989,800	

(1) Costs are based on Lakeview and Tennessee Colony Reservoirs being operational.
(2) Includes $114,100 to provide channel through existing Dallas Floodway.
(3) Includes $231,700 to provide multiple-purpose channel size through existing Dallas Floodway.
(4) None behind existing levees with standard project flood protection.
(5) Includes allowance for overtopping agricultural levees.
(6) Improvement on portions of channel consists of clearing only
(7) Does not include $99,900 benefits for land enhancement.
(8) Does not include $230,900 benefits for land enhancement.
(9) Included in reach II-e Livingston Dam to head of Wallisville Reservoir.
(10) Natural cleared channel.

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61. SUMMARY OF FLOOD CONTROL STUDIES.- Table 9 shows a summary of the benefits, costs, and the benefit-cost ratios for the flood control plan as it was developed in the preceding paragraphs. The table shows the benefits and benefit-cost ratios for each unit in the plan using both next added and the adjusted fair share benefits assuming all elements to be in the plan. The flood control channel increment is considered basic to the flood control plan for the Trinity River Basin since additional flood control reservoirs would not preclude the need for additional channel capacity. Therefore, the channel increment is considered as the next added project to the existing and authorized flood control plan. As demonstrated in previous paragraphs, the degree of protection afforded by the flood control channel plan was inadequate in the urban areas and that the only feasible means of affording the degree of protection needed was by the addition of levees. Therefore, the addition of the levees was considered as the next added unit to the channel project. There remained considerable flood damages in the rural areas along the main stem which were not afforded a sufficiently high degree of flood protection by the channel project. It was found that by the addition of flood control storage in the Lakeview and Tennessee Colony Reservoirs the rural areas would be afforded adequate protection and the reservoirs were considered as the next added units to the channel and levee projects. The Elm Fork Floodway and Duck Creek Local Protection projects are independent units in the plan of development and were considered as the first added units in the plan as developed. The incremental and fair share benefits for these two units are the same.

62. Table 10 shows the year in which the average annual flood control benefits creditable to each separable unit of the total flood-control plan would equal or exceed the annual charges for the unit. The conditions under which each unit has been analyzed is also shown. It may be seen from this table that the average annual flood control benefits would equal or exceed the annual charges for all projects by 1983.

TABLE 9

SUMMARY OF FLOOD CONTROL ONLY STUDIES
(in thousands of dollars)

Item	Annual Charge	Incremental Benefits	Incremental Benefit-cost ratio	Fair Share Benefits	Fair Share Benefit-cost ratio
I. Main Stem					
1. Flood control - channel only (1)					
a. Fort Worth to Dallas Floodway	222.8)	944.2	2.8	944.2	2.8
b. Through existing Dallas Floodway	114.1)				
c. Extension of Floodway to Five Mile Creek	180.0	233.5	1.3	233.5	1.3
d. Five Mile Creek to Tennessee Colony	935.2	1,639.9	1.8	1,334.4	1.4
e. Tennessee Colony to Livingston	1,082.3	1,482.8	1.4	1,092.5	1.0
f. Livingston to Wallisville	1,027.2	1,780.4	1.7	1,091.2	1.1
Sub-total - channel	3,561.6	6,080.8	1.7	4,695.8	1.3
2. Levees to standard project flood protection (2)					
a. West Fork (3) (4)	2,118.4	2,359.4	1.1	2,359.4	1.1
b. Dallas Floodway Extension (3)	684.4	841.1	1.2	685.0	1.0
c. Liberty Local Protection	79.2	151.5	1.9	240.9	3.0
Sub-total - levees	2,882.0	3,352.0	1.2	3,285.3	1.1
Total - channels and levees	6,443.6	9,432.8	1.5	7,981.1	1.2
3. Flood control only reservoirs					
a. Lakeview	527.7	909.2	1.7	1,391.0	2.6
b. Tennessee Colony	1,989.8	2,268.1	1.1	3,238.0	1.6
Sub-total - Main Stem	8,961.1	12,610.1	1.4	12,610.1	1.4
II. Local Protection Projects					
1. Elm Fork					
a. Elm Fork - channel only	203.0	1,342.9	6.6	1,342.9	6.6
b. Denton Creek - channel only	3.6	6.1	1.7	6.1	1.7
Sub-total - channels	206.6	1,349.0	6.5	1,349.0	6.5
c. Levees	516.8	517.7	1.0	517.7	1.0
Sub-total - Elm Fork Project	723.4	1,866.7	2.6	1,866.7	2.6
2. Duck Creek					
a. Standard project flood control channel	160.4	224.4	1.4	224.4	1.4
Sub-total - Local Protection Projects	883.8	2,091.1	2.4	2,091.1	2.4
Total - Flood control projects	9,844.9	14,701.2	1.5	14,701.2	1.5

(1) Single purpose flood control channel.
(2) Levee costs are based on Lakeview and Tennessee Colony Reservoirs being operational.
(3) Includes added cost of bridge modifications and channel enlargement necessary for proper functioning of leveed floodway.
(4) Includes added cost of bridge modifications and channel enlargement in existing Dallas Floodway.

TABLE 10

COMPARISON OF AVERAGE ANNUAL FLOOD CONTROL BENEFITS AND ANNUAL CHARGES

Proposed flood-control project	Condition of analysis	Year in which average annual flood-control benefits would equal or exceed annual charges
West Fork Floodway	Levees incremental to multiple-purpose channel	1970
Dallas Floodway Extension	Levees incremental to multiple-purpose channel	1980
Liberty Levee	Levees incremental to multiple-purpose channel	1972
Flood-control portion of Lakeview Reservoir	Incremental to multiple-purpose channel and levees	1970
Flood-control portion of Tennessee Colony Reservoir	Incremental to multiple-purpose channel and levees	1982
Elm Fork Floodway	First added	1970
Duck Creek channel	First added	1983

63. SINGLE PURPOSE WATERWAY.- Four plans of improvement were investigated in the development of a single purpose navigation project by extending the existing waterway to Dallas. The four plans were identical except for channel size. Channel sizes investigated were 9 x 150 feet, 12 x 150 feet, 9 x 200 feet and 12 x 200 feet. All four investigated plans provided for sea level channels extending from the Houston Ship Channel to Lock No. 1 at the Wallisville Dam and for a canalized waterway extending upstream of Wallisville Dam following the general alignment of the Trinity River to a proposed navigation terminal at Dallas. The single purpose plan for extending the existing waterway did not consider Tennessee Colony Reservoir in place. The alignment of the four channels followed in general the alignment of the single purpose flood control channel. However, a number of cutoffs and channel rectifications were necessary to meet the criteria of curvature and approach to channel structures for the single purpose navigation channel that were not necessary for the larger flood control channel. Each of the major cutoffs was studied to determine whether or not it was economically justified by comparing the additional cost of construction with the transportation savings it would provide as the result of a shorter channel alignment. The overall length of the investigated channels to Dallas was 318 miles.

64. The proposed channel improvements would provide for a waterway having curves with minimum radii of 2,500 feet, straight bridge approaches of 1,500 feet and straight lock approaches of 2,500 feet. Comparative cost estimates for the four single purpose plans were based on channel side slopes of 1 on 2 and an allowance of 1-foot of channel overdepth. Proposed bridge modifications would provide horizontal clearances of 250 feet and minimum vertical clearances of 50 feet above the water surface elevation equalled or exceeded 2 percent of time. The single purpose waterway extension to Dallas would have 19 locks, with clear dimensions of 84 x 600 feet. A summary of estimates of annual charges for the four channels to Dallas are contained in a tabulation following paragraph 69. Annual charges are based on an assumed construction period of 10 years, Federal and non-Federal interest rates of 2-7/8 percent and 3 percent, respectively, and a 100-year project life. First cost for the four channels are tabulated below.

Channel Size in Feet	Cost
9 x 150	$415,071,000
12 x 150	447,012,000
9 x 200	457,734,000
12 x 200	478,181,000

65. Prospective transportation savings were computed for all four channel sizes to Dallas. Prospective traffic and transportation savings for the 200-foot channels were estimated on the basis that all commerce

except sand and gravel and stone would move in tows consisting of four barges, two abreast and two in tandem. Prospective traffic and transportation savings for the 150-foot channels were estimated on the basis that all commerce except sand and gravel and stone would move in tows consisting of three barges connected in tandem. Barge sizes for all commerce except sand and gravel and stone were 35 feet wide and 195 feet long. Barge tows for sand and gravel and stone consist of two and three barges, 26 feet wide and 175 feet long, connected in tandem.

66. Basic criteria used to determine relationships between tow sizes and channel sizes were the sectional-area ratio, draft-depth ratio and maneuverability ratio. Tests have shown that the resistance to movement of tows in a restricted channel decreases rapidly as the ratio of the sectional area of the channel to the submerged sectional area of tow is increased to a value of six and decreases to a lesser degree as the ratio increases above a value of six. A sectional-area ratio greater than six is therefore preferred. The draft-depth ratio is also important because resistance to tow movement is unduly increased if the draft is greater than 75 percent of the channel depth. Consideration was also given to the maneuverability ratio defined as the length of tow divided by the difference between the average width of channel and width of tow. EM 1110-2-2601 recommends that this ratio be not less than 3.0 and not more than 4.0 if adequate tow maneuverability is to be obtained.

67. Pertinent information concerning the sectional-areas, draft-depth and maneuverability ratios for the investigated channels is contained in the following tabulation:

CHANNEL SIZE STUDY
SECTIONAL-AREA, DRAFT-DEPTH AND MANEUVERABILITY RATIOS
FOR INVESTIGATED CHANNEL SIZES

Channel Size in Feet	Tow Formation	Draft-Depth Ratio	Sectional-Area Ratio	Maneuverability Ratio
9 x 150	1 x 3	0.78	6.2	5.6
12 x 150	1 x 3	0.70	7.0	5.3
9 x 200	2 x 2	0.78	4.0	3.7
12 x 200	2 x 2	0.70	4.5	3.5

68. The above tabulation shows that none of the investigated channel sizes meet all of the recommended ratios. The 12- x 150-foot channel meets the recommended draft-depth and sectional-area ratio, but its maneuverability ratio is 5.3 as compared to a recommended ratio of not less than 3.0 and not greater than 4.0. To compensate for lack of maneuverability and to provide for adequate handling, towboats operating on the 150-foot wide channel would require reserve horsepower for maneuvering in addition to horsepower needed to move tows at optimum

operating speeds. This additional towboat horsepower requirement was taken into account when barge rate factors were being computed for the four investigated channels.

69. Barge rate factors were computed for all four channel sizes and used to determine the net transportation savings that would be creditable to each channel. These savings were compared with annual charges for each of the four channels to determine which of the channels would be most economical. A comparison of annual charges and net annual transportation savings based on prospective traffic for the four channels to Dallas is contained in the tabulation below. This tabulation shows the 12- x 150-foot channel to be the most economical channel size for a waterway from the Houston Ship Channel to Dallas.

COMPARISON OF FIRST COSTS, ANNUAL CHARGES AND ANNUAL BENEFITS FOR SINGLE-PURPOSE NAVIGATION CHANNELS TO DALLAS

Item No.	Channel Size in feet	Annual Charges	Annual Benefits	Benefit Cost Ratio	Excess Benefits
(1)	12 x 150	$18,454,000	$23,486,000	1.27	$5,032,000
(2)	9 x 150	17,334,000	20,682,000	1.19	3,348,000
	(1) minus (2)	$ 1,120,000	$ 2,804,000	-	$1,684,000
(3)	9 x 200	$18,904,000	$22,108,000	1.17	$3,204,000
(4)	9 x 150	17,334,000	20,682,000	1.19	3,348,000
	(3) minus (4)	$ 1,570,000	$ 1,426,000	-	$ -144,000
(5)	12 x 200	$19,623,000	$24,666,000	1.26	$5,043,000
(6)	12 x 150	18,454,000	23,486,000	1.27	5,032,000
	(5) minus (6)	$ 1,169,000	$ 1,180,000	-	$ 11,000

70. Projected tonnage for the reach of channel between Dallas and Fort Worth would be less than half of the tonnage for the waterway below Dallas. For this reason, a channel size study was not made for the reach between Dallas and Fort Worth, a minimum navigation channel having a bottom width of 125 feet and 12-foot depth was selected. This channel is considered to be adequate in size at this time to provide for movement of prospective commerce in barge tows consisting of two barges connected in tandem. Bridges crossing this reach would have to provide horizontal clearances of 200 feet. The necessary lift in this reach would require four locks with dimensions of 56 feet by 400 feet. Since preliminary estimates of cost for extending the single-purpose waterway to Fort Worth indicated marginal merit when considered singly and because of the previously established conclusion that the most efficient solution to the flood problem along the Trinity River and the West Fork was by an improved channel and floodway, tests were made to determine the savings in cost that would accrue to the various project purposes by joint use of a common channel alignment and the corresponding benefits which would accrue thereto. The results of this study are presented in subsequent paragraphs.

71. EXTENSION OF WATERWAY BY MULTIPLE-USE CHANNEL.- A multiple-purpose channel for solution to the flood problem and to meet the need for barge navigation to the Fort Worth-Dallas complex could have significant cost saving advantages and thereby each purpose served would share in such rewards. The sizes of the previously presented plan for a single-purpose flood control channel for the streams below the existing and recommended flood control reservoirs were selected primarily on the basis of operational releases from the reservoirs; by the most efficient combination of floodway channel sizes; and by other economic and design objectives adopted for this study. The flood control only plan was aligned so that the natural river channel and all existing bridges or bridge locations would be most efficiently utilized. The plan provided for the modification of existing highway and railroad bridges where necessary in order to provide required clearances, pier protection, and bank stabilization. The single-purpose waterway channel size study showed that a 12-x 150-foot channel would be the most efficient of four different sizes investigated. The canalized waterway extending upstream of the existing project followed the general alignment of the single-purpose flood control channel. The single-purpose waterway improvements would provide for a channel having curves with minimum radii of 2500 feet, straight bridge approaches of 1500 feet, and straight lock approaches of 2500 feet. The single-purpose waterway to Dallas would have 19 locks with clear dimensions of 84 x 600 feet. Locks for the single-purpose waterway would be at the same location as those for a multiple-use channel, except for the reach through the Tennessee Colony Reservoir.

72. Data presented in prior paragraphs have clearly demonstrated economic justification for both functions, as single-purpose projects. There remains an evaluation of the economic advantages of integrating the two project purposes into a common channel and alignment. Preliminary design and cost estimates show that a common channel alignment would effect significant savings in construction cost. The multiple-use channel follows, in general, the alignment of the single-purpose channels. Several cutoffs were justified for the single-purpose navigation alignment that were not justified for the multiple-use channel. At these locations, the multiple-use alignment follows the river more closely than the single-purpose navigation channel. The single-purpose flood control channel followed the natural river channel in reaches where existing capacities were adequate, and where existing capacities were inadequate, the more economic route was selected in balancing land cuts versus the longer river cuts.

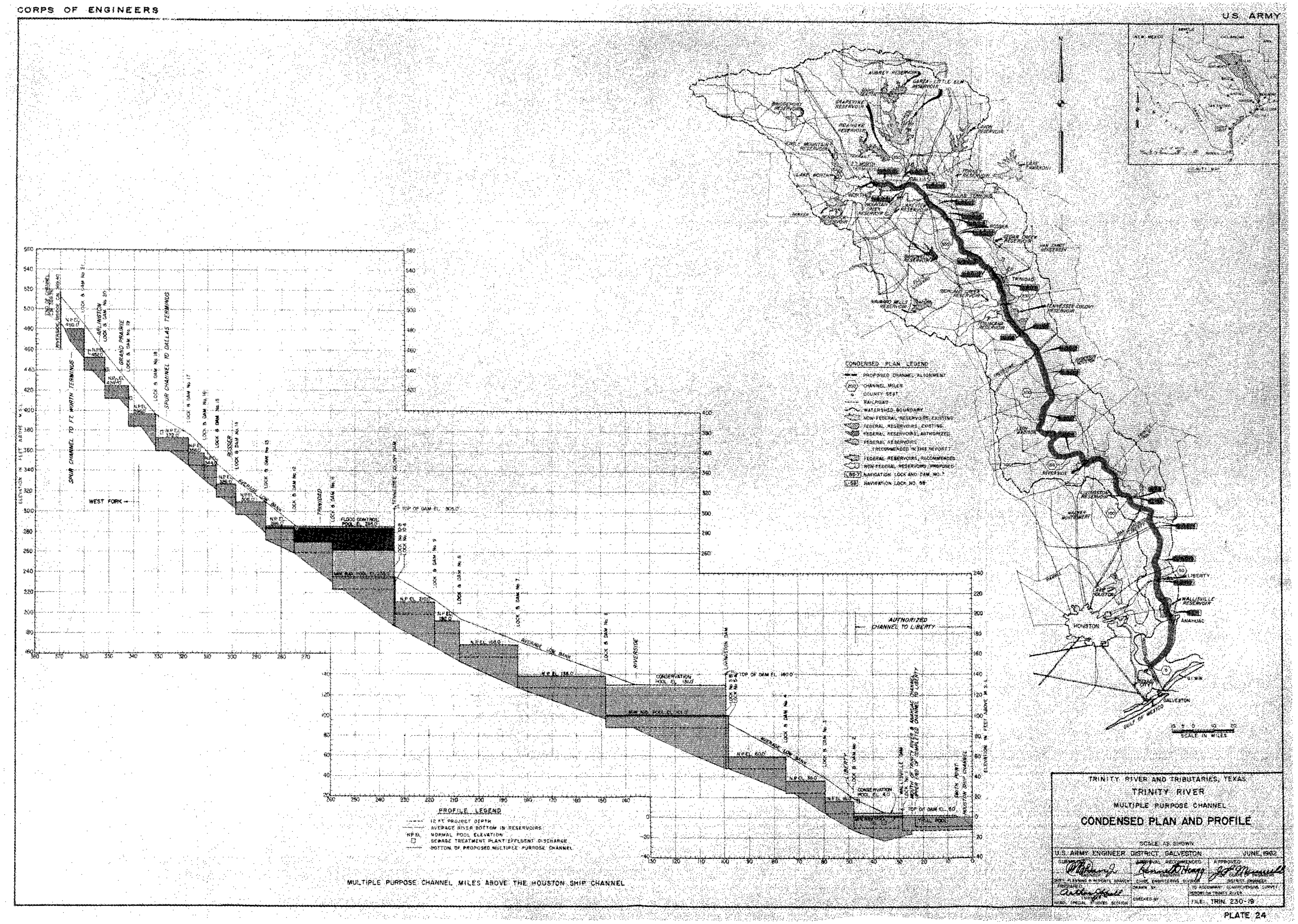
73. The multiple-purpose channel to mile 35.5, as proposed in this report, provides for deepening to 12 feet the completed and uncompleted portions of the 9-x 150-foot channel to Liberty project from the Houston Ship Channel and includes channel realignment at and below Wallisville, Texas. At channel mile 35.5, the 9-x 150-foot authorized (uncompleted) channel to Liberty would be incorporated in the proposed multiple-purpose channel which would have a bottom width of 300 feet and a depth of about 27 feet below top of river banks. Upstream of channel mile

43.5, the dimensions of the channel would decrease to a minimum of 150 feet at Lock and Dam No. 4. Upstream of the Livingston Dam, the channel would have a bottom width of 150 feet excepting three widely separated reaches where the channel width would be 200 feet. The plan provides for a channel, 12 feet deep and 150 feet wide extending through the Tennessee Colony, Wallisville and Livingston Reservoirs. The top of the navigation pool through the reservoirs would be located at the bottom elevation of the conservation pools of the respective reservoirs, and thereby the channel would provide 100 percent navigation through the reservoirs when conservation storages are fully depleted. Pertinent information regarding the dimensions and capacity of various sections of the multiple-purpose channel is given in the following tabulation, and the condensed plan and profile are presented on plate 24.

PERTINENT DATA MULTIPLE-PURPOSE CHANNEL
HOUSTON SHIP CHANNEL TO DALLAS

Channel mile From	Channel mile To	Length (miles)	Bottom width(ft)	Depth (ft)(1)	Recommended operating discharge (cfs)	Recommended channel capacity (cfs)
0.0	28.30	28.30	150	13.3	Tidal pool	
			Wallisville Reservoir			
35.50	43.50	8.00	300	27.0	35,000	45,000
43.50	55.70	12.20	350	30.0	35,000	45,000
55.70	74.85	19.15	200	34.0	35,000	45,000
74.85	100.88(2)	26.03	150	40.0	35,000	45,000
			Livingston Reservoir			
147.92	234.60(3)	86.68	150	45.0	35,000	45,000
			Tennessee Colony Reservoir			
274.51	293.00	18.49	200	25.0	25,000	32,000
293.00	304.00	11.00	150	28.0	25,000	32,000
304.00	331.31	27.31	150	26.0	20,000	27,000

(1) Approximate depth of channel below top of river bank.
(2) Upper end of flood release discharge channel at the Livingston spillway basin.
(3) Upper end of flood release discharge channel at the Tennessee Colony spillway basin.



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74. The advantage of combining a waterway channel with a floodway channel to constitute a multiple-purpose channel project is demonstrated in the tabulation below.

Annual Charges for Flood Control-Waterway Channel to Dallas	$18,230,200
Annual Charges for Flood Control Only Channel to Dallas (including Liberty Levee)	$ 3,123,900
Incremental Annual Cost of the Waterway	$15,106,300
Incremental Annual Benefits	$20,746,000
Benefit-Cost Ratio	1.4

75. The navigation project from the Houston Ship Channel to Dallas extends through the Tennessee Colony Reservoir. Many of the cost items such as land and relocation costs are common to both projects which cannot readily be separated for the two functions. Also a saving can be effected by the joint construction of these two projects in this reach. The Tennessee Colony Reservoir project costs used in this report include the necessary cost to make navigation functional from the downstream side of Lock 10B in the Tennessee Colony Dam up to the downstream side of Lock and Dam No. 12. There is no meaningful way to evaluate the navigation benefits that would accrue to this segment of the navigation project through the Tennessee Colony Reservoir. However, it appears reasonable to consider that the benefit-cost ratio of 1.4 for the navigation project from the Houston Ship Channel to Dallas would be applicable to the separate segment through Tennessee Colony Reservoir.

76. The flood control only plan, between Five Mile Creek below Dallas and the downstream limits of the existing floodway at Fort Worth, provides for floodway discharges varying from about 95,000 to 174,600 cubic feet per second. The channel capacity in this reach would vary from 30,000 to 35,000 cubic feet per second. Standard project flood protection would be provided. The channel bottom widths would vary from 150' to 200'. These widths would serve the needs for a waterway. The channel was aligned so that all existing bridges or bridge locations were utilized where practicable. Existing highway and railroad bridges were modified where necessary to provide required clearances, pier protection, and bank stabilization. The annual charges and benefits for this reach of the plan are $3,319,700 and $4,222,100, respectively. The benefit-cost ratio is 1.3.

77. It is anticipated that shippers and receivers of waterway commerce would likely locate in the protected areas behind the floodways that would extend throughout the reach of the Trinity River in the Fort Worth-Dallas complex. Several public wharves and terminals are expected to become operational and used extensively along the waterway if the recommended project is authorized. However, industrial, manufacturing,

commercial, and transportation business establishments are expected to locate at strategic points between Fort Worth and Dallas and in other sites downstream toward Houston and Galveston. The pattern of location will be influenced by demographic, economic, legal, and other practical considerations. Information presented in Appendix VII, Economic Base Study, demonstrates that the rapid growth of the Fort Worth-Dallas complex can be expected to continue at an accelerated rate. For these and other reasons, it is inescapable that sound planning dictates extending the existing waterway to a point that would be centrally located for prospective users of the waterway. Practical considerations of the demand that will be made by prospective users of the waterway, if extended, focuses on the need to terminate the waterway at a point near the mouth of Big Fossil Creek.

78. Because the prospective tonnage for the channel reach between Dallas and Fort Worth will be about half of the tonnage for the waterway below Dallas, a minimum navigation channel having a bottom width of 125 feet and 12-foot depth was selected for the Dallas-Fort Worth reach at this time. This channel is considered to be adequate in size to provide for movement of commerce in barge tows consisting of two barges connected in tandem. Bridges crossing this reach would provide horizontal clearances of 225 feet between bridge fenders. Four locks would be required with dimensions of 56 feet by 400 feet. The alignment for a waterway channel in this reach is largely controlled by design criteria of minimum curvature of 2500 feet between tangent reaches, straight bridge approaches of 1500 feet and straight lock approaches of 2500 feet. Channel alignment for a plan of joint use for flood control and navigation would, in general, follow the alignment of flood control only plan. However, the multi-use alignment provides for numerous cutoffs of small river bends and straightening of the river to provide tangent reaches on the general alignment of the river to meet design criteria for curvatures and approach tangents to locks and bridge structures. Proposed bridge modifications would provide minimum clearances of 50 feet above the water surface elevation equalled or exceeded 2 percent of the time. Pertinent information regarding the dimensions and capacity of the reach between Fort Worth and Dallas of the multiple-purpose channel is given in the following tabulation.

PERTINENT DATA - MULTIPLE-PURPOSE CHANNEL
FORT WORTH TO DALLAS

Channel mile From	Channel mile To	Length (miles)	Bottom width(ft)	Depth (ft)(1)	Recommended operating discharge (cfs)	Recommended channel capacity (cfs)
331.31	337.30	5.99	150	26.0	20,000	25,000
337.30	342.51	5.21	150	26.0	12,000	15,000
342.51	360.17	17.66	200	26.0	12,000	15,000
360.17	367.83	7.66	150	26.0	12,000	15,000
367.83	369.78	1.95	200	26.0	12,000	15,000

(1) Approximate depth of channel below top of river bank.

79. Costs and benefits studies show that the flood control channel only plan along the Trinity River from Wallisville Reservoir to Dallas and thence up West Fork to Fort Worth has a favorable benefit-cost ratio of 1.3. The annual charges are $3,561,600 and the annual benefits are $4,695,800. The joint flood control-waterway project, including levees, to Fort Worth would have an annual charge exclusive of recreation of $24,770,100. The tabulation below shows the cost advantage of combining the flood control and waterway improvement works.

Annual Charges of Flood Control-Waterway to Fort Worth	$24,770,100
Annual Charges of Flood Control Only Plan to Fort Worth	$ 6,443,600
Incremental Cost of Waterway Improvements	$18,326,500
Incremental Waterway Benefits	$24,002,000
Benefit-Cost Ratio for Waterway to Fort Worth	1.3

80. Another more rigorous test shows that extending the waterway from Dallas to Fort Worth would also be justified. This test is considered to be of little significance, however, primarily because the practical aspects of waterway extension dictate that the focus of use will be centralized in the Fort Worth-Dallas complex. Information on the test is tabulated below.

Annual Charges for Flood Control-Waterway Dallas to Fort Worth	$ 6,539,900
Annual Charges for Flood Control Only Plan from Dallas to Fort Worth	$ 3,319,700
Incremental Cost of Waterway Extension Dallas to Fort Worth	$ 3,220,200
Incremental Waterway Benefits	$ 3,256,000
Benefit-Cost Ratio	1.0

81. GENERAL.- In relation to future needs, water is the most important natural resource of the Trinity Basin. With the rapid growth of urban population in the last 20 years there has been a firm realization by responsible interests that future water supply is one of the area's most important concerns. The Trinity River Basin has less length and drainage area than several other Texas river basins, but due to the moderate to heavy rainfall occurring over its drainage area, the flow near its mouth is exceeded only by the Sabine and Neches Rivers. The statistics of mean annual precipitation show that, on the whole, the Trinity River Basin receives a generous supply of fresh water through rainfall. The water problems, however, arise not from the averages but from the extremes. The history of the basin shows a recurring pattern of long to moderate droughts followed by periods of heavy rainfall, sometimes torrential in character. This is illustrated by the prolonged drought experienced throughout the basin during the years 1950-1957, followed by severe floods in 1957. The rainfall records for Fort Worth are typical for this period. Fort Worth has a normal annual rainfall of 33.7 inches. During the six full years, 1951 through 1956, the annual rainfall ranged from 18.6 inches to 25.2 inches and averaged 22.4 inches. The accumulated deficiency during the period was over 68 inches. The drought was broken by heavy rainfall which began in April 1957 and extended into the early part of June and totaled 28.8 inches.

82. Drought periods cause serious shortages of water throughout the basin to the cities and towns which depend upon the river for municipal and industrial water supplies and to the agricultural areas which withdraw river water for irrigation purposes. During the 1950-1957 drought, both Dallas and Fort Worth, as well as many smaller cities, were forced to significantly curtail water use and seek temporary and expensive means of supplementing their water supplies. Dallas found it necessary to import low quality water from the Red River Basin as a temporary measure. On the other hand, during the periods of heavy rainfall, vast quantities of water flow unregulated and often destructively down the river in floods. As the basin develops and population, industry and the general economy expands, more and more water will be needed. To a large extent the only practical solution lies in controlling and regulating the river so that flood waters can be stored, conserved and used more efficiently.

83. In addition to surface waters, a large portion of the area is underlaid by great natural underground water reservoirs. These ground water supplies have played an important part in the economic development of the area, furnishing water for municipal and industrial needs and irrigation. In most of these aquifers there has been a general lowering of the water table, but by future increase in the use of

surface waters and the possibility of recharging the ground-water reserves by injection of surface waters, it is anticipated that underground water resources will be available and used for many years in the future.

84. QUALITY OF WATER.- Maintenance of water quality and reduction of stream pollution are essential in the future consideration of water as a natural resource. The two primary measures of water quality used (in this study) are total dissolved solids and biochemical oxygen demand (BOD). The total dissolved solids concentrations of waters within the basin presently vary from a low of 100 milligrams per liter to a high of 1,000 milligrams per liter. Concentrations in excess of 500 milligrams per liter are very few and are confined to the lower coastal region. These high concentrations are due to brackish estuarine waters which affect the mineral quality of the river as far as 40 miles inland. In general, the mineral quality of the Trinity Basin can be described as good to very good.

85. On the other hand, the organic quality of a large part of waters of the basin is presently very poor. Above Fort Worth, and below the San Jacinto County line, the organic quality of basin streams can be classified as good. This is due to light pollution loads entering the basin above Fort Worth and the self-recovery of the stream from the high loads imposed by the Fort Worth and Dallas complex by the time the river reaches the San Jacinto County line. Below the confluence of Marine Creek with the West Fork in Fort Worth and downstream to Rosser in Kaufman County, the conditions in the river are generally anaerobic and associated offensive odors persist. Downstream from Rosser, sufficient tributary dilution and reaeration occur, almost overcoming the effects of the organic pollution upon reaching the San Jacinto County line. The waters in the watersheds of the proposed reservoirs, with the exception of Tennessee Colony Reservoir, are not presently subjected to extensive contamination from communities, industries, or other sources.

86. The future expansion of population and industrial activity with resultant increased waste loads being discharged into the streams of the basin will direct more attention to contributions that should be made to the improvement of water quality either through direct reduction of waste loads, or by dilution from increased stream flow.

87. WATER FOR IRRIGATION.- In the Trinity River Basin and adjacent coastal area, about 68,000 acres of land were irrigated in 1958 with a total water use of about 165,000 acre-feet from the Trinity River Basin supplies. Present surface-water irrigation is concentrated largely in the lower basin where water is diverted from the Trinity River for rice production. There is some additional surface-water irrigation on numerous small tracts scattered along the Trinity River

below Dallas and along several tributaries. In addition to the surface-water irrigation there is some ground-water irrigation in the lower portion of the basin and on small, scattered tracts throughout the basin.

88. Based on the projected population and industrial expansion and increased water demands in the Trinity River Basin, it is believed that irrigation in the future will remain about the same except along the Trinity River below Dallas. A study of available land resources revealed that about 42,000 acres between Dallas and the Tennessee Colony Reservoir site; about 49,000 acres between that site and the Livingston Reservoir; and about 80,000 acres in the lower basin and in the adjacent coastal area for a total of 171,000 acres are physically suitable for sustained permanent-type irrigation and production of agricultural crops and have been considered in the overall plan of development for the basin. The total projected water requirements for irrigation of these areas are 356 million gallons a day or about 399,100 acre-feet per year.

89. With respect to the 80,000 acres in the lower basin and adjacent coastal area there are existing appropriative rights and permits which provide for the future irrigation water supply of this area. However, in the interest of developing the remaining 91,000 acres of land along the Trinity River, consideration was given to Federal project-type facilities. From a study of these areas, the Bureau of Reclamation concluded that since the areas lie in scattered tracts along the river, they are best suited for development by indivivual landowners rather than large project-type irrigation. However, information furnished by the Soil Conservation Service indicates that some irrigable areas are well-adapted to small project-type development under Public Law 566, as amended. The municipal and industrial return flows from the Fort Worth - Dallas area will provide a large sustained flow that will be physically accessible to landowners desiring to irrigate holdings along the main stem.

90. WATER AS A RESOURCE.- Water supply for the Trinity River Basin both in terms of available resources and total needs for the present and the future is a subject which has received considerable attention during recent years. Many water supply studies have been made by various echelons of government - local, state, and Federal. Many actions have been completed in connection with the water supply for the Trinity River Basin such as: the presentations which have been filed with the Texas Water Commission for specific allocations of storage for water supply in reservoir projects; the permits which have been issued by the Texas Water Commission for conservation storage space in various projects both existing and under construction; the agreements which have been consummated that affect the present and future use of water resources in the basin; and the construction of a number of reservoir projects both single and multiple purpose which contain conservation storage.

91. The economic development and growth of the area are dependent to a great extent on the efficient development of the water and related land resources. In the interest of a fully-coordinated water supply plan, cognizance must be given to the completed actions, in the field of water supply, as they influence further development of the water resources in the basin.

92. There are many other factors which must also be recognized and evaluated in satisfying the water supply needs of the basin such as the specific locations of the future needs; the available resources both ground and surface; the imports to and exports from the basin; the use and recirculation of return flow; the distribution problems; the expressed policy of the State for maximum practical development of the water resources; the water quality aspects both in terms of available supply and requirements for rehabilitation of quality; and the development of projects consistent with the concept of sound planning and serving the best interest of the people.

93. PROJECTED WATER REQUIREMENTS.- An evaluation of the projected economic development and the impact of this development on the basin indicates that during the next century the population of the basin will have increased about 6 times and the total water demands on the basin will have increased from about 380 million gallons per day in 1958 to about 3,400 million gallons per day in 2020 and to about 5,200 million gallons per day in 2070 as shown in the following tabulation:

WATER REQUIREMENTS
(Million Gallons Per Day)

Sub-basin	Municipal and Industrial	Non-Municipal	Water quality control	Navigation	Irrigation	Exports	Total
			Year 2020				
Upper	1,513(1)	15	80(2)	0	69	0	1,677
Middle	227	3	0	0	65	0	295
Lower	340	2	0	57	222	840	1,461
Total	2,080	20	80	57	356	840	3,433
			Year 2070				
Upper	2,797	11	0(2)	0	69	0	2,877
Middle	435	4	0	0	65	0	504
Lower	686	1	0	57	222	840	1,806
Total	3,918	16	0	57	356	840	5,187

(1) Includes 40 MGD yield from Aubrey Reservoir for interim use as water quality control.

(2) 80 MGD for water quality control would be converted to water supply as the need develops.

94. ESTIMATED WATER SUPPLY.- The water supply for the Trinity River Basin has been considered on the basis of three general geographic areas of demand based on the system of water supply developments and their probable intended use. The upper basin which comprises all of the drainage area above Tennessee Colony Dam; the middle basin which includes the area from Tennessee Colony Dam to the headwaters of Livingston Reservoir; and the lower basin which consists of Livingston Reservoir and the area downstream therefrom. The lower basin requirements also include the demands on the basin for exports to Houston, Texas and the irrigation demands in the adjacent coastal area.

95. Water supply in the basin will be a problem if water resources are not developed sufficiently in advance to satisfy projected needs. In the Trinity River Basin, about 235 million gallons of water per day were used in 1958 for municipal and industrial purposes. At the present time the water resources of the basin from in-basin supplies and importations are about 1.4 billion gallons of water per day. These resources are more than adequate to satisfy the projected demands for 1975. In the Trinity Basin where wide variations in stream flow are experienced, supply and demand and distribution of the water resource is a continuing problem.

96. YIELDS FROM EXISTING SURFACE SOURCES.- At the present time there are both existing and authorized facilities to cope with these problems as they exist today. The tabulation that follows indicates that under 2020 conditions of basin development water yields of about 1,390 million gallons per day can be expected from existing, under construction and authorized projects, and projects recommended for authorization in prior reports.

PRIMARY RESERVOIR YIELDS (million gallons per day) (1)

Reservoir Project (2)	Upper Basin: Federal	Upper Basin: Non-Federal	Lower Basin: Federal	Lower Basin: Non-Federal	Total
Existing, Under Construction and Authorized					
Benbrook	6.5				
Grapevine	18.1				
Garza-Little Elm	86.0				
Lavon	35.5				
Navarro Mills	18.1				
Bardwell	4.2				
Bridgeport		50.4			
Eagle Mtn & Lake Worth		17.5			
Weatherford		0.6			
Arlington		5.8			
White Rock		1.9			
Forney		58.8			
Tawakoni (Iron Bridge)	(Imports)	174.0			
Terrell		0.6			
Cedar Creek		173.2			
Waxahachie		1.9			
Flat Creek	(Imports)	6.0			
Livingston			670.9		
Anahuac			13.4		
Totals	168.4	490.7	684.3		1,343.4
Recommended for Federal Authorization in Previously Submitted Reports					
Lavon (enlargement)	42.7				
Wallisville			(3)		
Totals	42.7				42.7

(1) Based on recurrence of 1950-1957 critical dry period under 2020 conditions of watershed development.
(2) No projects in Middle Basin.
(3) Included with yield of Livingston Reservoir.

97. PROPOSALS TO SOLVE RESIDUAL WATER REQUIREMENT NEEDS.- In consideration of means to meet the existing and potential water supply needs in the Trinity River Basin all known physical possibilities for improvement or development of the water resources of the basin were given study. Investigations were made of various dam and reservoir sites and the physical effects of each site were evaluated and compared in terms of potential for meeting water supply needs and their possibilities for solutions of other problems, particularly flood problems. The obviously unjustified and least favorable projects were eliminated from further consideration and more detailed study was given to the more favorable sites. Projects were considered both singly and in combination to determine the most practical solution to the basin's water problems. The extent of consideration given to each project varied but was sufficiently thorough in each case to provide a sound conclusion concerning its suitability. More than 40 potential reservoir sites throughout the basin were studied. Twenty-two of the reservoir sites on the main stem of the Trinity River and major tributaries were selected as having favorable locations, topography, and effectiveness for this study. In consideration of solutions to the flood problems of the basin, studies showed that Lakeview and Tennessee Colony Reservoirs were desirable adjuncts to the existing Trinity River plan (see Paragraphs 49 and 51). Preliminary considerations clearly show that these reservoirs would also be efficient sites for water supply purposes primarily because of their favorable location with respect to the high demand area of the Fort Worth - Dallas complex. Studies also showed that Roanoke and Aubrey Reservoirs should also be included in the plan to help meet the water supply and quality needs of the area. A system of 13 other reservoirs was also found to be desirable additions to the Trinity River plan, primarily to meet future long-range water supply needs and secondly for their potential use to solve localized flood problems that are likely to develop as the economy expands. In selecting the number and size of these projects, a primary consideration was the water use agreement between the Trinity River Authority and the city of Houston, Texas, pertaining to the Livingston and Wallisville Reservoirs. The terms of this agreement with respect to water resources development by reservoir projects have been included in the water permits issued by the Texas Water Commission, and have established a control with respect to the location and the degree of development of the resources for utilization within the basin. Other primary factors considered were existing water permits by the State to in-basin water users; importation of water from adjoining basins; location of areas of projected economic development; available yields from existing, under construction, and proposed water supply reservoirs; and the State's policy for maximum practical development of river basin water resources. The yields of these reservoirs are in general in agreement with the permissible limits of upper basin development as established by the Texas Water Commission in their permit dated October 11, 1960, to the Trinity River Authority and

the city of Houston. All these reservoirs are in the Trinity River Authority Master Plan. Richland, Tehuacana, and Boyd Reservoirs are considered as a part of the long-range water supply plan for the city of Fort Worth. The following tabulation shows the yield from the reservoirs in the long range plan.

RESERVOIR YIELDS (1)
(million gallons per day)

Reservoir project	Upper basin	Middle basin	Lower basin	Total
RECOMMENDED FOR INCLUSION IN LONG RANGE PLAN BUT NOT FOR AUTHORIZATION AT THIS TIME(2)				
Boyd	31.7			
Richland Creek	169.3			
Tehuacana	56.9			
Upper Keechi		54.3		
Hurricane		17.5		
Lower Keechi		25.2		
Bedias		94.4		
Harmons		16.8		
Gail		31.0		
Mustang		25.2		
Caney		25.2		
Long King			34.9	
Capers Ridge			98.0	
Total	257.9	289.6	132.9	680.4

(1) Based on recurrence of 1950-1957 critical dry period under 2020 conditions of watershed development.
(2) Authorization studies will be required to determine the extent of Federal participation.

98. UPPER BASIN WATER SUPPLY.- In the upper basin the projected water requirements for years 2020 and 2070 can be satisfied from the water resources shown in the following tabulation.

UPPER BASIN WATER SUPPLY

Water Resources	Available Supply (Million gallons per day) 2020	2070
Reservoirs - existing, under construction, & authorized	479.1	479.1
Importations	174.0	180.0
Reservoirs previously recommended for authorization	42.7	42.7
Reservoirs recommended for authorization in this report	410.4	410.4
Sub-total	1,106.2	1,112.2
Potential long-range reservoir projects	257.9	257.9
Total reservoirs	1,364.1	1,370.1
Additional use of ground water, return flows, and possible importations	312.9	1,506.9
Total developed resources	1,677.0	2,877.0

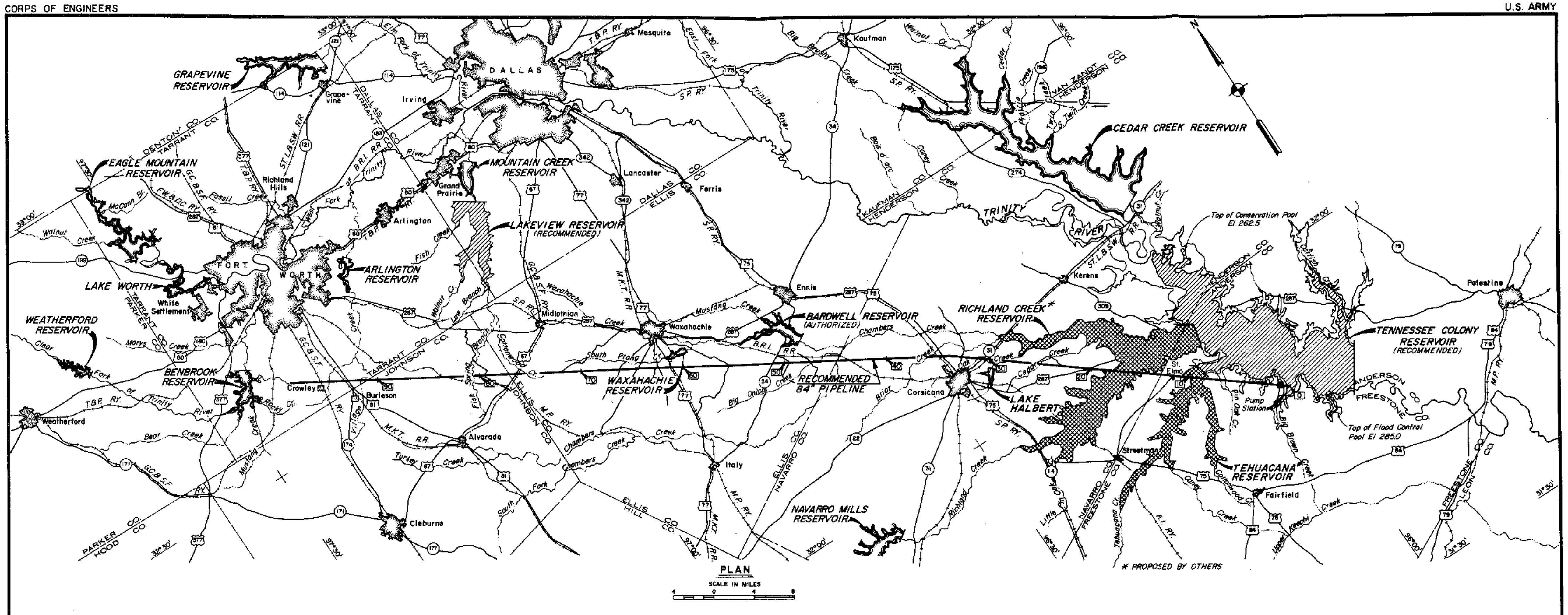
The upper basin has the water resource potential to satisfy the projected needs for the next century (2020 - 1677 MGD and 2070 - 2877 MGD) based on an orderly development of the reservoir projects sufficiently in advance of the needs, the progressive increase in the use of ground water within the practical limits of available supply, the reuse of water by recirculation, and by a continuation of the existing importations. Planning studies indicate that previously referred to Lakeview, Lavon enlargement, and Tennessee Colony Reservoirs plus Aubrey Reservoir above Garza-Little Elm Reservoir and Roanoke Reservoir above the Grapevine Reservoir - all in addition to the existing, under construction, and authorized projects should be considered for added elements to the

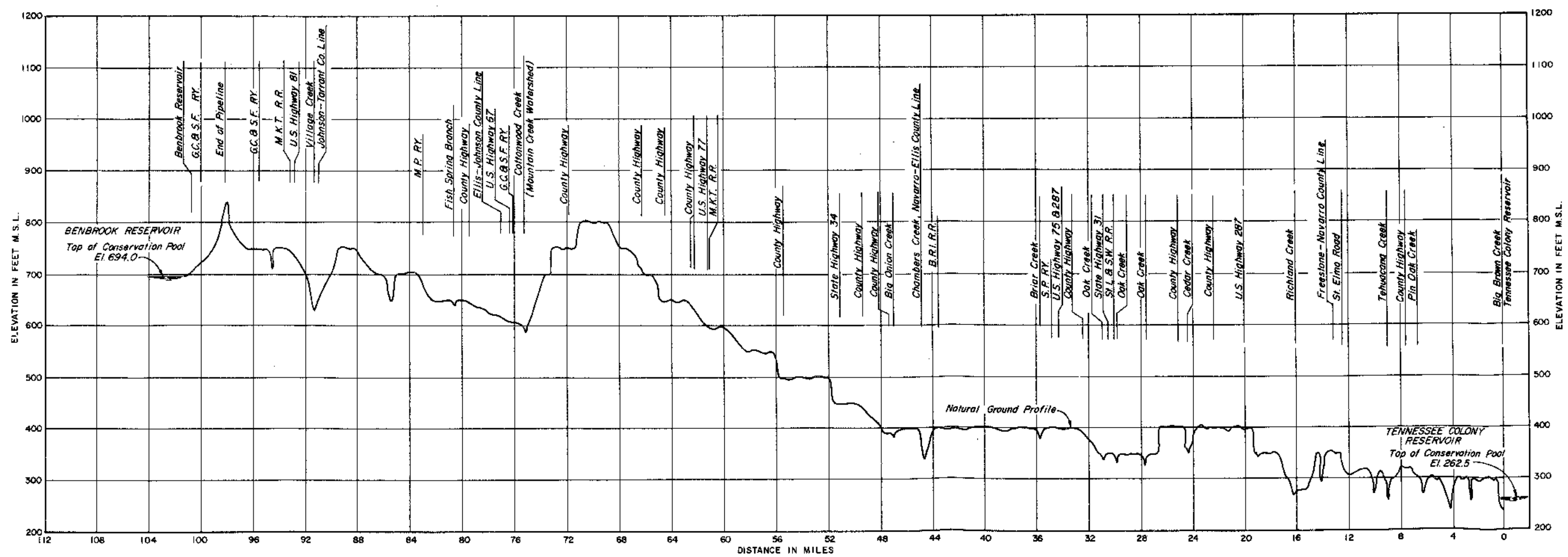
Trinity plan. Lakeview and Lavon enlargement could be used to satisfy municipal and industrial water requirements; whereas, the yield from the Tennessee Colony Reservoir and Aubrey Reservoir Projects could serve dual purposes -- a source for dilution water and water supply for municipal and industrial purposes.

99. Studies show there is an immediate need for 120 million gallons of water per day for water quality control in the Fort Worth-Dallas area which would be reduced to 80 million gallons per day by year 1985 and be practically eliminated by year 2040. The 80 million gallons per day of water could be conveyed by a 98 mile long pipeline from Tennessee Colony Reservoir to the existing Benbrook Reservoir. Releases could then be made from this project to satisfy water quality control requirements on the West Fork of the Trinity River. In the Dallas area the major portion of the yield from Aubrey Reservoir for the first few years could be used in the interest of water quality control on the Trinity River below Dallas. As the demand for municipal and industrial water supply increases in the Dallas area a transition in use would be made from water quality to municipal and industrial.

100. The reduction in dilution water requirements from Tennessee Colony and Aubrey Reservoirs and the progressive increase in re-use of water are predicated upon improvements in sewage treatment processes. Professional opinions forecast that technological improvements in the field of treating municipal and industrial wastes will be accomplished in the foreseeable future, and thereby permit the re-use of significant volumes of waste water.

101. Ultimately, total resources of the Tennessee Colony Reservoir could be used in the upper basin through development of reservoir projects in the middle basin, which will be coordinated with upstream needs, and reservoir development in an orderly manner to permit a transfer of use from the middle to the upper basin. From the Tennessee Colony Reservoir sufficient volumes of good quality water could be recirculated to supplement the supply from reservoirs, ground water and importations to satisfy the projected requirements. Releases to satisfy navigation requirements will be made from Tennessee Colony Reservoir. The construction of the Roanoke Reservoir project can be phased into the overall demand pattern for the upper basin when the need becomes apparent. Supply and demand curves for the basin follow presentation of the middle and lower portions of the basin. The plan and profile for the proposed pipe line for water quality control and possible future water supply are shown on plate 25. Plate 23, Tennessee Colony Reservoir map, also shows the pipe line location with respect to the reservoir.





TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER

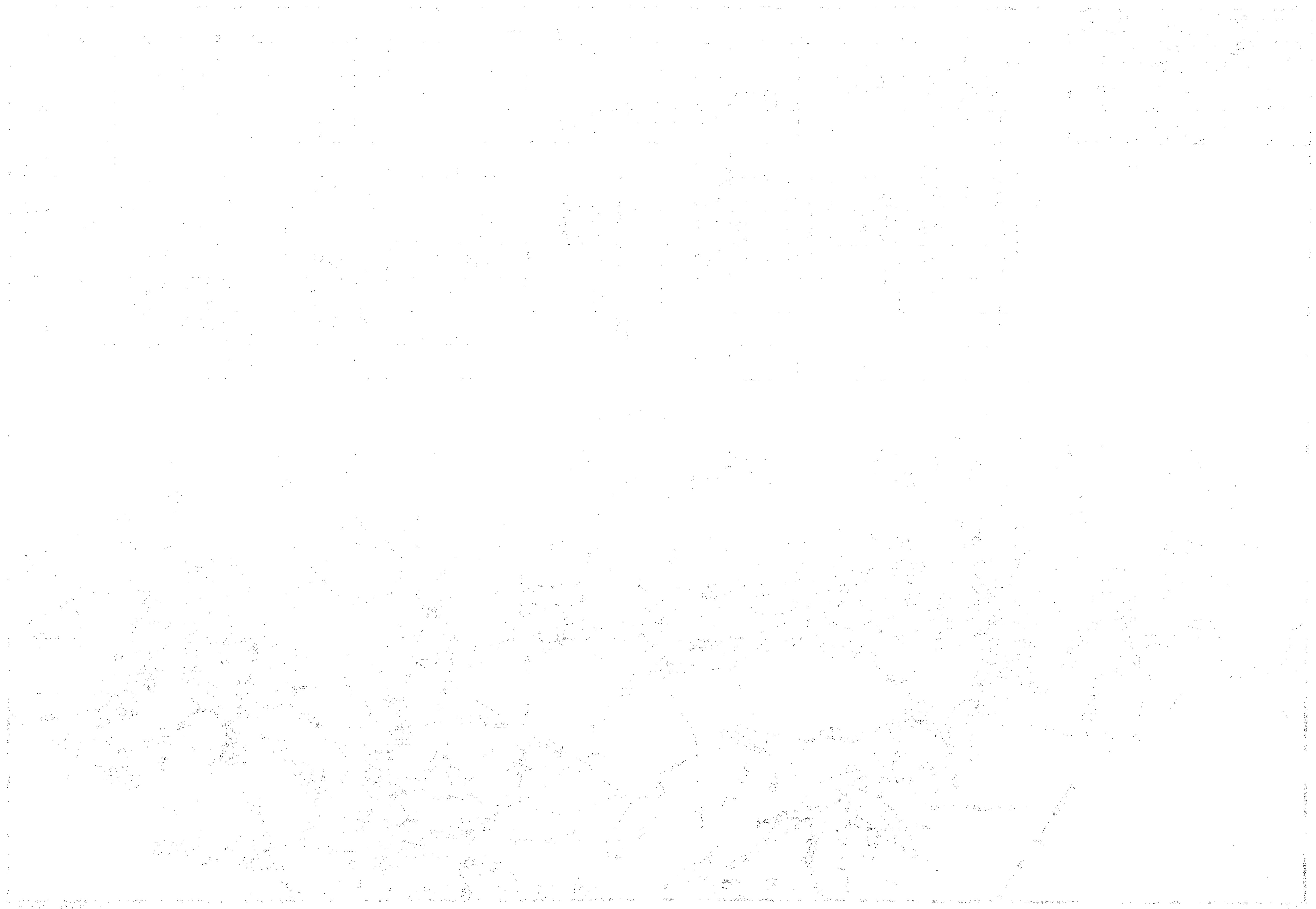
PIPE LINE FOR WATER QUALITY CONTROL AND POSSIBLE FUTURE WATER SUPPLY

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH JUNE 1962

SUBMITTED: W. E. Wood, ENGINEER, CHIEF, PLANNING & REPORTS BRANCH	APPROVAL RECOMMENDED: C. J. Swenson, ENGINEER, CHIEF, ENGINEERING DIVISION	APPROVED: COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: A. W. Hawley, ENGINEER, HEAD, SPECIAL STUDIES SECTION	DRAWN BY: M.B.F. CHECKED BY: M.B.W.	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER; FILE: TRIN. 230-19

PLATE 25



102. MIDDLE BASIN WATER SUPPLY.- The projected water requirements of the middle basin for years 2020 (295 MGD) and 2070 (504 MGD) can be satisfied from the water resources shown in the following tabulation:

MIDDLE BASIN WATER SUPPLY

Water Resources	Available Supply (Million gallons per day) 2020	2070
Reservoirs - existing, under construction & authorized	0	289.6
Importations	0	0
Reservoirs previously recommended for authorization	0	0
Reservoirs recommended for authorization in this report	0	0
Sub-total	0	289.6
Potential long-range reservoir projects	289.6	0
Total reservoirs	289.6	289.6
Additional use of ground water, return flows, and possible importations	5.4	214.4
Total developed resources	295.0	504.0

This portion of the basin has repeatedly experienced major floods which perhaps is the major single controlling factor that has curtailed the development of the natural resources in this area. There are a number of excellent damsites, with locations shown on plate 1, which afford opportunities for the development of the surface water resources. Construction of the multiple-purpose channel through this reach of the basin will eliminate the major flood problem and attract development along the channel. Initially the water supply demands of this area could be met from the Tennessee Colony Reservoir project. As the water supply needs develop throughout the middle basin many of the other referenced damsites are expected to be developed and the demand on Tennessee Colony could be transferred from the middle basin to the upper basin. In addition to the reservoir yields, ground water and reuse of water could be used in sufficient quantities to satisfy the projected needs for the middle basin.

103. LOWER BASIN WATER SUPPLY.- In the lower basin the total projected water requirements for years 2020 (1461 MGD) and 2070 (1806 MGD) which include an export to Houston of 840 million gallons per day and 222 million gallons per day for irrigation in the adjacent coastal area, could be satisfied from the water resources shown in the following tabulation:

LOWER BASIN WATER SUPPLY

Water Resources	Available Supply (Million gallons per day) 2020	2070
Reservoirs - existing, under construction & authorized	684.3	817.2
Importations	0	0
Reservoirs previously recommended for authorization	0	0
Reservoirs recommended for authorization in this report	0	0
Sub-total	684.3	817.2
Potential long-range reservoir projects	132.9	0
Total reservoirs	817.2	817.2
Additional use of ground water, return flow, and possible importations	643.8	988.8
Total developed resources	1,461.0	1,806.0

The Livingston Reservoir, being developed by local interests, will be operated in combination with the Wallisville Reservoir project (recommended for authorization in a separate report) as a coordinated system for maximum utilization of the runoff from the uncontrolled drainage area between these projects and the return flow from the upstream areas. As the water supply needs in the lower basin develop beyond the supply available from the Livingston - Wallisville system, ground water, and reuse, the Long King Reservoir and Capers Ridge Reservoir projects could be developed as supplemental supplies to satisfy the projected needs for year 2070.

104. SUMMARY OF SUPPLY AND DEMAND FOR TRINITY WATER RESOURCES.- The foregoing planning considerations have been accomplished within the framework of legal requirements, physical yield of streams and of underground water sources, topographic and physical site limitations at damsites and reservoir areas, and most importantly, on an inescapable conclusion that the overall need and demand for the development of the water resources of the Trinity Basin is a certainty. However, the exact time and place of need and demand is not as certain. To meet this uncertainty one of the built-in objectives of planning considerations used in this study has been to develop a plan that is amendable to various combinations of projects and uses to meet the demands of localized areas that may develop differently in yields and time than now envisioned. Table 11 that follows is a summary of estimated water requirements in the years 2020 and 2070 by 6 categories of uses and it also shows 3 major physical methods of developing the water resources to meet the project requirements. A basic element in rationalization of the merits of the various projects inevitably concerns the costs and benefits in terms of use. This is treated in subsequent paragraphs.

105. PROJECTS TO DEVELOP TRINITY WATER RESOURCES.- As previously pointed out, studies of some 40 reservoir sites showed that 19 of these sites had merit with respect to development of the water resources in the Trinity River Basin. Data on these projects are given in table 12.

TABLE 11

WATER RESOURCES AND REQUIREMENTS
(Million Gallons Per Day)

Subbasin	WATER RESOURCES (1)				WATER REQUIREMENTS						
	Reservoir Yields	Imports	Ground water and use of return flow	Total	Municipal and Industrial	Non-Municipal	Water Quality Control	Navigation	Irrigation	Exports	Total
YEAR 2020											
Upper	1,190	174	313	1,677	1,513(2)	15	80(3)	0	69	0	1,677
Middle	290	0	5	295	227	3	0	0	65	0	295
Lower	817	0	644	1,461	340	2	0	57	222	840	1,461
Total	2,297	174	962	3,433	2,080	20	80	57	356	840	3,433
YEAR 2070											
Upper	1,190	180	1,507	2,877	2,797	11	0	0	69	0	2,877
Middle	290	0	214	504	435	4	0	0	65	0	504
Lower	817	0	989	1,806	686	1	0	57	222	840	1,806
Total	2,297	180	2,710	5,187	3,918	16	0	57	356	840	5,187

(1) Based on recurrence of 1950-1957 critical dry period under 2020 conditions of basin development.
(2) Includes 40 MGD yield from Aubrey.
(3) 80 MGD for water quality control would be converted to water supply as the need develops.

TABLE 12

WATER SUPPLY RESERVOIRS
TRINITY RIVER BASIN

Reservoir	Conservation Storage (acre-feet)	Yield 2020 conditions (MGD)	First Cost(1) (dollars)	Annual Charges (dollars)	Cost per 1000 gals (dollars)	Est. Yr. of need
UPPER BASIN						
Lakeview	316,300	30.4	20,138,000	735,900	0.066(3)	1970
Roanoke-Grapevine exchange	223,700	23.9(2)	15,505,000	551,700	0.063(4)	2000
Aubrey-Garza-Little Elm exchange	862,100	65.3(2)	24,240,000	889,500	0.037(5)	1970
Tennessee Colony	1,040,000	290.8	41,710,000	1,525,700	0.014(6)	1970
Boyd	600,000	31.7	29,500,000	1,063,100	0.092	2010
Richland Creek	1,000,000	169.3	26,940,000	1,024,700	0.017	2000
Tehuacana	282,500	56.9	12,100,000	471,400	0.023	2010
MIDDLE BASIN						
Upper Keechi	125,000	54.3	6,690,000	277,300	0.014	2010
Hurricane	150,000	17.5	6,600,000	279,700	0.044	2010
Lower Keechi	170,000	25.2	7,320,000	305,900	0.033	2010
Bedias	360,000	94.4	18,100,000	667,300	0.019	2010
Harmons	78,000	16.8	6,700,000	267,600	0.044	2010
Gail	168,000	31.0	8,400,000	337,800	0.030	2010
Mustang	156,000	25.2	7,900,000	323,000	0.035	2010
Caney	134,000	25.2	7,200,000	297,300	0.032	2010
LOWER BASIN						
Long King	184,000	34.9	6,100,000	274,900	0.022	2000
Capers Ridge	818,100	98.0	39,400,000	1,400,800	0.039	2040

(1) Cost of single-purpose conservation reservoir. (2) Net yield effected by exchange of storages. (3) Allocated cost of water, $0.051 per thousand gallons. (4) Allocated cost of water, $0.060 per thousand gallons. (5) Allocated cost of water, $0.035 per thousand gallons. (6) Allocated cost of water, $0.010 per thousand gallons.

106. LONG-RANGE RESERVOIR PROJECTS.- From the foregoing paragraphs and rationalization of the need for development of the Trinity water resources it is readily apparent that serious consideration should not be given at this time to the construction of 13 of the smaller reservoirs because of their relative costs in terms of yield, the year of probable demands for water supply therefrom, and their flexibility and suitability to be placed under construction within a relatively short period of time confident that their construction and contributions would be compatible with the comprehensive plan for the Trinity Basin. For these and other reasons, more comprehensive treatment was not given in the study to design, costs, and economics of the referenced 13 reservoirs. However, the studies made are sufficiently thorough in each case to provide a sound conclusion concerning their desirability as elements of any long-range plan for the Trinity River Basin.

107. OTHER RESERVOIRS - TENNESSEE COLONY.- Paragraph 47 presents the preliminary considerations that were used as a basis for the conclusion that a reservoir at the Tennessee Colony site would be highly efficient for storage of water to prevent flooding in the lower basin and of its possible merit for the development of the water resources of the basin. A single-purpose flood-control project (2,192,400 acre-feet) at the Tennessee Colony site comparable in design and quality of cost estimates to the recommended multiple-purpose project to the Tennessee Colony site would cost in the magnitude of $56,380,000 and the annual charges would be $1,989,800. The benefit cost ratio for the flood-control only project was 1.6. As previously pointed out in paragraphs 94-99, the Tennessee Colony site has a practical maximum yield of about 290.8 million gallons per day that could be used to satisfy municipal and industrial requirements and to provide a source of dilution for water quality control in the Fort Worth - Dallas area. The most significant upstream pollution source in the basin is the city of Fort Worth. Other major sources are the Trinity River Authority sewage disposal plant and the city of Dallas in that order. There is no water available for quality control in basin reservoirs upstream from Fort Worth. The first stage of development to meet water quality requirements would be a pipeline from Tennessee Colony Reservoir to Benbrook Reservoir which would transport a yearly average of 80 million gallons per day. This water initially would be released from Benbrook Reservoir to satisfy monthly needs varying from 136 million gallons per day in July to 29 million gallons per day in January. Aubrey Reservoir would provide additional releases amounting to an annual average of 40 million gallons per day initially to abate the pollution imposed by the city of Dallas. This first stage development would satisfy water quality needs in the upper basin until the year 1985. Additional treatment to improve the oxygen economy in the effluents of the Fort Worth, Trinity River Authority, and Dallas waste treatment plants are expected to obtain by the year 1985. This additional treatment, coupled with 80 million gallons per day of dilution water from Tennessee Colony Reservoir would be adequate to satisfy water quality needs in the upper Trinity River Basin until the year 2020.

108. After the year 2020, the water from Tennessee Colony Reservoir would be needed to meet municipal and industrial requirements in the upper basin and should revert to this use completely by the year 2040. In all probability, waste treatment technology will have advanced sufficiently to negate the need for quality control water beyond the year 2020. The period of 20 years between 2020 and 2040 allows for stage construction of such facilities. On this premise, no needs for quality control water are envisioned beyond this year.

109. The cost of a single-purpose water conservation reservoir at the Tennessee Colony site to provide a yield of 290.8 million gallons per day (1,040,000 acre-feet) comparable in design and quality of cost estimate for the recommended multiple-purpose project would be $41,710,000 and the annual charges would total $1,525,700. The water conservation benefits are estimated to be $1,844,100. The benefit-cost ratio would be 1.2. The advantage of joint use of the Tennessee Colony site for flood control and water conservation is demonstrated in the following tabulation. The area and location of Tennessee Colony Reservoir are shown on plate 23.

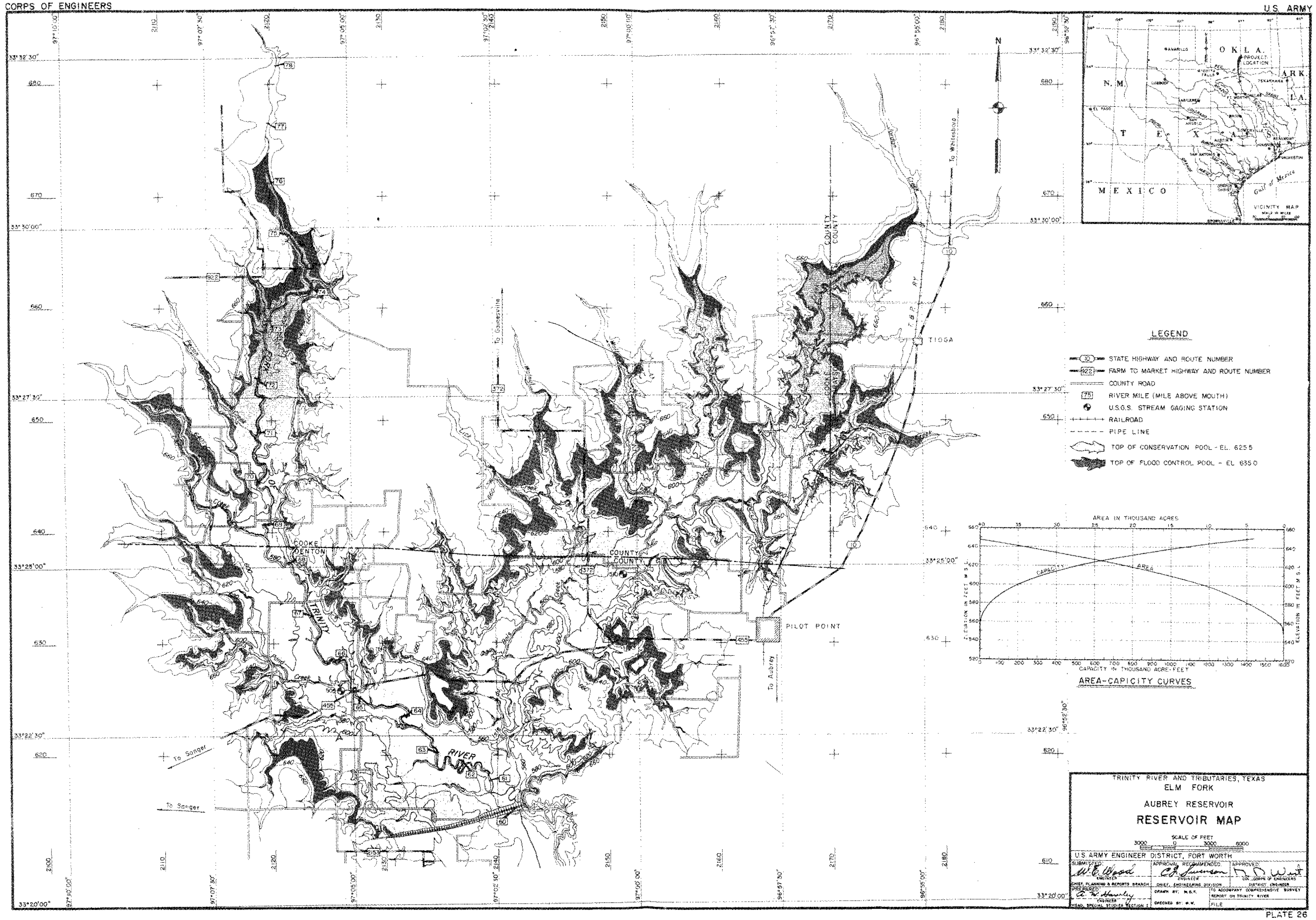
Item	Cost
Cost of dual-purpose project	$77,300,000
Cost of single-purpose flood-control project	56,380,000
Cost of single-purpose water supply project	41,710,000
Incremental cost of water supply to flood control	20,920,000
Incremental flood control to water supply	35,590,000
Annual charges dual-purpose project	2,789,500
Annual charges single-purpose flood control	1,989,800
Incremental costs of water supply	799,700
Water supply benefits	1,844,100
Benefit-Cost Ratio	2.3

110. AUBREY - GARZA-LITTLE ELM RESERVOIR SYSTEM.- The Aubrey Dam Site is located at mile 60.0 on the Elm Fork Trinity River, 30 river miles upstream from the existing Lewisville Dam (Garza-Little Elm Reservoir). The site was investigated in the interest of facilitating the development of additional conservation storage and was undertaken on an exchange of storage basis with the existing Garza-Little Elm Reservoir. Aubrey would provide, in combination with Garza-Little Elm Reservoir, the same degree of flood control as that provided by the existing project. Sufficient flood-control storage would be retained in Garza-Little Elm Reservoir to regulate the flood runoff originating on the 976 square miles of intervening area. Flood-control storage allocated to Aubrey Reservoir would allow for runoff rates resulting from a relatively greater areal distribution of higher rainfall intensities on the smaller drainage area controlled by

the Aubrey Dam. Garza-Little Elm Reservoir now contains 1,002,900 acre-feet of controlled storage capacity of which 513,400 acre-feet are for flood control, 436,000 acre-feet for water conservation, and 53,500 acre-feet for sediment reserve. The proposed Aubrey Reservoir would contain 899,900 acre-feet of controlled storage capacity of which 258,300 acre-feet would be for flood-control, 603,800 acre-feet for water conservation, and 37,800 acre-feet for sediment reserve. The flood-control storage proposed for Aubrey Reservoir would permit a reallocation of storage in Garza-Little Elm Reservoir and increase that storage presently allocated to water conservation. Garza-Little Elm Reservoir reallocated storages would consist of 1,002,900 acre-feet of controlled storage capacity of which 331,600 acre-feet would be for flood-control, 630,600 acre-feet for water conservation, and 40,700 acre-feet for sediment reserve. Under 2020 conditions of watershed development and a recurrence of the 1950-1957 drought period, the dependable yield from the proposed Aubrey-Garza-Little Elm Reservoir system is estimated to be 234 cubic feet per second or 151.3 million gallons per day. This represents an increase of dependable yield of 101 cubic feet per second or 65.3 million gallons per day.

111. As pointed out previously, water yield from storage in Aubrey would be used initially in the interest of water quality control on the Trinity below Dallas. As the demand for municipal and industrial water supply increases in the Dallas area, a transition in use would be made from water quality to municipal and industrial use. For planning purposes the transition has been estimated to accrue about the year 1985 plus or minus a few years. Subsequently, the entire yield would be dedicated to municipal and industrial water supply purposes. The cost of a single-purpose water supply project to develop the increased yield of 101 cubic feet per second is estimated to be $24,240,000. The annual charges and benefits are estimated to be $889,500 and $1,085,200, respectively, and the benefit-cost ratio is 1.2. The incremental cost of water supply in the Aubrey Reservoir project to effect the exchange of storage is $23,974,000, which indicates a saving of about $266,000 over the single-purpose water supply project. The location and area of Aubrey Reservoir are shown on plate 26.

112. ROANOKE - GRAPEVINE RESERVOIR SYSTEM.- The Roanoke Dam Site is located at mile 32.0 on Denton Creek 20.3 river miles upstream from Grapevine Dam. This site was investigated in the interest of furthering the development of additional conservation storage and as in the case of the proposed Aubrey Reservoir, studies were undertaken on an exchange of storage basis with an existing Corps of Engineers reservoir located downstream. Roanoke would provide, in combination with Grapevine Reservoir, the same degree of flood control as that provided by the existing Grapevine Reservoir. Drainage areas at the Roanoke Dam Site and Grapevine Dam are 604 and 694 square miles, respectively. Sufficient flood-control storage is retained in Grapevine Reservoir to regulate the flood runoff originating on the 90 square miles of intervening area. Flood-control storage allocated to Roanoke



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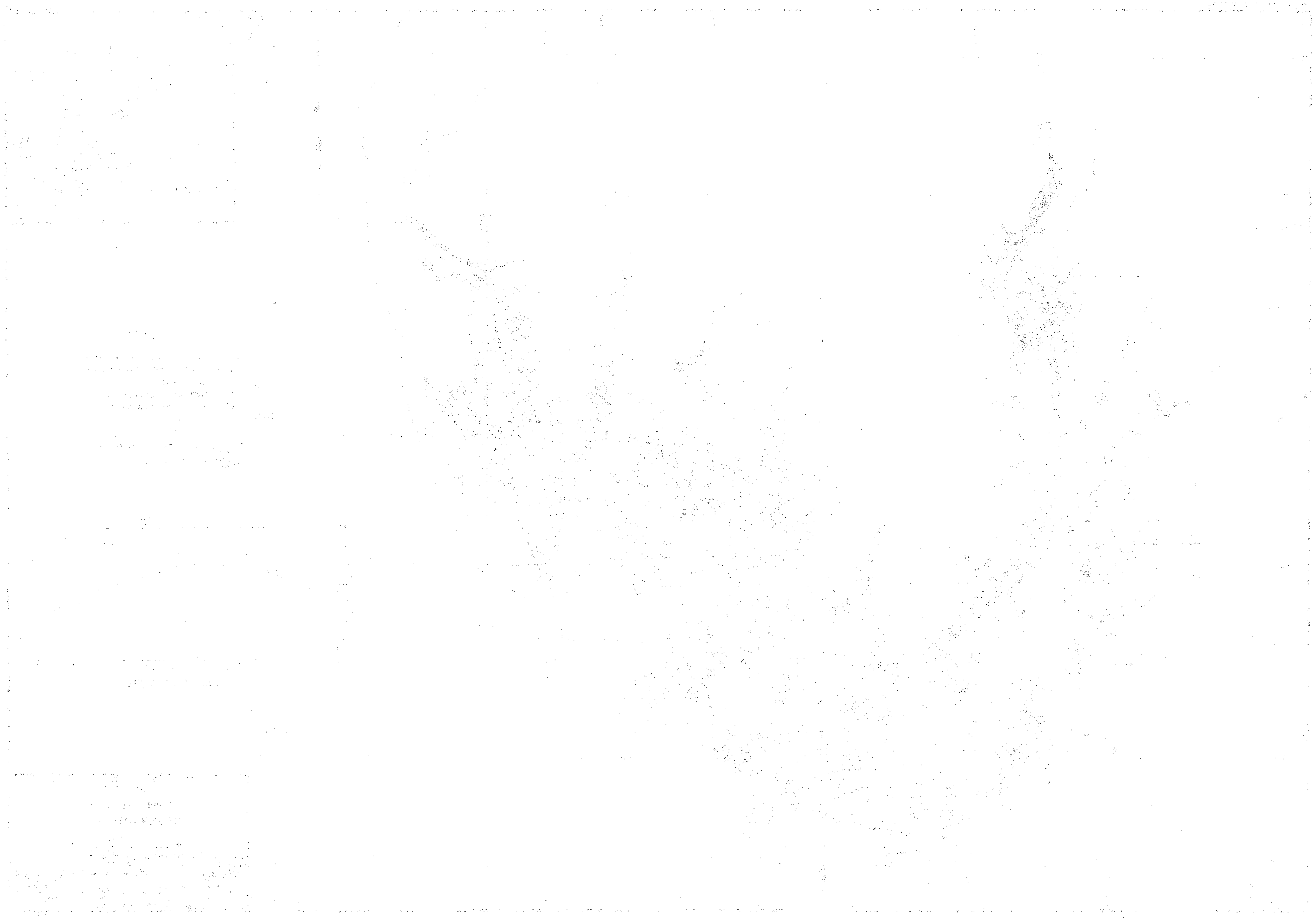

Reservoir would allow for runoff rates resulting from a relatively greater areal distribution of higher rainfall intensities on the smaller drainage area controlled by the Roanoke Dam.

113. Grapevine Reservoir now contains 435,500 acre-feet of controlled storage capacity of which 238,250 acre-feet are for flood control, 161,250 acre-feet for water conservation, and 36,000 acre-feet for sediment reserve. The proposed Roanoke Reservoir would contain 249,900 acre-feet of controlled storage capacity of which 223,700 acre-feet would be for flood control, and 26,200 acre-feet for sediment reserve. The flood-control storage proposed for Roanoke Reservoir would permit a reallocation of storage in Grapevine Reservoir, and increase that storage presently allocated to water conservation. Grapevine Reservoir storages resulting from the reallocation would consist of 435,500 acre-feet of controlled storage capacity of which 47,300 acre-feet would be for flood-control, 372,200 acre-feet for water conservation, and 16,000 acre-feet for sediment reserve. The dependable yield from the Grapevine Reservoir, with the reallocation made possible by the flood-control storage in Roanoke Reservoir, under 2020 conditions of watershed development and a recurrence of the 1950-1957 drought period is 65 cubic feet per second, or 42 million gallons per day. This represents an increase in yield of 37 cubic feet per second or 23.9 million gallons per day over that which would be produced by Grapevine Reservoir alone.

114. The need for storage in the Roanoke Reservoir for conservation uses is expected to be 25 or 30 years hence. For many years the Roanoke damsite and reservoir area has been the subject of study by various governmental units in the interest of water supply, flood control and other purposes. Roanoke has been included in the comprehensive Trinity River plan by the Trinity River Authority, the U. S. Study Commission - Texas, and in the long-range plan of the city of Dallas. The land needed for the Roanoke project to permit additional development of the water resources yield in Grapevine Reservoir comprises about 13,200 acres. The land and improvements thereon are presently used primarily for agriculture. The city of Justin (population 622) is located in the headwater areas as is the Gulf Colorado and Santa Fe Railroad and farm-to-market highways 156 and 407, and State Highway 114 crosses the Henrietta Creek arm of the reservoir. Other secondary roads, utilities, and farm houses are located in the reservoir area. The cost of lands and improvements totals about $3,500,000.

115. Consideration of the pattern of economic growth in the areas of the Roanoke Reservoir strongly suggests that extensive development can be expected to take place before water supply demands are likely to develop. Such development, if not limited, would preclude the later construction of the Roanoke Reservoir because of the high cost for lands, relocations and damages. For these and other reasons, it is recommended in the report that an interest be acquired in the necessary land in

advance of construction so as to preserve the damsite and reservoir area from encroachment by future residential, commercial , industrial, and other development. The interest in land to be acquired would be the minimum necessary consistent with the objective of site and reservoir preservation. Reliance would be placed with non-Federal authorities on tax rolls and control development until the Roanoke project is needed for the development of water resources. Such measures would include provisions for advanced participation and construction or reconstruction of the transportation and utility facilities where necessary. For purposes of this study it has been concluded that revenue and net income from the land and improvements would liquidate the annual charges of the cost of interest acquired in reservoir land. The cost of a single-purpose water supply project to develop the increased yield of 37 cubic feet per second is estimated to be $15,505,000. The annual charges and benefits are estimated to be $551,700 and $683,700, respectively, and the benefit-cost ratio is 1.2. The incremental cost of water supply in the Roanoke Reservoir project to effect the exchange of storage is $15,330,000 which indicates a saving of about $175,000 over the single-purpose water supply project. The location and area of Roanoke Reservoir is shown on plate 27.

116. LAKEVIEW RESERVOIR.- Information previously presented with respect to possible solution to the flood problems in the area showed a reservoir at the Lakeview site was highly efficient in control of flood flows originating on the Mountain Creek watershed. A single-purpose flood-control project at that site had a benefit-cost ratio of 2.6 when considered as single-purpose project. Studies also showed that a reservoir at the Lakeview site would produce the maximum practical yield that could be obtained from the watershed. For maximization studies, capacity-cost and capacity-benefit curves were used to develop a graph showing excess benefits over cost (see figure 7). The point of maximum excess benefits for water conservation would be realized from a reservoir that would have a net dependable yield of 47 cubic feet per second. This yield is the maximum that could be obtained from the watershed at this site. Cost and benefit data on water conservation aspects of the reservoir are shown in the tabulation following:

Item	Cost
Annual charges for single-purpose water supply project	$735,900
Annual benefits for single-purpose water supply project	$907,300
Benefit Cost Ratio	1.2
Annual charges for flood-control water supply project	$984,700
Annual charges for flood-control only project	$527,700
Incremental costs of water supply	$457,000
Benefits	$907,300
Benefit Cost Ratio	2.0

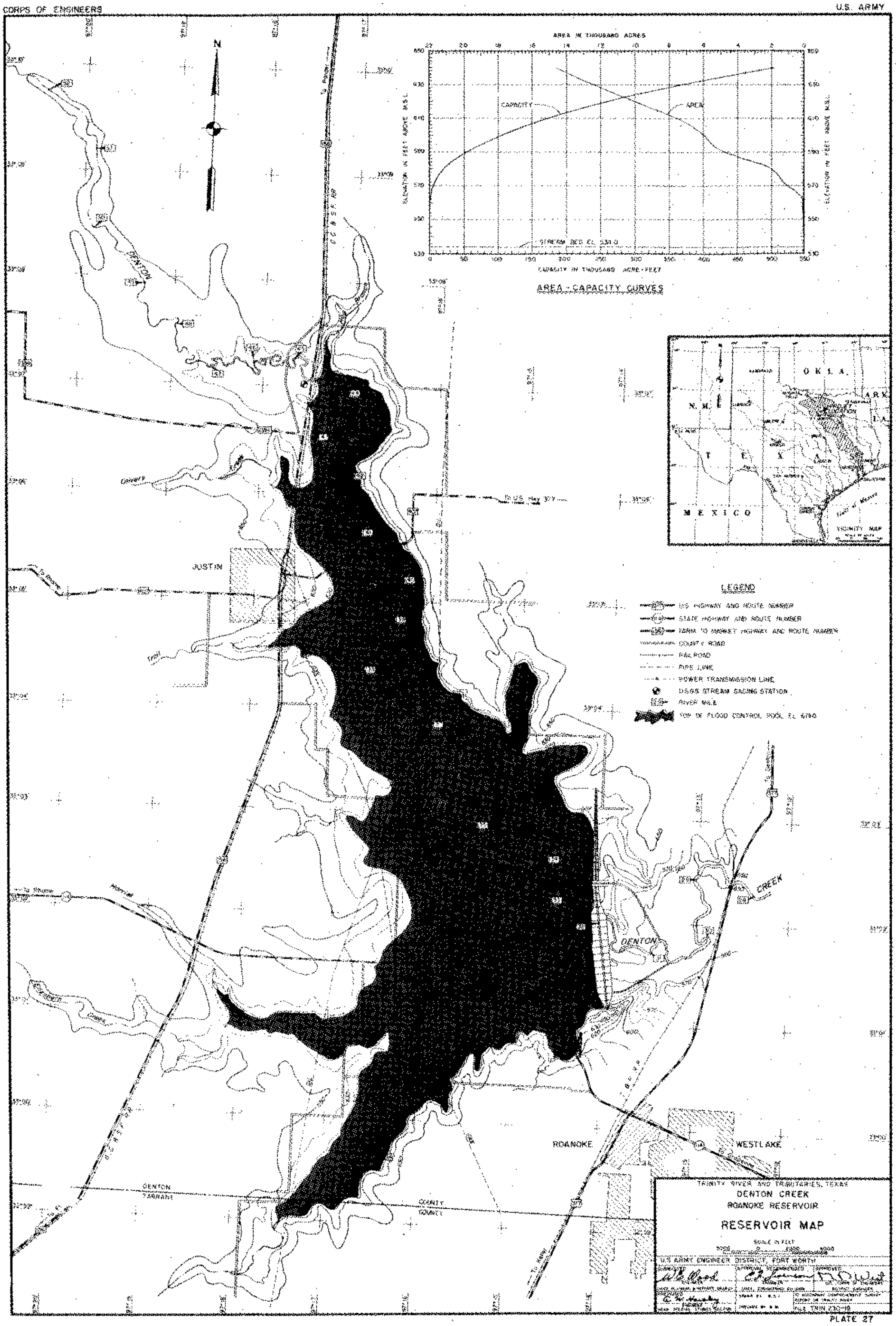
AREA IN THOUSAND ACRES
CAPACITY
AREA
ELEVATION IN FEET ABOVE M.S.L.
STREAM BED EL. 534.0
CAPACITY IN THOUSAND ACRE-FEET
AREA - CAPACITY CURVES
OKLA.
ARK.
LA.
N. M.
T E X
M E X I C O
VICINITY MAP
LEGEND
U.S. HIGHWAY AND ROUTE NUMBER
STATE HIGHWAY AND ROUTE NUMBER
FARM TO MARKET HIGHWAY AND ROUTE NUMBER
COUNTY ROAD
RAILROAD
PIPE LINE
POWER TRANSMISSION LINE
U.S.G.S. STREAM GAGING STATION
RIVER MILE
TOP OF FLOOD CONTROL POOL EL. 619.0
JUSTIN
DENTON
CREEK
ROANOKE
WESTLAKE
DENTON
TARRANT
COUNTY
COUNTY
TRINITY RIVER AND TRIBUTARIES, TEXAS
DENTON CREEK
ROANOKE RESERVOIR
RESERVOIR MAP
SCALE IN FEET
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
FILE TRIN 230-10

PLATE 27

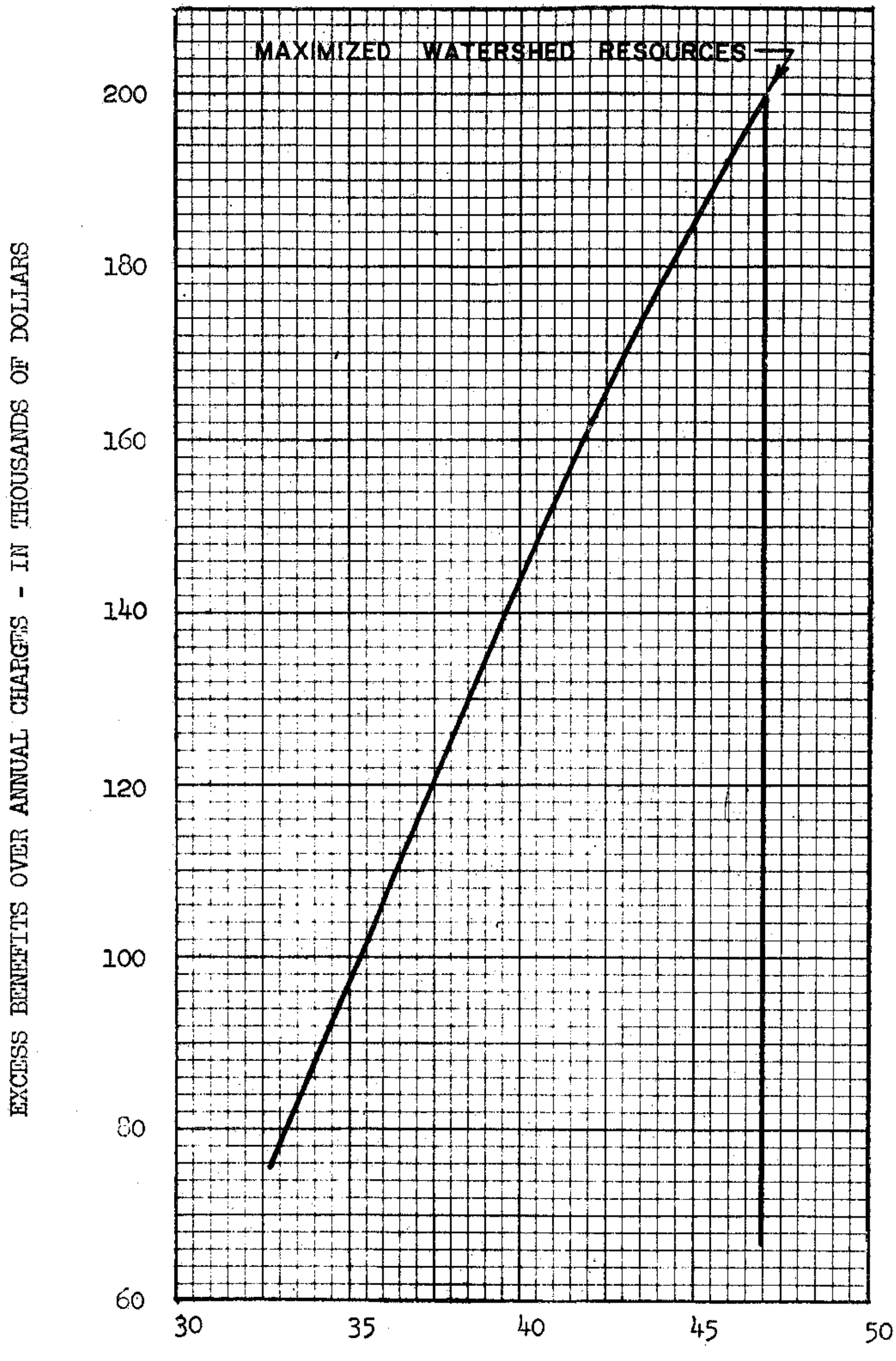

FIGURE 7
LAKEVIEW RESERVOIR
MAXIMIZATION OF EXCESS WATER SUPPLY BENEFITS

117. WATER CONSERVATION BENEFITS.- The benefits of storage for water supply for municipal and industrial, and quality control purposes in the reservoir projects were computed by the U. S. Public Health Service and used in the economic analysis of these projects. The alternative cost method was used for evaluation of the storages and since investigation revealed no other sources of supply than at the projects selected, single-purpose reservoirs at these sites were used as the alternative project. The single-purpose water supply project cost was amortized over a 100-year period at a non-federal interest rate of 4 percent to determine the benefits creditable to each project. Since there is an immediate need for the water from the Lakeview, Tennessee Colony, and Aubrey projects and since construction is deferred on the Roanoke project until it is needed, no discount of the benefits has been considered. The benefits creditable to the pipeline for quality control purposes was computed in the same manner; that is, the pipeline cost was amortized over a 100-year period at a non-Federal interest rate of 4 percent. The following tabulation shows the average annual benefits creditable to each project based on the amount and period of use (as determined by the U. S. Public Health Service) of the stored water for water supply and quality control purposes.

Project	Reservoir Yield (mgd)	Benefits	
		Water Supply - $	Water Quality - $
Lakeview	30.4	907,300	-
Aubrey	65.3	679,000	406,200
Roanoke	23.9	683,700	-
Tennessee Colony	290.8	1,416,600	427,500
Pipeline	80 (1)	558,800	3,186,700

(1) Capacity of 84-inch pipeline from Tennessee Colony Reservoir to Benbrook Reservoir will revert to municipal and industrial use as the need develops.

RECREATION AND FISH AND WILDLIFE

118. GENERAL.- Many factors are to be considered in the development of a water resource project to obtain maximum sustained benefits from conservation and use of natural resources. Among these factors are public park and general recreation use and fish and wildlife recreation. The demand for outdoor recreation is large, and is growing as is the population. More and more people are seeking the outdoors, and the trend is expected to increase with the coming decades. This increase is evidenced by visitations to recreation areas; increase in the number of hunting and fishing licenses issued; and the increase in sales of boats, motors, and equipment for camping, fishing and hunting, and other recreation activities. Visitation to all water resource projects located in the Trinity River Basin, including those under the jurisdiction of the Fort Worth District, are increasing each year. Related to the projected population growth in the Trinity River Basin, existing recreation areas and facilities will not be adequate to accommodate the crowds seeking outdoor recreation. The facilities required to accommodate the public seeking outdoor recreation, will consist of land and recreation facilities for public use at each proposed water resource project. The land designated for public use and rights-of-way to provide access should be acquired in fee title and use easements during the land acquisition program.

119. Experience indicates that there is a degree of visitation or usage which, if regularly exceeded, makes the recreational aspects of a project less attractive and results in deterioration. This density of visitation may be termed the optimum visitation capacity or recreation design capacity of the project. In effect, it becomes a visitation design load, which should not be regularly exceeded. This may be expressed in terms of annual visitor peak-day (normal summer weekend) visitation. For purposes of this report the design capacity of each project is expressed in terms of optimum annual visitation. There are a number of factors which affect the optimum capacity of a water-resource project. Major factors to be considered include:

a. Principal types of recreational use.

b. Area of usable lands and waters.

c. Nature and length of shoreline.

d. Nature of recreation resource.

120. On the basis of experience at existing Corps reservoirs, taking the above factors into consideration, it is estimated that the optimum capacity of projects in the plan of improvement will be as follows:

Project	Optimum annual visitation
Aubrey	6,000,000
Bardwell	1,500,000
Benbrook	2,500,000
Grapevine	3,500,000
Garza-Little Elm	7,500,000
Lakeview	3,500,000
Lavon	5,000,000
Navarro Mills	2,500,000
Tennessee Colony	8,000,000
Wallisville	2,000,000
Multiple-purpose Channel	6,000,000
Total	48,000,000

121. The recreation demand for the basin by the year 2070 is estimated to be 78,000,000 visits, whereas total project capacity is estimated to be 48,000,000. Thus, it may be seen that even with the proposed plan of improvement, the recreation demand for the basin would not be met by Corps projects alone. Requirements over and above the capabilities of these projects can be met by additional projects or development by the Corps, the State or other agencies. In this connection, a statewide master plan for the State Parks System is now in the process of preparation by the Horticulture and Parks Management Department of the Texas Technological College. When this study has progressed to the point that State Park requirements are more definitely known, the proposed plan of improvement for the basin will be coordinated in more detail with representatives of the State Parks Board in order that the development proposed would be fully considered and cooperative actions taken where feasible.

122. PROJECT VISITATION.- In estimating the number of annual recreation visits that would be made to the project, it has been assumed that the project would be physically complete by 1970. On this basis, taking into account experienced visitaton at existing reservoirs, together with project capacities and other considerations involved, it is estimated that the initial and average annual visitation to the projects included in the plan of improvement would be as follows:

Project	Initial 1970	Average Annual	Optimum annual Visitation
Lakeview	1,500,000	3,000,000	3,500,000
Aubrey	2,000,000	4,000,000	6,000,000
Grapevine	2,500,000	3,000,000	3,500,000
Garza-Little Elm	3,000,000	5,000,000	7,500,000
Tennessee Colony	2,500,000	6,000,000	8,000,000
Multiple-purpose Channel	1,350,000	5,000,000	6,000,000
Totals	11,850,000	22,000,000	29,000,000

123. The above visitation figures include sightseers, presently estimated at approximately 25 percent of the total. As population increases in the area surrounding a project the percentage of sightseers may increase, with a resultant increase over the estimated visitation shown. However, this would not affect materially the amount of lands or facilities actually required.

124. The location, size and number of areas to be developed at each authorized project will be presented in a preliminary master plan. Details of the proposed development to provide for public recreation and the conservation and management of fish and wildlife will be presented in a master plan for each project. Basic recreational facilities to be provided would include access roads, parking areas, public camping and picnicking areas, water supply, sanitary facilities, boat launching ramps, signs, essential safety devices, etc. Group picnic shelters, beach improvements for public swimming, including simple change houses, and boat anchorage areas would also be provided where such facilities are warranted. Additional facilities and services necessary or desirable for full development of the recreation potential will normally be arranged for by concessions and permits to private organizations and individuals or by leases or licenses to other Federal agencies or to state and local governmental agencies. Pertinent information relative to size, land requirements, costs, and benefits of the recreational purposes in the proposed projects are shown in table 13 and described in the following paragraphs.

125. LAKEVIEW PROJECT.- Lakeview Reservoir would cover 12,300 acres at the top of conservation storage level. Based on the existing and projected population for this area and the number of visitors the existing projects have attracted, it is estimated that the proposed Lakeview Reservoir project would attract an initial annual visitation of about

TABLE 13

PERTINENT DATA - RECREATION AND FISH AND WILDLIFE

Project	Water surface area (acres)	Lands required (Acres): Recreation, incl sport fishing & hunting: Project purposes	Public use & access	Total	Fish and wildlife: Water area	Land area	Project purposes	Abv upperguide: Natl. Refuge	Mitigation losses	Total	Benefits
Lakeview	12,300	2,800	760	3,560	-	-	-	-	-	-	$2,025,000
Aubrey	24,340	4,800	1,300	6,100							
Garza-Little Elm	5,900(1)		2,900	2,900							
Subtotal	30,240	4,800	4,200	9,000	-	-	-	-	-	-	2,900,000
Roanoke											
Grapevine	4,360(2)		1,100	1,100							
Subtotal	4,360		1,100	1,100	-	-	-	-	-	-	150,000
Tennessee Colony	73,540										
P.U. & Access		6,400	1,907	8,307	-	-	-	-	-	-	4,050,000
F & WL Service					9,500	10,900	20,400	600		21,000	
T.G. & F.C.					1,000	1,950	2,950		8,050	11,000	
Subtotal	73,540	6,400	1,907	8,307	10,500	12,850	23,350	600	8,050	32,000	
Multiple purpose channel	15,200(3)	860	2,600	3,460	-	-	-	-	-	-	3,375,000
Grand Total	135,640	14,860	10,567	25,427	10,500	12,850	23,350	600	8,050	32,187	

(1) 5,900 increase in water surface area plus existing 23,470 = 29,370 total.
(2) 4,360 increase in water surface area plus existing 7,380 = 11,740 total.
(3) 6,600 acres in river cutoffs below Tennessee Colony Dam.

1,500,000 visitors after sufficient water is impounded, and would eventually attract about 3,500,000 visitors annually. The average annual visitation would be approximately 3,000,000. The total lands required for public use and access is estimated to be 3,560 acres. Of this amount 2,800 acres would be acquired under the 1962 joint land acquisition policy for project purposes. The remainder consists of 760 acres for public use and access. The estimated cost for lands, clearing, and facilities in the interest of public use are shown in table 14.

126. AUBREY PROJECT SITE.- Aubrey Reservoir, in combination with Garza-Little Elm Reservoir, with the same degree of flood control protection as that provided by the existing Garza-Little Elm Reservoir, would permit a reallocation of storage in Garza-Little Elm Reservoir, and increase that storage presently allocated to water conservation. The impounded water in Aubrey Reservoir would cover 24,340 acres at the top of the conservation storage level. Based on the existing and projected population for this area and the number of visitors the existing projects have attracted, it is estimated that the proposed Aubrey Reservoir project would attract an initial annual visitation of about 2,000,000 visitors and would eventually attract about 6,000,000 visitors annually. The average annual visitation would be 4,000,000. The total land required for public use and access is estimated to be 6,100 acres. Of this amount 4,800 acres would be acquired under the 1962 joint land acquisition policy for project purposes. The remainder consists of 1,300 acres for public use and access for the Aubrey Reservoir. In addition, about 2,900 acres of which about 2,800 would be acquired in fee title in lieu of existing flood flowage easements and 100 acres in fee title above the upper guide contour to meet requirements for public use at the modified Garza-Little Elm Reservoir. The estimated costs for lands, clearing and facilities, in the interest of public use are shown in table 14.

127. GARZA-LITTLE ELM RESERVOIR.- When the storage is reallocated in the Garza-Little Elm Reservoir, the top of the conservation level would be raised seven feet. The impounded water level would then cover 29,370 acres, or an increase of 6,400 acres. Based on the results of studies made in connection with raising the conservation pool level at Lavon Reservoir and the number of additional visitors this reservoir would attract, it is estimated that the increased water surface area at the Garza-Little Elm Reservoir will initially attract an additional 400,000 visitors. Based on the existing and projected population for this area and the number of visitors the existing projects have attracted, it is estimated that the modified Garza-Little Elm Reservoir project would attract an annual visitation of about 3,000,000 visitors after the additional water is impounded, and would eventually attract about 7,500,000 visitors annually. The average annual visitation would be approximately 5,000,000. The estimated costs for lands, clearing, and facilities in the interest of public use are shown in table 14.

128. ROANOKE PROJECT.- Roanoke Reservoir, in combination with Grapevine Reservoir, would provide the same degrees of flood control protection as that provided by the existing Grapevine Reservoir. The flood control storage proposed for Roanoke Reservoir would permit a reallocation of storage in Grapevine Reservoir, and increase that storage presently allocated to water conservation. The Roanoke project was investigated as a dual-purpose project, flood control and water storage for recreation, and it was determined that this type project would reduce the dependable yield of Grapevine Reservoir by about 6.5 million gallons per day. By comparison of benefits realized from recreational uses and the reduction in water conservation yield, it was found that provision of storage of water for recreational purposes is not economically feasible. The total land required for public use and access is estimated to be 1,100 acres. This would involve the acquisition of fee title in lieu of existing flood flowage easements on 600 acres and the acquisition of additional 500 acres of privately owned lands above the upper guide contour to meet requirements for public use at the modified Grapevine Reservoir, since Roanoke will serve only as a flood control reservoir.

129. GRAPEVINE RESERVOIR.- When the storage is reallocated in the Grapevine Reservoir, the top of the conservation pool level will be raised 21 feet. The impounded water level would then cover 11,740 acres, or an increase of 4,360 acres. Based on the results of studies made in connection with raising the conservation pool level at the Lavon Reservoir and the number of additional visitors this reservoir would attract, it is estimated that the increased water surface area at the Grapevine Reservoir would initially attract an additional 300,000 visitors. Based on the existing and projected population for this area and the number of visitors the existing projects have attracted, it is estimated that the modified Grapevine Reservoir project would attract an annual visitation of about 2,500,000 visitors after the additional water is impounded, and would eventually attract about 3,500,000 visitors annually. The average annual visitation would be approximately 3,000,000. The estimated costs for lands, clearing, and facilities in the interest of public use are shown in table 14.

130. TENNESSEE COLONY PROJECT.- Tennessee Colony Dam is located at river mile 339.2 on the main stem of the Trinity River. The impounded water would cover 73,540 acres at the top of the conservation storage level. The Fort Worth District is presently constructing one reservoir project and proposes to initiate construction on another reservoir project during 1963, both of which are located within a 50-mile radius of the proposed Tennessee Colony project. There are also other reservoir projects located within a 50-mile limit of this proposed reservoir which are operated by agencies other than the Corps of Engineers, as indicated on plate 1. Based on the existing and projected population for the Tennessee Colony area and the number of visitors attracted at comparable reservoirs, it is estimated that the proposed Tennessee Colony Reservoir would attract an initial annual visitation of about 2,500,000 visitors and would

eventually attract about 8,000,000 visitors annually. The average annual visitation would approximate 6,000,000. The total land required for public use and access is estimated to be 8,120 acres . Of this amount 6,400 acres would be acquired under the 1962 joint land acquisition policy for project purposes. The remainder consists of 1,720 acres for public use and access. It would also involve the acquisition of an additional 600 acres for a national refuge requested by the U. S. Fish and Wildlife Service, if approved by Congress. The estimated costs for lands, clearing, and facilities, in the interest of public use are shown in table 14.

131. MULTIPLE PURPOSE PROJECT.- The multiple-purpose channel would extend from the existing Houston Ship Channel in Galveston Bay to the city of Fort Worth, Texas, having an overall length of about 370 miles. The bottom width of the channel would vary from 150 to 300 feet. Diversion dams would be constructed at the upper end of each river cutoff where the course of the existing river would be changed by the construction of the multiple-purpose channel. These dikes or dams would prevent the river from reverting to its existing course and divert the flow into the multiple-purpose channel. Under normal operating conditions all or a portion of the cutoffs would be partially filled with water resulting from impoundments upstream from the proposed locks and dams. Many of these river cutoffs and some of the tributary streams would provide excellent areas for the development of facilities associated with both general and fish and wildlife recreation activities. The water impounded in many of the cutoffs and tributary streams would provide excellent areas for fishing and the storage of boats. About 8,600 acres would be inundated, exclusive of the portion in the three reservoirs, when the water surface in the completed multiple-purpose channel is at the top of the normal operating pools for navigation purposes. Furthermore, about 6,600 additional acres would be inundated in the cutoffs between the locks and dams numbered 1 through 12 when the water in the completed multiple-purpose channel is at its normal operating level for navigation purposes. All the cutoffs upstream from lock and dam number 13 would be filled with spoil material resulting from excavation of the multiple-purpose channel, since this portion of the river is located in an existing or proposed leveed floodway. Due to its nature, the 15,200 acres of impounded water in the channel would not attract as many visitors for recreational activities as a similar size reservoir project. However, the channel would attract many visitors desiring to observe the passage of floating equipment through the locks, to navigate the channel for sport and pleasure, and to fish. Appropriate facilities should be developed along the channel to provide access, vehicle parking, picnicking, camping, boat launching, boat storage, etc. Facilities located on or adjacent to the channel for the storage and servicing of pleasure craft as well as providing the general public with their needs and demands such as food, drinks, etc., should be spaced at about 30-mile intervals. Since the Federal Government is acquiring fee title only to those lands within and adjacent to the channel where structures would be constructed and for the development for public use and access, private industry will, no doubt, develop these types of activities on privately-owned land. This

TABLE 14

ESTIMATED COST OF LANDS, CLEARING, AND FACILITIES FOR PUBLIC USE AND ACCESS

Project	Lands (1) Public use and access		Clearing (1)		Facilities (2)			Grand Total
	Acres	Cost	Acres	Cost	Initial Dev. Cost	Future Dev. Cost	Optimum Dev. Cost	
Lakeview	760	$805,000	8,500	$372,000	$1,694,000	$1,750,000	$3,444,000	$4,621,000
Aubrey -	1,300	350,000	3,000	813,000	2,310,000	3,750,000	6,060,000	7,223,000
Garza-L.E.	2,900	824,000	3,000	281,000	500,000	-	500,000	1,605,000
Subtotal	4,200	1,174,000			2,810,000	3,750,000	6,560,000	8,828,000
Roanoke - Grapevine	1,100	871,000	2,300	215,000	375,000	-	375,000	1,461,000
Tennessee Colony	1,907	451,000	20,000	1,875,000	2,997,000	5,100,000	8,097,000	10,423,000
Multiple-purpose Channel	2,600	1,076,000			2,150,000	1,433,000	3,583,000	4,659,000
Grand Total	10,567	4,377,000	46,800	3,556,000	10,026,000	12,033,000	22,059,000	29,992,000

(1) Separable cost over and above project requirements.
(2) Does not include engineering and design or supervision and administration costs.

condition will preclude the normal control exercised by the Corps of Engineers in regulation of spacing of such facilities to provide sufficient service and to prevent undue competition. Based on the existing and projected population for the entire basin area and the visitors attracted to the existing reservoirs previously discussed, it is estimated that the proposed multiple-purpose channel would attract an annual visitation of about 1,350,000 visitors during its first three years of operation and eventually attract about 6,000,000 visitors annually. The average annual visitation would be approximately 5,000,000. A large percentage of these visitors would be sightseers only. The total land required for public use and access is estimated to be 2,600 acres. This is in addition to the lands to be acquired in fee title for project purposes. The estimated costs for lands and facilities in the interest of public use are shown in table 14.

132. ECONOMIC BENEFITS OF RECREATION.- Economic benefits resulting from the development of the recreation resources associated with water resource projects can be evaluated and expressed in several different ways, including actual assignment of a monetary value for each project visit. The latter method has been used in benefits versus cost considerations of this report, using a conservative unit value of 50¢ per visit for general recreation and $1.00 for sport fishing and hunting, the latter being in accordance with the schedule of value adopted by the Inter-Agency Committee on Water Resources at its 18 October 1960 meeting. While values used indicate substantial benefits from recreational aspects of the project, they are considered most conservative and in many ways do not indicate fully the economic impact of recreation and related activities associated with large water resource projects. The fact is that recreation invariably improves the local economy, the degree depending primarily on the recreation demand of the area and the quality of recreation afforded. Benefits for projects recommended are tabulated in table 15.

TABLE 15
RECREATION COST, CHARGES, AND BENEFITS

Project	Incremental Cost (1)	Annual Charges	Annual Benefits	Benefit Cost Ratio
Lakeview Reservoir	$ 5,262,000	$ 387,300	$ 2,025,000	5.2
Aubrey Reservoir (2)	10,099,000	743,600	2,900,000	3.9
Roanoke Reservoir (3)	1,570,000	75,700	150,000	2.0
Tennessee Colony Reservoir	12,083,000	978,400	4,050,000	4.1
Multiple-Purpose Channel (4)	4,723,200	434,600	3,375,000	7.8
Grand Total	33,737,200	2,619,600	12,500,000	4.8

(1) As last added purpose.
(2) Includes increased facilities in Garza-Little Elm Reservoir as a result of exchange in storage.
(3) Increased facilities in Grapevine Reservoir as a result of exchange in storage.
(4) Excludes facilities in Tennessee Colony Reservoir reach.

SUMMARY

133. ACCOMPLISHMENTS.- Stated briefly, it is evident that the projects recommended in this report would:

a. Provide a high degree of flood protection to the Trinity River Basin. The projected average annual damages of over 15.4 million dollars would be reduced, under the 1960 existing and authorized project development plan, to less than 1.1 million dollars.

b. Develop the maximum potential yield of the streams in the Trinity River Basin into a positive resource through storage and regulation to efficiently serve the needs of the people that are expected to occupy the basin during the next 50-100 years. By the year 2020 and 2070 the water requirements are expected to be about 3433 million gallons per day and 5187 million gallons per day, respectively, and the water resources can be developed to supply these needs. (See table 11) Projects recommended for authorization would provide 453.1 million gallons per day in 2020. The requirements of the basin would be fully met and within the framework of water rights and priorities established by the State of Texas.

c. Provide dilution water to help solve the water quality problem in the upper basin that is expected to continue in existence to about the year 2020. Additional sewage and waste treatment efficiency plus a buildup of a more stabilized base flow in future years as the economy expands and projects are constructed is expected to gradually reduce the requirements of storage specifically dedicated for water quality dilution purposes. This storage would then be used for meeting the municipal and industrial water supply demands.

d. Provide a 370-mile long waterway extending from the existing intracoastal waterway system in the lower Trinity River Basin to the Fort Worth-Dallas complex. This waterway would provide an efficient means to move over 20 million tons of bulk type commodities. The beneficial effect of the waterway would extend to a significant area beyond the limits of the basin, particularly with respect to the movement of wheat and other grains that would use the waterway.

e. Provide outdoor recreation and fish and wildlife of over 79,000 day use opportunities to help meet the regional demands for outdoor water oriented recreation and fish and wildlife.

f. Provide a framework plan within which selected major elements of the plan, when completed, would produce justifiable benefits independently and without reference to when other elements of the plan might be completed. One of the major contributions of the plan is the long-range integrated aspect thereof that would provide the ingredients for a step-by-step development in an orderly manner and based upon sound engineering practice.

134. Tests made during the formulation processes show that each project purpose of the multiple-purpose projects and single-purpose projects are economically justified. It has also been demonstrated that functional segments of the flood control-waterway channel are feasible and justified. Table 16 shows a summary of the justification of all elements in the plan recommended for authorization in this report. The benefits used are the fair share creditable to each project purpose considering all units to be in the plan. The plan is consistent with formulation concepts and objectives outlined in the first part of this appendix. The overall plan is well justified on the basis of monetary benefits and if intangible benefits could be rationally equated into monetary terms, the benefits used herein would increase many times. Table 17 shows the first cost, annual charges and benefits of the elements of the plan recommended for authorization at this time.

TABLE 16

JUSTIFICATION OF ELEMENTS IN THE PLAN OF DEVELOPMENT
(in thousand dollars)

RESERVOIR PROJECTS

Item	Lakeview Reservoir			Aubrey Reservoir			Roanoke Reservoir			Tennessee Colony Reservoir		
	Benefits	Charges	B/C	Benefits	Charges	B/C	Benefits	Charges	B/C	Benefits	Charges	B/C
Flood control only	1,391.0	527.7	2.6	-	-	-	-	-	-	3,238.0	1,989.8	1.6
Water conservation added	907.3	457.0	2.0	-	-	-	-	-	-	1,844.1	799.7	2.3
Dual purpose F.C. and W.C.	2,298.3	984.7	2.3	-	-	-	-	-	-	5,082.1	2,789.5	1.8
Water conservation only	907.3	735.9	1.2	1,085.2	889.5	1.2	683.7	551.7	1.2	1,844.1	1,525.7	1.2
Flood control added	1,391.0	248.8	5.6	-	-	-	-	-	-	3,238.0	1,263.8	2.6
Dual purpose W.C. and F.C.	2,298.3	984.7	2.3	-	-	-	-	-	-	5,082.1	2,789.5	1.8
Navigation added	-	-	-	-	-	-	-	-	-	2,951.0	2,269.3	1.3
Multiple-purpose W.C., F.C. and Nav.	-	-	-	-	-	-	-	-	-	8,033.1	5,058.8	1.6
Recreation added	2,025.0	387.3	5.2	2,900.0	734.9	3.9	150.0	72.1	2.1	4,050.0	978.4	4.1
Multiple-purpose W.C., F.C., Nav., and Rec.	4,323.3	1,372.0	3.2	3,985.2	1,624.4	2.5	833.7	623.8	1.3	12,083.1	6,037.2	2.0
Pipe line added	-	-	-	-	-	-	-	-	-	3,745.5	3,164.2	1.2
Multiple-purpose W.C., F.C., Nav., Rec., and pipeline	-	-	-	-	-	-	-	-	-	15,828.6	9,201.4	1.7

MULTIPLE-PURPOSE CHANNEL AND FLOODWAY

Item	Houston to Dallas			Dallas to Fort Worth (1)			Houston to Fort Worth		
	Benefits	Charges	B/C	Benefits	Charges	B/C	Benefits	Charges	B/C
Flood control channel	3,518.1	3,044.7	1.2	1,177.7	516.9	2.3	4,695.8	3,561.6	1.3
Levees added	240.9	79.2	3.0(2)	3,044.4	2,802.8	1.1 (3)	3,285.3	2,882.0	1.1 (3)
Flood control channel and levees	3,759.0	3,123.9	1.2	4,222.1	3,319.7	1.3	7,981.1	6,443.6	1.2
Navigation added	20,746.0	15,106.3	1.4	3,256.0	3,220.2	1.0	24,002.0	18,326.5	1.3
Multiple-purpose channel and floodways	24,505.0	18,230.2	1.3	7,478.1	6,539.9	1.1	31,983.1	24,770.1	1.3
Recreation added	2,875.0	366.5	7.8	500.0	68.1	7.3	3,375.0	434.6	7.8
Multiple-purpose channel, levees and recreation	27,380.0	18,596.7	1.5	7,978.1	6,608.0	1.2	35,358.1	25,204.7	1.4 (4)

LOCAL FLOOD PROTECTION

Item	Elm Fork			Duck Creek		
	Benefits	Charges	B/C	Benefits	Charges	B/C
Flood control channel	1,349.0	206.6	6.5	224.4	160.4	1.4
Levees added	517.7	516.8	1.0	-	-	-
Flood control channel and levees	1,866.7	723.4	2.6	-	-	-

(1) Charge based on four year construction period for this increment of the multiple-purpose channel.
(2) Liberty Local Protection Project.
(3) Includes $2,359,400 benefits and $808,100 annual charges in West Fork, $685,000 benefits and $604,900 annual charges in Dallas Floodway Extension; also included are additional costs for multiple-purpose channel size and bridge modifications.
(4) Mulitple-Purpose Channel and recreation benefits are $32,072,800 and annual charges $23,712,500.

Abbreviations: B/C - Benefit Cost Ratio, F.C. - Flood Control; W.C. - Water Conservation; Nav. - Navigation; Rec. - Recreation.

TABLE 17

FIRST COST, ANNUAL CHARGES, ANNUAL BENEFITS AND BENEFIT-COST RATIOS
PROJECTS RECOMMENDED FOR AUTHORIZATION
(in thousands of dollars)

Item	Multiple-Purpose Chan. Locks and Dams	Lakeview Reservoir	Tennessee Colony Reservoir	Elm Fork Floodway	West Fork Floodway	Dallas Floodway Extension	Duck Creek Channel	Aubrey Reservoir	Roanoke Reservoir	Liberty Local Protection	Total Recommended Plan
First Cost	568,738	31,180	193,782(1)	16,823	17,809	14,327	5,024	34,073	16,900	2,091	900,747
Annual Charges	23,713	1,372	9,201(1)	723	808	605	160	1,624	624	79	38,909
Annual Benefits											
Navigation	24,002	-	2,951(1)	-	-	-	-	-	-	-	26,953
Flood Control	4,696	1,391	3,238	1,867	2,359	685	224	-	-	241	14,701
Water Supply and Water Quality	-	907	5,590(1)	-	-	-	-	1,085	684	-	8,266
Recreation	1,625	975	1,950	-	-	-	-	1,500(2)	150 (3)	-	6,200
Fish and Wildlife	1,750	1,050	2,100	-	-	-	-	1,400(2)	-	-	6,300
Total	32,073	4,323	15,829	1,867	2,359	685	224	3,985	834	241	62,420
Benefit-Cost Ratio	1.4	3.2	1.7	2.6	2.9	1.1	1.4	2.5	1.3	3.0	1.6

(1) Includes costs and benefits for pipeline and navigation.
(2) Includes increased benefits at the Garza-Little Elm reservoir project.
(3) Includes increased benefits at the Grapevine reservoir project.

135. INTRODUCTION.- Cost allocations for the multiple-purpose projects were made to determine the equitable distribution of the costs to be credited to each project purpose and to determine the apportionment of these costs to Federal and non-Federal interests. The construction expenditures, annual operation, maintenance, and replacement costs allocated to flood control have been apportioned between Federal and non-Federal interests in accordance with the general policy given in the Flood Control Act of 1936 (Public Law 738, 74th Congress), as subsequently amended.

136. The generally accepted procedures of cost allocation and apportionment are (a) for reservoir projects, the Separable Costs-Remaining Benefits method wherein separable costs are charged to the various purposes and the joint use costs are distributed so that each purpose shares equitably in the fair share benefits of multiple-purpose construction, with the allocated cost of water supply being charged to non-Federal interests; (b) for local protection projects, the division of costs between Federal and non-Federal interests are subject to the requirements of local cooperation as generally specified for such projects in which all construction costs are the responsibility of the Federal Government except for rights-of-way and relocation costs (excluding railroads) which are the responsibility of local interests; (c) for navigation projects, the Federal Government will be responsible for all construction costs except for rights-of-way and relocation costs except bridge alterations over existing channels which costs will be apportioned to Federal and non-Federal interests in accordance with the principles of Section 6 of the Bridge Alteration Act (Truman-Hobbs) of 21 June 1940, as amended, and the Federal Government will bear the entire cost of the structure on new land cuts for the channel. However, the plan of improvement for the Trinity River Basin is complex and the units in the plan so interlocked that the procedures indicated above could not be simply applied to each individual project. The following paragraphs describe in detail the cost allocation and apportionment to Federal and non-Federal interests as applied to each project and is in consonance with the accepted procedures.

137. MULTIPLE-PURPOSE CHANNEL.- The non-Federal costs of the multiple-purpose channel were separated from the total construction costs on the basis of the requirements to be met by local interests for a navigation project as stated above. In determining the local interest costs, those that were specifically for navigation or flood control were separated from the joint local interest costs that serve both the navigation and flood control purposes. Since the flood control purpose of the channel is necessary for the proper functioning of the existing and proposed flood control reservoirs these costs are considered to be a Federal responsibility. The division of the joint local interest cost was made on the basis of the navigation-flood control benefit ratio for each

reach, both upstream and downstream from the Dallas turning basin. The benefits for navigation do not include those assigned to the Tennessee Colony Reservoir and the flood control benefits are those that accrue only to the West Fork Floodway, the Dallas Floodway Extension, and the channel downstream from Five Mile Creek. In addition, the highway bridge relocation costs above those assigned to local interests by the application of the Truman-Hobbs Act in the Dallas Floodway Extension and the West Fork Floodway, have been divided on the basis of the benefit ratio division and the flood control portion assigned to local interests. These bridge modifications are also necessary for the proper functioning of these floodways and in such a floodway project such relocation costs are chargeable to local interests. The cost of the recreation facilities is considered to be a Federal responsibility. The operation, maintenance, and replacement costs of the multiple-purpose channel are Federal costs except those for the railroad lift bridges which are local interests costs.

138. LOCAL FLOOD PROTECTION PROJECTS.- The costs of the local protection projects have been apportioned between Federal and non-Federal interests in accordance with the general policy given in the Flood Control Act of 1936 (Public Law 738, 74th Congress), as amended, and as stated in paragraph 132, item b, above as this Act affects this type project. The portion of the West Fork Floodway and Dallas Floodway Extension, (excluding the costs of the multiple-purpose channel), the Liberty Levee, and the Duck Creek projects were apportioned to Federal and non-Federal interests based upon this premise. In the Elm Fork project, the main stem channels are considered necessary for the proper operation of the Grapevine and Garza-Little Elm Reservoirs and the costs necessary for the construction of the channels is considered a Federal cost. The remaining costs of the project were apportioned to Federal and non-Federal interests in consonance with the usual procedure for local protection projects.

139. RESERVOIRS.- The Separable Costs-Remaining Benefits method was used in allocating the cost of each reservoir project to its purposes.

140. The Lakeview Reservoir was allocated to flood control, water supply, and recreation with the local interest cost being that allocated to the water supply purpose.

141. Roanoke Reservoir will be operated as a flood control only reservoir. However, its purpose is to provide an exchange of storage with Grapevine Reservoir in order to develop additional water resources of the watershed; therefore, the effectual purpose of the reservoir is for water conservation. In the exchange of storage the recreation facilities in the Grapevine Reservoir are increased and the Roanoke Reservoir costs, including the cost of changes in Grapevine, have been allocated to water supply and recreation purposes with local interests bearing the costs allocated to water supply.

142. Aubrey Reservoir will be operated for flood control, water supply, water quality control (on an interim basis), and recreation purposes. However, the reservoir will be constructed to develop additional resources of the watershed through an exchange of storage with Garza-Little Elm Reservoir and, therefore, the net result of Aubrey Reservoir is to provide conservation storage. In the exchange of storage the recreation facilities in the Garza-Little Elm Reservoir are increased and the Aubrey Reservoir costs, including the cost of changes in Garza-Little Elm Reservoir, have been allocated to water supply and recreation purposes. The water supply would not be needed for municipal and industrial purposes immediately but would be used for quality control on an interim basis. The allocation of the cost of water supply would be further allocated on the basis of the yield used for quality control and municipal and industrial purposes. The charges allocated to quality control would be a Federal responsibility and the remaining water supply cost a non-Federal responsibility.

143. Tennessee Colony Reservoir was allocated to flood control, water supply, recreation, and navigation by the Separable-Costs-Remaining Benefits method. The costs of the water supply function of the reservoir are a non-Federal responsibility and the Federal Government would be responsible for the costs of all the other functions. However, a portion of the water supply yield will be used for quality control purposes on an interim basis and this use is a Federal responsibility. The costs of the water supply function is further allocated on the basis of the yield used for the quality control purpose. In this connection, the pipe line, which is considered a separable cost, is allocated in this same manner and when the water is no longer needed for quality control the remaining pipe line cost will become a non-Federal responsibility.

144. Table 18 shows the allocation of costs to each purpose for the four reservoir projects by the Separable-Costs-Remaining Benefits method. Costs allocated to water supply by this method for the Aubrey and Tennessee Colony projects were further allocated between municipal and industrial use and quality control purposes on the basis of the quantity and the period the water would be used on each purpose. The pipe line costs also were allocated on this same basis and added to the Tennessee Colony Reservoir project costs. Table 19 shows the apportionment of costs to Federal and non-Federal interests for the proposed plan of improvement in the Trinity River Basin.

TABLE 18

SUMMARY OF RESERVOIR COST ALLOCATION STUDIES

Project and Purpose	First Cost	Operation & Maintenance	Annual Charges	Annual Benefits	Benefit-Cost Ratio
Lakeview Reservoir					
Flood control	$ 9,213,700	$ 56,500	$ 358,100	$ 1,391,000	3.9
Water supply (M&I)	14,960,200	76,600	566,300	907,300	1.6
Recreation - fish & wildlife	7,006,100	218,200	447,600	2,025,000	4.5
Total	31,180,000	351,300	1,372,000	4,323,300	3.2
Aubrey Reservoir					
Water supply	22,951,600	75,250	826,550	1,085,200	1.3
(Municipal & Industrial)	(14,360,800)	(47,080)	(517,150)	(679,000)	(1.3)
(Quality control)	(8,590,800)	(28,170)	(309,400)	(406,200)	(1.3)
Recreation - fish & wildlife	11,121,400	433,750	797,850	2,900,000	3.6
Total	34,073,000	509,000	1,624,400	3,985,200	2.5
Roanoke Reservoir					
Water supply (M&I)	14,997,100	41,750	526,100	683,700	1.3
Recreation - fish & wildlife	1,902,900	36,250	97,700	150,000	1.5
Total	16,900,000	78,000	623,800	833,700	1.3
Tennessee Colony Reservoir					
Flood control	42,663,600	40,300	1,492,800	3,238,000	2.2
Water supply	84,277,300	1,521,900	4,192,900	5,589,600	1.3
(Municipal & industrial)	(29,679,200)	(281,300)	(1,262,300)	(1,975,400)	(1.6)
(Quality control)	(54,598,100)	(1,240,600)	(2,930,600)	(3,614,200)	(1.2)
Navigation	51,893,000	660,500	2,427,600	2,951,000	1.2
Recreation - fish & wildlife	14,948,100	579,000	1,088,100	4,050,000	3.7
Total	193,782,000	2,801,700	9,201,400	15,828,600	1.7

TABLE 19

APPORTIONMENT OF COSTS

Project	FIRST COST			OPERATION, MAINTENANCE & REPLACEMENTS			ANNUAL CHARGES		
	Federal	Non-Federal	Total	Federal	Non-Federal	Total	Federal	Non-Federal	Total
Multiple-Purpose Channel	$537,029,100	$31,708,600	$568,737,700	$3,863,200	$289,900	$4,153,100	$22,311,900	$1,400,600	$23,712,500
Reservoirs									
Lakeview	16,219,800	14,960,200	31,180,000	274,700	76,600	351,300	805,700	566,300	1,372,000
Aubrey (1)	19,712,200	14,360,800	34,073,000	461,920	47,080	509,000	1,107,250	517,150	1,624,400
Roanoke (2)	1,902,900	14,997,100	16,900,000	36,250	41,750	78,000	97,700	526,100	623,800
Tennessee Colony	164,102,800	29,679,200	193,782,000	2,520,400	281,300	2,801,700	7,939,100	1,262,300	9,201,400
Local Protection									
West Fork (3)	10,719,000	7,090,000	17,809,000	-	224,000	224,000	346,200	461,900	808,100
Elm Fork	11,191,000	5,632,000	16,823,000	70,000	103,000	173,000	431,400	292,000	723,400
Dallas Floodway Extension (3)	8,949,000	5,378,000	14,327,000	-	135,500	135,500	289,000	315,900	604,900
Duck Creek	4,176,000	848,000	5,024,000	-	6,000	6,000	127,600	32,800	160,400
Liberty Levee (3)	1,794,000	296,700	2,090,700	-	15,000	15,000	54,800	24,400	79,200
TOTAL	775,795,800	124,950,600	900,746,400	7,226,470	1,220,130	8,446,600	33,510,650	5,399,450	38,910,100

(1) Including modification of Garza-Little Elm Reservoir.
(2) Including modification of Grapevine Reservoir.
(3) Exclusive of multiple-purpose channel.

TABLE 20

ALLOCATED FIRST COST, ANNUAL CHARGES, ANNUAL BENEFITS AND BENEFIT-COST RATIOS
PROJECTS RECOMMENDED FOR AUTHORIZATION
(in thousands of dollars)

Item	Multiple-Purpose Chan, Locks and Dams	Lakeview Reservoir	Tennessee Colony Reservoir(1)	Elm Fork Floodway	West Fork Floodway(2)	Dallas Floodway Extension(2)	Duck Creek Channel	Aubrey Reservoir(3)	Roanoke Reservoir(4)	Liberty Local Protection	Total Recommended Plan
First Cost											
Navigation	453,438	-	51,893	-	-	-	-	-	-	-	505,331
Flood Control	110,577	9,214	42,664	16,823	17,809	14,327	5,024	-	-	2,091	218,529
Water Supply and Water Quality	-	14,960	84,277	-	-	-	-	22,952	14,997	-	137,186
Recreation - Fish and Wildlife	4,723	7,006	14,948	-	-	-	-	11,121	1,903	-	39,701
Total	568,738	31,180	193,782	16,823	17,809	14,327	5,024	34,073	16,900	2,091	900,747
Annual Charges											
Navigation	19,183	-	2,427	-	-	-	-		-	-	21,610
Flood Control	4,095	358	1,493	723	808	605	160	-	-	79	8,321
Water Supply and Water Quality	-	566	4,193	-	-	-	-	826	526	-	6,111
Recreation - Fish and Wildlife	435	448	1,088	-	-	-	-	798	98	-	2,867
Total	23,713	1,372	9,201	723	808	605	160	1,624	624	79	38,909
Benefits											
Navigation	24,002	-	2,951	-	-	-	-	-	-	-	26,953
Flood Control	4,696	1,391	3,238	1,867	2,359	685	224	-	-	241	14,701
Water Supply and Water Quality	-	907	5,590	-	-	-	-	1,085	684	-	8,266
Recreation - Fish and Wildlife	3,375	2,025	4,050	-	-	-	-	2,900	150	-	12,500
Total	32,073	4,323	15,829	1,867	2,359	685	224	3,985	834	241	62,420
Benefit-Cost Ratio											
Navigation	1.3	-	1.2	-	-	-	-	-	-	-	1.2
Flood Control	1.1	3.9	2.2	2.6	2.9	1.1	1.4	-	-	3.0	1.8
Water Supply and Water Quality	-	1.6	1.3	-	-	-	-	1.3	1.3	-	1.4
Recreation - Fish and Wildlife	7.8	4.5	3.7	-	-	-	-	3.6	1.5	-	4.3
Total Plan	1.4	3.2	1.7	2.6	2.9	1.1	1.4	2.5	1.3	3.0	1.6

(1) Includes costs and benefits for pipe line to Benbrook Reservoir and navigation in reservoir reach.
(2) Excludes costs in main stem channel which are included with multiple-purpose channel costs.
(3) Includes costs and benefits for modification of recreation facilities and reallocation of storage space in Garza-Little Elm Reservoir.
(4) Includes costs and benefits for modification of recreation facilities and reallocation of storage space in Grapevine Reservoir.

COMPREHENSIVE SURVEY REPORT

ON

TRINITY RIVER AND TRIBUTARIES, TEXAS

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U. S. ARMY ENGINEER DISTRICTS
FORT WORTH AND GALVESTON
CORPS OF ENGINEERS
FORT WORTH AND GALVESTON, TEXAS

JUNE 1962

COMPREHENSIVE SURVEY REPORT

ON

TRINITY RIVER AND TRIBUTARIES, TEXAS

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NAVIGATION AND NAVIGATION ECONOMICS

INTRODUCTION

1 . SCOPE AND PURPOSE.- This appendix concerns the review of a congressionally approved plan of improvement for the Trinity River, Texas, that provides for a navigable channel, 9 feet deep and 150 feet wide, from the Houston Ship Channel in Galveston Bay to Fort Worth, Texas. That plan proposed the canalization of the Trinity River channel by a system of 26 locks and dams with locks having clear basin dimensions of 75 feet wide by 400 feet long, and tainter gated dams located within the river banks to overcome a total river fall of 496 feet between Fort Worth and Liberty, Texas. The plan was approved and authorized by the River and Harbor Act of March 2, 1945, in accordance with the reports contained in House Document No. 403, 77th Congress, 1st session.

2 . The report of the Chief of Engineers, dated September 4, 1941, in House Document No. 403, concluded that the prospective monetary benefits from the project were only slightly less than the annual cost, and that there was a reasonable possibility that with continued growth of industrial development in the area and with favorable changes in the conditions that affect water transportation the benefits would probably increase sufficiently in the future to warrant the construction of the waterway. The Chief of Engineers recommended that the proposed plan be approved as a whole for consideration in the future and that the existing projects which afford a 6-foot channel to Liberty be modified to conform with that plan.

3 . The scope of this report comprises a comprehensive investigation of the physical and economical aspects of providing a shallow-draft navigation channel for modern barge tow operation from the Houston Ship Channel via the authorized channel to Liberty and the Trinity River to Fort Worth, Texas. The primary object of the investigation was to determine the feasibility of providing barge navigation upstream to Fort Worth and, if found feasible, to develop a plan for navigation which is in accord with full development of the entire Trinity River Basin's water resources.

4 . Engineering studies utilized existing topographic data augmented by cross-sections of the river and controlled aerial mosaics for channel alinement studies, channel excavation, clearing and grubbing, right-of-way, spoil disposal areas and severed land areas. Available subsurface information augmented by additional borings at selected lock sites, including laboratory testing of typical samples from the core borings, were used in determining types of material to be encountered in excavation of the proposed channel and for analysis of bank stabilization works. Office studies included design studies relating to the proposed locks and dams, highway and railroad bridges, access roads, including the preparation of detailed

estimates of construction costs of these structures and facilities. Hydrologic and hydraulic studies were made to determine the design of the proposed channel and the extent and character of the regulated flows in the various reaches of the channel. The studies also include the hydraulic analyses of tainter gate requirements for the movable dams, the filling and emptying system of the locks including a determination of the water requirements for operation of the system of locks required for transportation of the prospective commerce.

5. The economic studies included a field traffic survey of the area tributary to the channel to Fort Worth, estimates of prospective commerce that would move by barge over the channel and savings in transportation charges creditable to the movement of commerce on the channel. Special studies were made to determine the current barge-line operating costs, transfer and terminal handling costs, switching and other charges incidental in determining full costs of commerce movement on the channel. Special studies also were made of the prospective sand, gravel and stone movements, and of the prospective grain and cotton movement over the proposed channel. Related studies on the characteristics of growth of economic factors in the tributary traffic area concerning population, agriculture, manufacturing, food processing, resources and transportation were made to determine a sound basis for projection of the economic appraisal over the life of the proposed navigation project.

6. RELATIONSHIP TO OTHER APPENDICES.- Information and data concerning studies and investigations of related matters to the proposed navigation channel to Fort Worth which are contained in other appendices of this report are as follows:

a. Appendix I - Project formulation, presents information on single and multiple purpose channel plans of improvements of different channel sizes for flood control and for barge tow operation from the Houston Ship Channel to Fort Worth, Texas.

b. Appendix II - Hydrology, hydraulic design and water resources, presents information on the design and capacity of the proposed multiple-purpose Trinity River channel from the Houston Ship Channel to Fort Worth, Texas, including analyses of the channel flow durations and velocities. It presents a study of the water needs for operation of barge navigation on the multiple purpose Trinity River channel, and the means of providing the water supply required for such operation during the life of the navigation project. Included in the appendix is a copy of the report on water resources of the Trinity River basin submitted by the Public Health Service, Region VII, of the United States Department of Health, Education and Welfare. Information is given in the appendix concerning the hydraulic design of the proposed lock filling and emptying systems, the tainter-gated dams required to pass the channel flows and maintain the design water surface elevation in the navigation pools, and a study of the prospective sediment inflow to various sections of the channel which would involve dredging of the deposited sediment to maintain project depth.

c. Appendix V - Recreation and Fish and Wildlife, contains information regarding the recreational facilities including public-use areas and access roads thereto to be provided in connection with the multiple purpose channel to Fort Worth and the existing and recommended reservoir projects discussed in this report. It also contains a copy of the report submitted by the Bureau of Sport Fishers and Wildlife, Fish and Wildlife Service of the United States Department of the Interior concerning the probable effects of the canalized channel to Fort Worth on the fish and wildlife resources of the Trinity River.

d. Appendix VI - Cost Estimates, Geology and Design Information, contains information regarding the gross real estate appraisal of lands required for the multiple purpose channel to Fort Worth, the structural design of locks, dams, highway and railroad bridges, access roads to lock sites and the relocation of utility lines. Information concerning the preliminary foundation materials and geology of the lock and dam site and character of material involved in channel excavation work is presented in the appendix. It also contains estimates of first cost and annual cost of maintenance and operation of various features of the canalized multiple purpose channel to Fort Worth.

e. Appendix VII - Economic Base Survey, contains information regarding the estimated growth trends of various economic factors in the tributary traffic area that are considered in determining the projected amount of prospective commerce which is expected to develop during the period of economic analysis of the navigation project.

GENERAL INFORMATION

7. BASIN DESCRIPTION.- The Trinity River Basin is relatively long and narrow having a maximum length of about 360 miles and a maximum width of about 100 miles near its upper end. The Trinity River which is about 505.5 miles long, is formed at Dallas by the confluence of the West Fork and the Elm Fork. The West Fork having a total length of about 209 miles is considered as the main stem headwater of the Trinity River. The Trinity River and the West Fork have a combined length of about 715 miles, a total fall of about 1,250 feet and drain an area of 17,845 square miles. Plate 1 shows the general features of the Trinity River basin.

8. The multiple purpose channel studies in this appendix covers the lower 46 miles of the West Fork downstream from the Riverside Drive bridges in Fort Worth, the 505.5 miles of Trinity River to its mouth near Anahuac and the 24.3 mile tidal section from the mouth of the Trinity River to the Houston Ship Channel in Galveston Bay. Thus, the total distance of river under consideration is 575.8 miles and the total fall of the river is about 483 feet. Pertinent information concerning the approximate low-water elevations and the approximate low-water slopes for the several reaches of the waterway from the Riverside Drive bridges to the Houston Ship Channel is given in table 1.

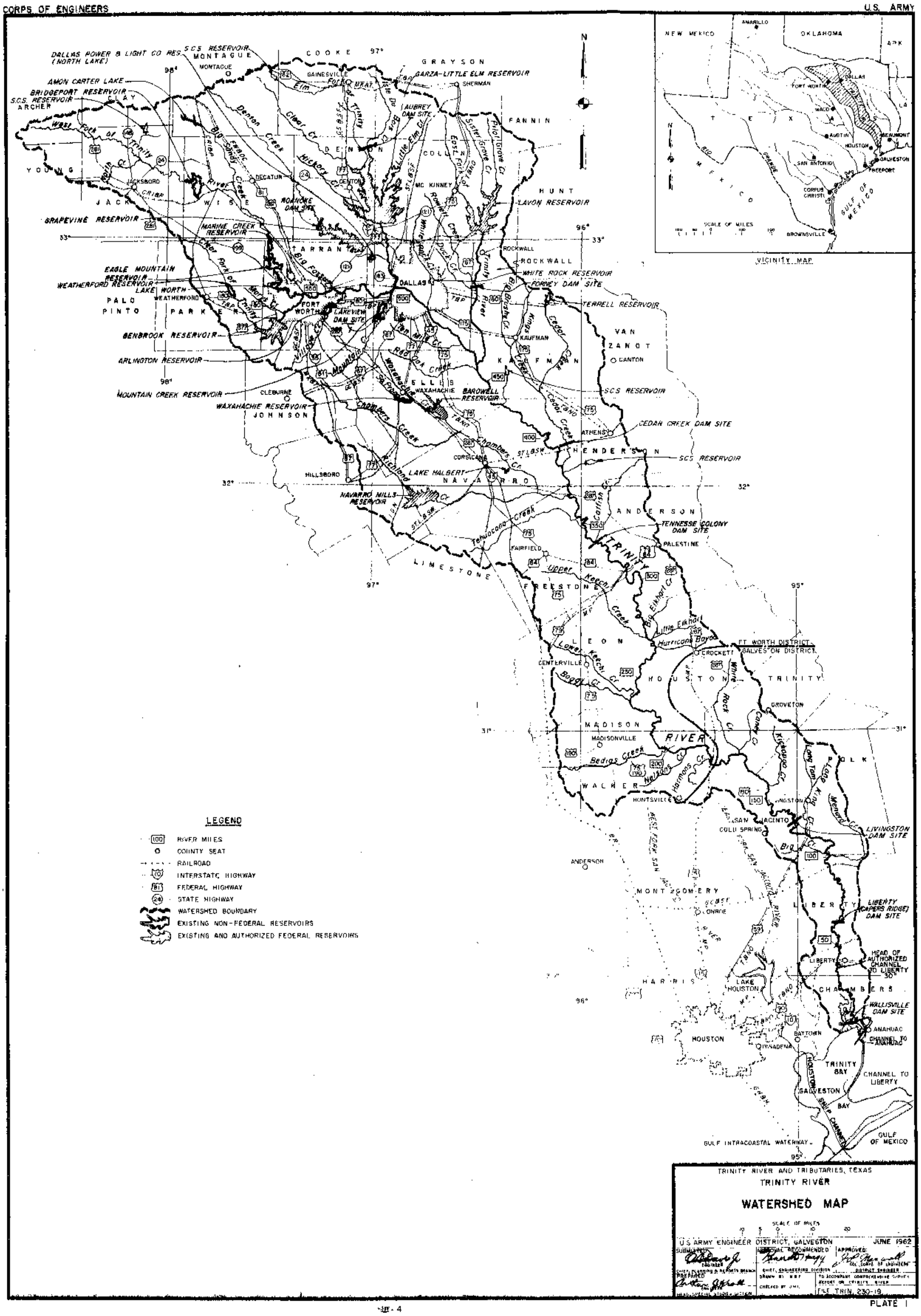

CORPS OF ENGINEERS
U.S. ARMY
VICINITY MAP
LEGEND
RIVER MILES
COUNTY SEAT
RAILROAD
INTERSTATE HIGHWAY
FEDERAL HIGHWAY
STATE HIGHWAY
WATERSHED BOUNDARY
EXISTING NON-FEDERAL RESERVOIRS
EXISTING AND AUTHORIZED FEDERAL RESERVOIRS
FT WORTH DISTRICT
GALVESTON DISTRICT
TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER
WATERSHED MAP
SCALE OF MILES
U.S. ARMY ENGINEER DISTRICT, GALVESTON
JUNE 1962
FILE TRIN. 230-19
PLATE I

TABLE 1
LOW-WATER ELEVATIONS AND SLOPES OF
WATERWAY UNDER CONSIDERATION

Landmark	River mile	Distance in reach (miles)	Approx. low-water elevation (feet)	Fall in reach (feet)	Average slope (feet per mile)
Riverside Drive Bridges	551.5		483.0		
		46.0		97.0	2.11
Mouth of Elm Fork	505.5		386.0		
		45.7		72.0	1.58
Mouth of East Fork	459.8		314.0		
		74.3		88.0	1.18
Mouth of Cedar Creek	385.5		226.0		
		46.3		32.0	.69
Tennessee Colony reservoir dam site	339.2		194.0		
		210.2		138.0	.66
Livingston reservoir dam site	129.0		56.0		
		66.0		31.0	.47
Lake Liberty (Capers Ridge) reservoir dam site	63.0		25.0		
		59.1		25.0	.42
Wallisville reservoir dam site	3.9		0.0		
		28.2		0.0	0.0
Houston Ship Channel Galveston Bay			0.0		

9 . The reservoirs referred to in table 1 are in various stages of development and for the purpose of this report it is assumed that the Wallisville and Livingston reservoirs are existing water resource developments. The Wallisville reservoir with dam at river mile 3.9 has been recommended in a separate report for Federal adoption and construction in the interests of salinity control, navigation, water supply, fish and wildlife and recreation. The recommended plan provides for maximum storage to elevation 4.0, which would extend up the Trinity River to about river mile 48.0.

10. The proposed Lake Liberty (Capers Ridge) reservoir with dam at river mile 63.0 is included in the long range master plan of the Trinity River sponsored by the Trinity River Authority of Texas primarily for water conservation purposes.

11. The Livingston reservoir is being sponsored jointly for construction by the city of Houston, Texas, and the Trinity River Authority of Texas. Preliminary plans of the reservoir propose that conservation storage be provided between elevation 101 and 131, in the interest of municipal, industrial and agricultural needs in the lower Trinity River area and the metropolitan Houston area.

12. The proposed Tennessee Colony reservoir, recommended in this report, would provide storage for flood control between elevation 262.5 and 285.0, and conservation storage between elevation 235.0 to 262.5.

13. Table 1 shows that the slope of the river below the Livingston dam site averages about .43 foot per mile, upstream the slope increases gradually to about 2.11 feet per mile in the lower 46-mile reach of the West Fork.

14. Throughout its entire length the Trinity River follows a tortuous course, meandering from one side of its valley to the other, for a channel length of about 2.0 times the length of the general axis of its valley. Between Liberty and Fort Worth the banks vary in height from about 25 to 50 feet, the highest banks being in the central section in the vicinity of Riverside and Long Lake. Near the mouth the banks are only a few feet above sea level. The width of the river at bankfull stage varies from about 500 feet in the lower sections to about 140 feet in the vicinity of Fort Worth.

15. From the mouth of the river to about mile 160 the banks are unstable and sand bars are numerous. Examination of the aerial survey of 1958 shows that the channel had shifted materially at 29 locations subsequent to the 1912-15 survey, causing a considerable change in river alignment. During the twenty-year period between these surveys, the river mileage from Dallas to the mouth of the river has decreased about 10 miles, as a result of artificial and natural cut-offs. Since 1934 the river has further shortened its length as a result of additional artificial and natural cut-offs. Above mile 160 the banks are generally composed of tight alluvial clay and are fairly stable. The shoals in the upper reaches consist generally of gravel, hardpan, or rock.

16. Under present ordinary low-water conditions, tidal influence extends up the Trinity River about 41 miles to Liberty, and at extreme low stages it extends upstream to about mile 50. After construction of the Wallisville reservoir tidewater would extend to the dam at river mile 3.9. The mean diurnal tidal range in Trinity Bay near Anahuac is about 0.9 feet. The water surface of Trinity Bay and the adjoining Trinity River is affected to a considerable extent by the winds and may be depressed as much as 1.5 feet below mean low tide by strong north winds in the winter season and raised as much as 15 feet above mean low tide by hurricanes during the summer and fall seasons. During the 1900 hurricane a tide of about 14 feet above sea level was experienced in Galveston Bay and the delta of the Trinity River. Unless otherwise stated, elevations given hereafter in this appendix refer to U. S. Coast and Geodetic Survey mean

sea level datum, which is established 1.36 feet above U. S. Corps of Engineers mean low tide datum.

17. The West Fork and the Trinity River proper are subject to wide variations in stream flow. Floods are likely to occur at all seasons of the year with annual high water usually occurring during the months of April, May and June. Major floods occurring on the basin require from to 90 days for the passage of the floods down the river. Low flows are usually experienced during the summer months, June through September. There have been two major drought periods experienced on the Trinity River Basin (1908 - 1913 and 1950 - 1957) and several minor periods of lesser extent. Minimum low flows experienced during the 1950 - 1957 drought period were recorded as follows:

Gage	Min.	Date	Av. Daily	Date
Romayor	102	24, 25 Aug 56	104	23 - 25 Aug 56
Riverside	84	21 Aug 56	87	21 Aug 56
Midway	87	27 Jul 56	87	Jul 56
Oakwood	89	14 Aug 56	91	12 & 14 Aug 56
Rosser	14	25 Sept 56	107	31 July 56, 7 Aug 56 & 25 Sept 56
Dallas	4.6	24 Sept 56	24	10 Apr 56
Grand Prairie	not	determined	29	17 Jul 56

18. The observed average annual run-off at the principal stream gaging station on the West Fork and the Trinity River proper are given in table 2. It also shows the minimum and maximum annual run-off for the purpose of illustrating the extremes to which the annual run-off is subject. The data in table 2 indicates that the run-off tends to increase from the upstream reaches to the mouth generally because of the greater rainfall on the lower part of the basin.

TABLE 2
ANNUAL RUN-OFF DATA (OBSERVED) (1)
CALENDAR YEAR

Stream and Station	Drainage area (sq. mile)	Period of record	Annual run-off in inches: Min.	Average	Max.
West Fork at Fort Worth	2,627	1921-1959	0.06	2.18	7.93
West Fork at Grand Prairie	3,070	1925-1959	0.31	2.51	8.30
Trinity River at Dallas	6,120	1903-1959	0.28	3.32	10.01
Trinity River near Rosser	8,162	1938-1959	0.48	4.61	10.87
Trinity River near Oakwood	12,912	1923-1959	0.82	5.10	12.78
Trinity River near Midway	14,484	1939-1959	0.88	5.63	13.11
Trinity River at Riverside	15,619	1903-1959	0.94	5.71	13.27
Trinity River at Romayor	17,192	1924-1959	1.00	5.83	13.39

(1) Observed run-off reflects depletions due to storage, evaporation, diversions, etc., in existing local interests and Corps of Engineers' projects.

19. WATERWAYS TO BE CONNECTED.- The proposed waterway would connect with the deep water ports of Galveston and Houston. These two ports provide transshipping points for world trade. The proposed waterway would connect with the shallow draft (12' x 125') Gulf Intracoastal Waterway which would provide water transportation to and from the direct tributary area to the Texas Gulf Coast as far east as St. Marks, Florida, and as far south as Brownsville and thence to the Tennessee-Tombigbee and the Missouri-Mississippi River systems throughout the central section of the United States. Major navigable waterways, mileages, and key ports, that were used in estimating the prospective traffic in this appendix are shown in figure 1.

TRIBUTARY AREA

20. EXTENT.- The tributary area that would be served by the proposed Trinity River navigation channel is the immediate tributary area, to or from which commodities could move over the Trinity River channel to other routes in the United States at a savings in transportation cost. This area is designated as the traffic area. The traffic area includes 148 counties in Texas and 30 counties in Oklahoma. These counties contain about 132,000 square miles in Texas and about 25,000 square miles in Oklahoma. The traffic area represents the portion of the geographic area, included in the economic base study in appendix VII, that pertains to the navigation purpose of this report. The 183-county economic base study area includes the aggregate area that would be influenced by all of the project purposes considered for river basin improvement. In most cases, areas influenced by each project purpose may overlap, for example areas included in the studies for flood control and navigation will include some counties that are common to both purposes and some areas that will apply only to flood control or navigation.

21. The economic base study area and the portion of the aggregate area that is included in the traffic area are shown in figure 2.

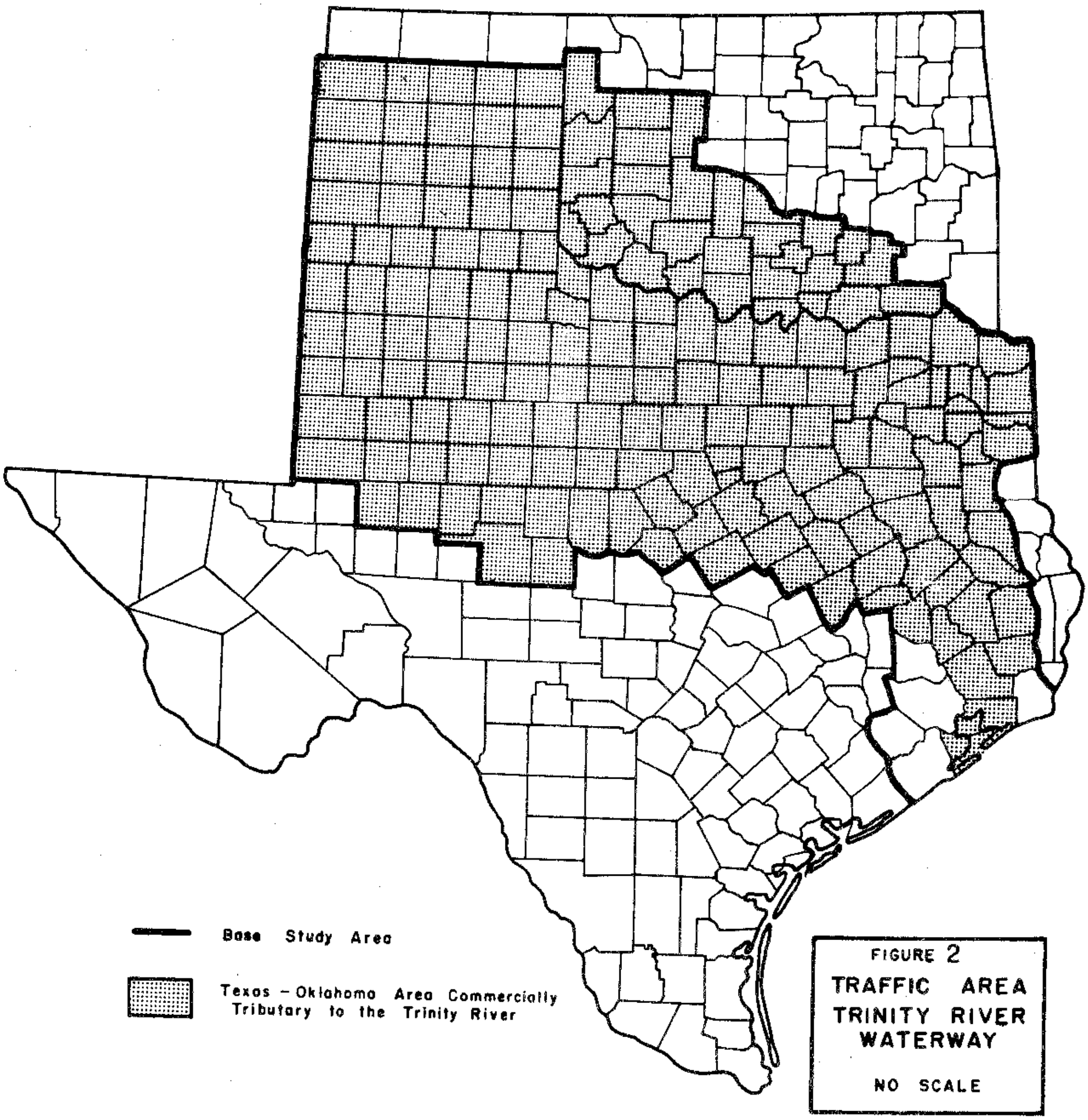


FIGURE 2
TRAFFIC AREA
TRINITY RIVER WATERWAY
NO SCALE

22. The area in which the commerce of the direct traffic area would originate or terminate includes the Gulf Coast from the Mexican border to Florida tributary to the Gulf Intracoastal Waterway and the midcontinent region tributary to the canalized reaches of the Mississippi, Ohio, Tennessee and Cumberland Rivers. This area is designated as the extended traffic area. The connecting waterways serving the extended traffic area are shown in figure 3.

FIGURE 3
MAP OF CONNECTING WATERWAYS

23. POPULATION.- The estimated population of the traffic area was about 5,350,000 in 1958, of which 4,788,000 resided in the 148 counties in Texas, and 562,000 resided in the 30 counties in Oklahoma. Texas estimates are from the Texas Employment Commission, and Oklahoma estimates are from the Oklahoma State Department of Health.

24. Based on the U. S. Bureau of the Census records for 1960, the traffic area includes 42 cities in Texas and 15 cities in Oklahoma with 5,000 to 10,000 population. The census population of the traffic area for the period 1900 - 1960 is shown in table 3.

TABLE 3

POPULATION OF TRAFFIC AREA

	POPULATION		
Year	Texas 148-county area	Oklahoma 30-county area	Texas-Oklahoma 178-county area
1900	1,897,050	(1)	1,897,050 (1)
1910	2,445,962	597,714	3,043,676
1920	2,827,005	654,587	3,481,592
1930	3,331,342	715,527	4,046,869
1940	3,521,198	673,908	4,195,106
1950	3,931,862	576,218	4,508,080
1960	4,663,632	559,003	5,222,635

(1) According to the Census, county data for 1900 are incomplete.
Source: United States Department of Commerce, Bureau of the Census

25. As shown in table 3, population in the aggregate Texas-Oklahoma area shows a growth of over 50 percent since 1900.

26. AGRICULTURE.- An extensive and diversified agriculture is the basic enterprise of the area. Agricultural activities include the operation of dairies near the urban centers and the growing of crops, livestock and all kinds of poultry. The 1954 census of agriculture gives a total of 89,601,000 acres of arable land, 31,936,000 acres of which are under cultivation. Table 4 shows the farmland in the area according to use.

TABLE 4

FARMLAND IN TRAFFIC AREA

Item	Year (in acres)	TEXAS (148 counties)	OKLAHOMA (30 counties)
Land in farms	1954	72,972,671	13,807,489
	1950	85,840,598	13,981,587
Cropland	1954	26,247,859	5,688,036
	1949	27,181,636	6,349,587
Land pastured	1954	49,180,115	8,484,784
	1949	45,710,698	7,805,058
Woodland	1954	8,194,776	1,602,033
	1949	12,878,532	1,881,597

(Source: 1954 Census of Agriculture)

27. Crops produced in the traffic area include cotton, corn, small grains, grain sorghums, rice, hay and vegetables. The markets for these crops are continually expanding because of domestic and overseas population growth and because of the increasing diversification in the use of agricultural foods and fibers in industry. The principal crops exported to world markets include wheat, cotton, barley, oats, and corn. A portion of the crops are consumed in the producing area as feed or forage in the production of beef, mutton, pork, milk, and poultry. An increasing percentage of the crops grown are finding markets as agricultural raw materials. These materials include vegetable oils for the production of cooking compounds, soap, margarine, paint vehicles, and other products; cellulosic materials for the production of rayon, varnishes, photographic film, explosives, hardboard, plastics, and other products; and derivative materials such as cottonseed meal and cake, rice hulls, and beet pulp for the production of feed supplements, and other by-products. Principal crops grown in the area and the annual production of these crops for the years 1949 and 1954 are given in table 5.

TABLE 5

PRINCIPAL CROPS GROWN IN TRAFFIC AREA

Item	Unit	TEXAS (148 counties) 1954	TEXAS (148 counties) 1949	OKLAHOMA (30 counties) 1954	OKLAHOMA (30 counties) 1949
Corn	Bushels	12,945,202	22,624,349	985,276	5,954,409
Sorghums	"	102,193,490	64,197,641	2,127,609	3,206,521
Wheat	"	30,068,413	74,067,382	22,408,550	24,854,276
Oats	"	14,187,446	18,132,918	7,429,016	2,879,321
Barley	"	1,919,512	1,981,579	1,493,267	238,998
Rice	162-lb.bbls.	1,732,859	1,858,546	-	-
Peanuts	Pounds	44,602,166	176,301,335	23,379,639	58,083,631
Hay:					
Alfalfa	Tons	436,317	333,464	394,648	358,787
Others	"	605,758	652,766	194,354	207,382
Cotton	Bales	2,230,380	3,866,571	234,118	468,669
Irish Potatoes	Bushels	1,293,097	1,117,963	171,340	216,890
Sweet Potatoes	"	1,246,383	2,906,693	83,615	124,171
Guar	Pounds	3,638,860	-	-	-

Source: 1954 Census of Agriculture

28. Pastureland in the traffic area in 1954 amounted to 67 percent of the total land in farms as shown in table 4. The pasturelands are spread over a wide range of temperatures, rainfall, altitude, and soil types. Most of the area is better adapted to pasture than to any other agricultural purpose. These factors have engendered the development of a large and diverse livestock-raising industry. Principal production of the industry includes beef cattle, sheep, and Angora goats. The other livestock produced that are of lesser importance are hogs, poultry, horses, and mules. Wool and mohair are important products of the sheep and Angora goat industry. Table 6 shows the principal classes of livestock and the numbers in the traffic area for the years 1950 and 1954.

TABLE 6

PRINCIPAL CLASSES OF LIVESTOCK IN THE TRAFFIC AREA

Item	TEXAS		OKLAHOMA	
	1954	1950	1954	1950
Cattle and calves	4,549,243	4,107,874	1,217,230	1,212,614
Horses and colts, including ponies	124,953	216,709	30,940	64,876
Mules and mule colts	32,295	68,865	3,327	8,248
Sheep and lambs	1,709,212	1,974,050	77,931	47,425
Goats and kids	687,110	-	7,639	-
Hogs and pigs	515,009	786,303	142,477	261,339
Chickens (4 months old and over)	8,205,886	9,706,980	1,975,694	2,585,185

Source: 1954 Census of Agriculture

29. A recent development in the livestock-raising industry in Texas is the growth of feed lots. Feed lots were first started in the state during World War II as a temporary measure. Prior to this period most of the heavy beef consumed in the state came from feed lots in the middle-western "Cornbelt." Texas cattle were sold as feeders for fattening and processing and were returned as graded beef. Most of the new commercial feeding pens and smaller feeding operations have been successful. Over a period of four years, 1955 to 1959, feeding capacity increased 50 percent from 160,000 head to 240,000 head. Examples of the expansion of feed lot activity are the programs of major feed lot operators. One operator's program, which includes the installation of a 300 ton per day capacity automatic feed mill, will increase his feeding capacity from 7,000 to 13,000 head. Another major corporate operator expanded its feed lots to accommodate 25,000 head of cattle in conjunction with construction of a million-dollar beef slaughtering and processing plant, while still another group is constructing a two-million dollar feeding facility to supply 400 to 1,000 head of cattle a week to a planned two-million dollar beef processing plant.

30. The Texas meat packing and processing industry supplements stock raising and feed lot activities. The growth of the meat packing industry is illustrated in table 7.

TABLE 7

TEXAS MEAT PACKING INDUSTRY

Beef processing	Census of Manufactures 1939	1954
Employees	6,089	10,464
Payroll	$ 8,247,087	$ 40,280,000
Value of products	85,461,000	379,912,000
Poultry & small game		
Employees	1,547	3,162
Payroll	$ 709,069	$ 5,758,000
Value added by manufacture	1,321,000	13,207,000

Source: Census of Manufacturers for 1939 and 1954

31. This expansion in the meat industries is an example of the state's general growth in manufacturing activities. An increasing portion of the state's livestock is slaughtered and processed for consumption within the state instead of sending livestock to out-of-state processing centers in the midwest.

32. FOOD PROCESSING.- An increasing share of Texas agricultural products is channeled into the growing food processing industry. This is also true of agricultural commodities produced in the traffic area. According to the University of Texas' Bureau of Business Research, one of Texas' biggest industries and one of the fastest growing, is food processing. In 1956 more than 60,000 persons were employed in food processing. These industries include cottonseed oil refining, sugar refining, flour milling, bottling plants, dairy products processing, seafood and vegetable freezing plants, meat and citrus packing plants, corn products plants, bakeries, canneries, cooking oil plants, margarine plants, shortening plants and others. Many of these plants are located in the traffic area in the urban centers of population and the manufactured products are distributed to eastern United States and world markets as well as the local regional market in Texas, Oklahoma, Arkansas and Louisiana.

33. INDUSTRY.- In the past 50 years Texas has evolved from an agricultural province to one of the country's leading manufacturing centers and is gradually approaching the position of long-established industrial regions. Industry in the traffic area is well diversified and covers a wide range of products. The 1956-1958 Directory of Texas Manufacturers lists 10,821 manufacturers in the state whose operations change form of

their product. The pattern of industry is illustrated by the 73 plants in Harris County which employ more than 250 persons and which are predominantly heavy industries, in contrast with the 1479 plants in Dallas County, which employ 50 or more persons and which are primarily light industries. Harris County is not in the traffic area; however, its proximity to the mouth of the Trinity River and the size of its industrial complex require that it be included in any discussion of the economic development of the traffic area.

34. The city of Houston typifies the entire Gulf Coast where cheap water transportation, and an abundance of raw materials have attracted chemical companies, refineries, metal industries, and heavy machinery plants. The city of Dallas is typical of northern Texas, the state's other major manufacturing region, where a large area represents markets rather far removed from seaports. Market-oriented industries, concentrated in the Dallas and Tarrant County area, are more specialized industries producing consumer goods of every description. The location of a large transportation equipment industry represented by Convair, Bell Aircraft, and General Motors in Tarrant County and by Chance Vought, Temco, and Ford Motor Company in Dallas County is an exception to the light industry pattern. Strategic considerations of the United States Government were instrumental in locating these plants in an area less vulnerable to air attack than the more exposed Gulf Coast.

35. The major manufacturing activities in the traffic area in 1958 are represented by a total of 1,375 plants in the traffic area, 155 of which employ 250 persons or more, and 318 plants in Harris County, 73 of which employ 250 persons or more. The range of products produced as major manufactures together with the relative density of major industrial development by product is illustrated in table 8.

TABLE 8

PRINCIPAL MANUFACTURES IN TRAFFIC AREA - 1958

Kind of industry	Number of Establishments		
	Tributary Area		Harris
	Texas	Oklahoma	County
Food	142	158	30
Apparel & Textiles	182	16	5
Wood products	111	49	57
Chemicals and Petroleum	232	43	53
Stone, Clay & Glass	53	34	6
Metal products	82	58	33
Machinery and equipment	223	39	123
Transportation	64	7	11
Total	1,089	404	318

Source: Texas - Directory of Texas Manufacturers 1956-1958
Okla. - Statistical Abstract of Oklahoma 1959
Note: Industry classifications modified and grouped for brevity.

36. It is difficult to derive a total measure of the industrial output of the traffic area. An overlapping or duplication of available statistics are frequently encountered in the flow of raw materials, intermediate materials and semifinished and finished commodities into and out of manufacturing plants; however, the value added by manufacture is some measure of the relative economic importance of these industries. Table 9, based on the U. S. Bureau of the Census' census of manufacturers for the year 1954, shows the value of the products manufactured in the tributary area for the years 1947 and 1954.

TABLE 9

VALUE ADDED BY MANUFACTURE IN THE TRAFFIC AREA

(in thousands of dollars)

State	Number of establishments	1954 Value added by manufacture	1947 Value added by manufacture
Texas (148 counties)	4,813	$1,516,471	$764,351
Oklahoma (30 counties)	374	52,926	28,522
Total	5,187	1,569,397	792,873

Note: Value added by manufacture for counties with only one establishment not included in total since figures for individual establishments are not disclosed. Only number of establishments shown were included in computing value added by manufacture.

Source: Census of Manufacturers for 1954
U. S. Bureau of the Census

37. NATURAL RESOURCES.- The volume, quality and diversity of natural resources in the traffic area have been a basic factor in the economic development of the area. These resources have a direct bearing on projected economic growth, particularly with reference to the flow of commerce over existing transportation media as well as over the proposed waterway.

38. FOREST RESOURCES.- According to the Forest Service, U. S. Department of Agriculture, forest land is (1) land which is at least 10 percent stocked by trees of any size and capable of producing timber or other wood products or, (2) land from which the trees have been removed to less than 10 percent stocking and which has not been developed for other use. Recent surveys by the Southern Forest Experiment Station in New Orleans indicate that forest lands of commercial significance in and adjacent to the traffic area are confined to a 17-county area in eastern Oklahoma and a 43-county area in east Texas.

39. The traffic area includes 31 of the 43 counties designated as forest lands in Texas and 3 of the 17 counties in Oklahoma. The total land area of the 31 counties in Texas is 15,496,900 acres, or 70.3% of the 22,033,900 acres in the counties with forest areas. The total land area of the 3 counties in Oklahoma is 1,473,300 acres, or 15% of the 9,798,400 acres in the counties with forest areas. The principal commercial soft woods are the loblolly and shortleaf pines, and the principal commercial hardwoods are the water and white oaks and sweetgum. The commercial forest land in the traffic area and the amount of growing stock and saw timber volume is shown in table 10.

TABLE 10

COMMERCIAL FOREST IN TRAFFIC AREA 1953-1956 (1)

Item	Unit	TEXAS 31-county total	Percent of total state forest resources	OKLAHOMA 3-county total	Percent of total state forest resources
Commercial forest	1,000 acres	8,547.8	70.2	744.0	13.2
Growing stock:					
Softwood	Mil. cu.ft.	2,596.5	64.5	2.1	0.4
Hardwood	" " "	2,473.9	70.5	162.5	19.8
All species		5,070.4	67.3	164.6	12.2
Saw timber:					
Softwood	Mil. bd.ft.	11,368.5	64.7	7.8	0.4
Hardwood	" " "	6,635.7	68.6	414.9	20.5
All species		18,004.2	66.1	422.7	10.5

(1) From Forest Service, U. S. Department of Agriculture forest survey release No. 77 & 79

40. In a modern economy, forest products have become an important factor in the industrial complex. In the state of Texas, where the bulk of forest industry is centered in the traffic area, more than 97 percent of the total output of forest products are produced in the east Texas commercial forest. Softwoods account for 68 percent of the saw logs cut for lumber and allied products and for 95.2 percent of the pulpwood. In 1957 the output of lumber amounted to 987,000,000 board feet and pulpwood production reached a total of 1,227,000 standard cords. Hardwoods accounted for all veneer logs and bolts, and for about 40 percent of all wood products. Cooperage, shook, fuelwood, piling, poles, posts, hewn ties and miscellaneous wood products such as axe handles and saddle trees, brought 1957 production of forest products up to a grand total of over 312 million cubic feet. According to the Texas Forest Industries Committee,

the forest industry in 1957 employed 40,000 persons and paid $138,000,000 in wages, of which $53,000,000 was for lumber and allied products; $38,000,000 was for pulp, paper and paper products; and $44,000,000 was for furniture. These wages find their way into the State's economy as payment for goods and services. As shown in table 10 the traffic area contains about two-thirds of the east Texas forest and would share proportionately in the State's economy.

41. The forest resources in the traffic area are a renewable resource. Despite the magnitude of forest products production in Texas, conservation practices such as tree farming, control of wildfire, disease, and insects, have produced a gain in total wood production of 39 percent over total wood depletion from industry, forest fires, disease, and other causes. As conservation practices become more universally followed and therefore more effective, the percentage of surplus production will increase, assuring a substantial margin for continued economic growth in the traffic area.

42. MINERAL RESOURCES.- Mineral development and resources in Texas and Oklahoma are major factors in the economies of both states. The volume and diversity of minerals available for industrial processes, construction materials, chemical industries and mineral consumer products are of national importance. In 1958, Texas alone produced about 25 percent of the nation's output of mineral value. The total production of minerals in 1958 for Texas and Oklahoma is given in table 11, by commodity, volume, and value.

TABLE 11

MINERAL PRODUCTION - 1958 (1)

Mineral	Unit	TEXAS Quantity	TEXAS Value (thousands)	OKLAHOMA Quantity	OKLAHOMA Value (thousands)
Cement	thousand 376-lb. bbls.	25,875	$ 79,756		
Clays	1000 short tons	3,719(3)	5,424(3)	576(2)	$ 579(2)
Coal	" " "			1,629	10,858
Gem stones	short tons	(4)	100		
Gypsum	1000 short tons	1,240	4,120		
Helium	1000 cu. ft.	294,452	4,807		
Lime	1000 short tons	691	7,146		
Natural Gas	mil. cu. ft.	5,178,073	517,807	696,504	70,347
Natural gasoline cycle products	1000 gals.	2,871,589	204,501	440,798	26,029
LP-gases	" "	3,786,575	151,896	657,114	25,822
Petroleum (crude)	thousand 42-gal.bbls.	940,706(5)	2,873,988(5)	202,699(5)	599,989(5)
Salt (common)	1000 short tons	3,843	15,115	4	41
Sand & gravel	" " "	32,871	30,808	7,232	5,859
Stone	" " "	36,076	40,912	10,794	12,232
Sulfur (Frasch)	1000 long tons	2,616	61,621		
Talc & Soapstone	short tons	60,827	168		
Zinc (recoverable content of ores, etc.)				5,267	1,074
Value of items that cannot be disclosed			50,635(6)		16,022(6)
TOTAL			4,038,656		767,856

Source: U. S. Bureau of Mines, Bartlesville, Okla.

Notes: (1) Production as measured by mine shipment, sales, or marketable production (including consumption by producers). (2) Excludes bentonite, included with "Value of items that cannot be disclosed." (3) Excludes certain clays, included with "Value of items that cannot be disclosed." (4) Weight not recorded. (5) Preliminary figure. (6) Texas: Native asphalt, bromine, fuller's earth, lignite, feldspar, graphite, iron (usable), magnesium chloride (for metal), magnesium compounds (except for metal), mercury, pumice, sodium sulfate, and uranium ore. Oklahoma: Native asphalt, bentonite, cement, gypsum, lime, pumice, and tripoli.

43. Minerals produced in the 178-county traffic area include most of the minerals in table 11 above, although quantities are in different proportions. A tabulation of the specific minerals, amount produced, and value of production for each commodity produced in the traffic area in 1959 is presented in table 12.

TABLE 12

VALUE AND PRODUCTION OF MINERALS IN TRAFFIC AREA - 1959

Mineral	Unit	Quantity	Value (thousands)
	TEXAS		
Cement	thousand 376-lb. bbls.	13,169	$ 40,473
Clays	thousand short tons	2,335	3,587
Gypsum	" " "	1,331	4,710
Helium	thousand cubic feet	238,113	3,918
Lime	thousand short tons	55	686
Natural gas	million cubic feet	1,661,525	166,153
Natural gas liquids	thousand gallons	3,654,493	199,535
Petroleum (crude)	thousand 42-gal. bbls.	563,953	1,680,579
Salt (common)	thousand short tons	696	6,106
Sand & gravel	" " "	17,792	18,850
Stone	" " "	18,718	22,282
Sulfur	thousand long tons	382	8,968
Value of items that cannot be disclosed: Clay (fuller's earth), coal (lignite), iron ore (useable), pumice, sodium sulfate, and uranium ore			11,898
		Total	2,167,745
	OKLAHOMA		
Clays	thousand short tons	415	448
Natural gas	million cubic feet	285,356	29,392
Natural gas (liquids)	thousand gallons	591,231	29,562
Petroleum (crude)	thousand 42-gal. bbls.	90,021	262,862
Salt (common)	thousand short tons	1,168	12,848
Sand & gravel	" " "	2,375	2,998
Stone	" " "	7,264	8,867
Value of items that cannot be disclosed: Native asphalt, cement, and gypsum			68,256
		Total	415,233

Source: U. S. Dept. of the Interior, Bureau of Mines, Bartlesville, Okla.

44. Mineral resources in commercially significant quantities in the traffic area that are relatively undeveloped include iron ore, lignite, salt, limestone, and burning clays. Surveys by private business interests have developed proven commercial reserves as shown in table 13.

TABLE 13

COMMERCIAL RESERVE OF UNDEVELOPED MINERAL RESOURCES
PRIVATE SURVEYS AND ESTIMATES

(long tons)

Resource	Quantity
Lignite	1,695,000,000
Salt	72,250,000,000
Limestone	Unlimited
Iron ore	70,800,000

45. SALT.- There are an estimated 72.25 billion tons of salt in salt domes located in the following counties: Anderson, Cherokee, Freestone, Houston, Leon, Smith, Van Zandt, Wood and Henderson.

46. Major uses of salt are in the manufacture of chlorine and caustic soda or in the manufacture of soda ash. The salt reserves in the prescribed area would produce 45 billion tons of 76% strength caustic soda and 39.6 billion tons of chlorine. If the salt were used in the manufacture of soda ash, it would make 45 billion tons of soda ash and would require in addition to the salt, 58.6 billion tons of limestone which must be supplied from counties other than those in which the salt domes are located but still within the traffic area. The average distance from the salt domes to the Trinity River is 33 miles.

47. IRON ORE.- Total reserves of iron ore in the traffic area are 70,808,000 long tons. This ore is located in Cherokee, Henderson, Anderson and other counties. Some of this ore is currently being processed in Houston.

48. The estimated iron content of this ore is 40%. On this basis, a total of 25.6 million tons of steel can be produced from this amount of ore. It is likely that the production of steel will be by one of the direct reduction processes. The production of this amount of steel will require the shipment of 6.4 million tons of limestone within the traffic area, as well as the consumption of 30 million tons of lignite. While all the tests have not been completed, it is likely that some anthracite coal will be required in these processes. This material must be shipped into the traffic area from outside the Trinity River Basin. The required anthracite may be replaced by briquettes made from lignite which would be produced within the traffic area.

49. Research work is now under way on the upgrading of extensive green sand deposits to make them suitable for use in the steel industry. If this research effort is successful, the total reserves of iron ore within the traffic area may well be increased by a factor of 3 or 4. A byproduct of the steel manufacture will be approximately 50 million tons of slag.

50. LIGNITE.- There are an estimated 1,695 million tons of recoverable lignite in the traffic area.

51. It is assumed that the primary use of lignite will be as a fuel for steam electric power plants within the traffic area. If this is true, and if all lignite is carbonized before its use as a fuel, 94,920,000 tons of low-temperature lignite tar will be produced, from which a variety of chemicals may be extracted. The burning of this quantity of lignite in power plant boilers would produce 51 million tons of fly ash and 150 million tons of slag aggregate.

52. A description of the process of the drying and carbonizing process which is essential to the successful use of lignite as a fuel is described in the report "Low Temperature Carbonization of Coal and Lignite for Thermal Power Generation" from the Bureau of Mines. Utilization studies to date indicate that the 94 million tons of lignite tar would find a market in the chemical industry, in the wood preservative industry, and in other industries utilizing pitches and similar products, although no established markets exist for low-temperature lignite tar at this time. A portion of the tar may be utilized in the refining industry.

53. The slag and fly ash may be utilized in the construction industry as a partial replacement for Portland cement, in the oil well cementing industry, and in the stabilization of highway base courses. In addition, the slag would probably be used as a highway surfacing material, and can also be used as the raw material for the manufacture of mineral wool insulating materials.

54. It is possible that, in addition to the use of lignite as a fuel for steam electric generating stations, lignite may also be used as a source of carbon for industries which now utilize carbon materials. The manufacture of briquettes from charred lignite shows great promise for use of this material as a carbon source in the metallurgical and other similar industries.

55. Electric power spokesmen state that there is a growing shortage of industrial electric power along the Gulf Coast, and assert that this shortage of power together with the diminishing spread between the cost of producing electric power from natural gas compared to production costs from coal and lignite will induce both industrial and power interests to develop a source of fuel for the generation of power to supplement natural gas, the present fuel. The nearest alternate fuel sources are the lignite deposits of northeast Texas. The use of these lignites would tend to accelerate the development and growth of the entire economy of the traffic area.

56. CEMENT.- There are a number of locations of which cement raw materials are located. It is virtually impossible to estimate the total reserves. The U. S. Bureau of Mines reported that 13,169,000 barrels or 2,476,000 tons of cement were produced in the traffic area in 1959. If it is assumed that the consumption of cement increases 100 percent each 10 years, the estimated production of cement in the traffic area would amount to about 4,952,000 tons by 1969 and about 9,904,000 by 1979.

57. STRUCTURAL CLAY PRODUCTS.- There is an almost unlimited quantity of burning clay located within the traffic area. These clays are of varying qualities and are used for different end products. Based on the state production of clay in recent years, and the number of structural clay products plants now in operation, it is estimated that 1.5 million tons of clay and clay products are produced annually within the traffic area.

58. LIMESTONE.- The reserves of limestone of all qualities which are found in the traffic area are virtually unlimited. Some beds are known to be several hundred feet thick. In the traffic area for the year 1958, 660,000 tons of limestone were used in the manufacture of lime. Reserves of limestone suitable for the manufacture of lime are indefinite, but it is expected that this rate can be maintained for the life of the project.

59. TRANSPORTATION.- The traffic area is served by the ship channel extending from the Gulf of Mexico to the ports of Galveston and Houston; a network of railroads; a system of all-weather highways; and by the Gulf Intracoastal Waterway which provides shallow-draft barge transportation to the Mississippi River System serving the central regions of the United States and the Great Lakes.

60. The entire area is served by an excellent system of Federal and state highways. The state highway system is supplemented by farm-to-market and county all-weather roads that form multiple highway routes between the principal centers of the area and serve all of the smaller communities.

61. The deep-water ports of Galveston and Houston provide two excellent transshipping points for world trade and serve the area through existing transportation systems. The proposed waterway would connect with these ports and provide all-water service to the area. In addition, the proposed waterway would connect with the shallow-draft Gulf Intracoastal Waterway which would provide water transportation to and from the traffic area to the Texas Gulf Coast as far south as Brownsville and as far east as St. Marks, Florida, as well as the tributary channels of the waterway and the Missouri-Mississippi River system.

62. Railroads are predominately located in the eastern half of the traffic area. Major railroads serving the area include the Missouri-Kansas-Texas; St. Louis-San Francisco; Atchison, Topeka and Santa Fe; Southern

Pacific; Missouri Pacific; Chicago, Rock Island and Pacific; St. Louis Southwestern (Cotton Belt); and Chicago, Burlington and Quincy. These railroads provide trunk line rail transportation between St. Louis, Kansas City, Tulsa, Oklahoma City, Little Rock, Fort Worth, Dallas, Houston, Galveston, Wichita Falls and El Paso. These lines are supplemented by numerous short lines and feeder branches that connect virtually every town or city of any size in the traffic area with the major centers of industry in Texas and in the United States.

63. Other transportation systems serving the area include a well organized and developed system of pipelines for transportation of natural gas, petroleum, petroleum products, and chemicals. Several major airlines service the principal centers in the area also.

BRIDGES

64. BRIDGES ACROSS TRINITY RIVER TO FORT WORTH.- There are 59 existing bridges over the 552-mile length of channel under consideration for improvement, which extends from the Houston Ship Channel in Galveston Bay to the lower end of the authorized Fort Worth floodway extension at the Riverside Drive bridges in Fort Worth, Texas. Pertinent data concerning the existing railroad and highway bridges over the 552-mile reach are given in tables 14 and 15.

65. Interstate Highway No. 10 with a high-level fixed bridge over the Trinity River at river mile 7.4 is the only bridge crossing the 49-mile reach of authorized channel to Liberty. There are 7 railroad bridges and 18 highway bridges in the 444-mile reach of the Trinity River between the authorized head of navigation at Liberty and Dallas. In the 59-mile reach between Dallas and Fort Worth, there are six railroad bridges and 27 highway bridges. None of the railroad bridges listed in table 14, is presently capable of being operated as a movable bridge. Investigation reveals that in practically all instances the existing railroad and highway bridges are inadequate with respect to providing minimum clearances for navigation or are not suitably located with respect to the selected alignment of the proposed channel improvement. Information concerning the modification of existing bridges or construction of new bridges required to provide adequate clearances for navigation on the proposed channel to Fort Worth is given in paragraph 115.

TABLE 14
PERTINENT DATA CONCERNING EXISTING RAILROAD BRIDGES OVER TRINITY RIVER TO FORT WORTH, TEXAS

Name of owner	Location (river miles above mouth)	Type of bridge (river span)	Total length (feet)(1)	Horizontal clearance (feet)(2)	Elevation low steel (m.s.l.)	Vertical clearance (feet)(3)	Date plans approved by Dept. of Army	Date bridge completed
Texas & New Orleans RR(SP)	40.4	225' swing truss (4)	1,561	98.3	29.5	13.5	20 Apr 1929	(5)
Missouri Pacific RR	49.0	210' swing D.P.girder (4)	1,157	87.5	34.5	18.5	31 Oct 1907	(5)
Gulf Colorado & Santa Fe RR	96.3	200' swing truss (4)	1,934	90.3	79.9	19.9	6 Jul 1901	(5)
Texas & New Orleans RR (SP)	117.3	150' thru truss	626	-	93.3	33.3	8 May 1897	(5)
Missouri Pacific RR	182.5	300' swing thru truss(4)	2,850	127.5	143.5	12.5	30 Dec 1914	(5)
Missouri Pacific	311.9	200' swing truss (4)	1,270	82.6	229.9	19.9	30 Dec 1914	(5)
St. Louis & Southwestern	391.7	200' thru truss	3,354	193.1	291.6	6.6(6)	(7)	(5)
Dallas Terminus								
Texas & New Orleans RR (SP)	494.4	130' thru truss	2,990	120.5	405.7	33.7	24 Aug.1954	(5)
Missouri Kansas & Texas RR	497.1	200' thru truss	330	194.7	405.9	33.9	(7)	(5)
Gulf Colorado & Santa Fe RR	498.0	199' thru truss	1,775	180.0	416.9	44.9	(7)	(5)
Texas & Pacific RR	500.5	200' thru truss	2,020	190.0	429.1	33.1	(7)	1931
Gifford Hill Gravel Co.	508.9	100' thru truss	175	100.0	425.3	29.3	(7)	1933
Chicago Rock Island & Pacific RR	521.9	160' thru truss	251	156.0	454.7	30.7	(7)	(5)
Fort Worth Terminus								

(1) Includes length of approach spans to river span.
(2) Minimum clearance of river span.
(3) Clearance between bridge low-steel elevation and proposed normal elevation of navigation pool.
(4) Designed for movable span but not operating.
(5) Date not determined.
(6) Clearance between bridge low-steel elevation and top of flood control pool, elevation 285.0, Tennessee Colony reservoir.
(7) Record not available.

TABLE 15
PERTINENT DATA CONCERNING EXISTING HIGHWAY
BRIDGES OVER TRINITY RIVER TO FORT WORTH, TEXAS

Name of owner	Location (river miles above mouth)	Type of bridge (river span)	Total length (feet)(1)	Horizontal clearance (feet)(2)	Elevation low steel (m.s.l.)	Vertical clearance (feet)(3)	Date plans approved by Dept. of Army	Date bridge completed
Interstate Hwy 10	7.4	507' Cont. pl. girder	2,849	150	74.5	70.5	24 Jul 1953	1955
U. S. Hwy 90 (east)	40.3	450' thru truss	1,457	144	30.7	14.7	26 Feb 1929	1930
U. S. Hwy 90 (west)	40.3	392' Cont. pl. girder	1,459	135	32.0	16.0	22 Dec 1958	1962
State Hwy 105	94.3	200' thru truss	440	196	74.6	14.6	8 Sep 1924	1926
U. S. Hwy 59	117.3	530' Cont. Pl. girder	1,810	152	100.7	40.7	28 Oct 1946	1950
U.S. Hwy 190	153.0	240' thru truss	750	228	116.5	(4)	11 Dec 1937	1943
State Hwy 45	182.7	650' thru truss	2,884	152	145.2	14.2	7 Jun 1939	1941
State Hwy 21	230.2	392' Cont. pl. girder	3,667	120	169.2	31.2	9 Jul 1957	1959
State Hwy 7	265.2	392' Cont. pl. girder	694	128	195.7	27.7	6 Sep 1955	1957
U. S. Hwy 79 & 84	313.4	342' Cont. pl. girder	1,723	135	230.8	20.8	6 Jan 1954	1955
U. S. Hwy 287	374.5	202' thru truss	819	195	269.9	(5)	11 Jan 1934	1935
State Hwy 31	392.0	200' thru truss	3,045	195	292.5	7.5(6)	23 Feb 1932	1931
State Hwy 1129	431.2	330' Cont. Pl. girder	1,241	120	314.1	30.1	21 Oct 1955	1958
State Hwy 34	451.4	150' thru truss	1,709	144	347.7	39.7	17 Oct 1933	1934
Dallas Co., Malloy Road	473.9	300' Cont. I-beam	2,145	117	387.6	31.6	24 Aug 1954	(7)
Dallas Co., Belt Line Road	477.8	276' Cont. I-beam	2,106	94	389.4	33.4	20 Aug 1953	(7)
Dallas Co., Dowdy Ferry Road	482.9	276' Cont. I-beam	1,038	96	400.6	28.6	8 Nov 1951	(7)
State Hwy Loop 12 (East)	491.8	341' Cont. pl. girder	1,341	135	407.0	35.0	29 Sep 1956	1958
State Hwy Loop 12 (West)	491.8	341' Cont. pl. girder	1,341	135	407.0	35.0	16 Aug 1949	1951
Dallas terminus								
Interstate Hwy 45 (North)	494.6	140' Deck truss	2,723	128	414.0	42.0	30 Jul 1937	1938
Interstate Hwy 45 (South)	494.6	380' Arched pl. girder	2,723	134	428.3	56.3	30 Apr 1947	1950
Dallas Co., Forrest Avenue	497.4	366' Deck pl. girder	2,588	122	419.0	47.0	25 Apr 1951	(7)
Dallas Co., Corinth Street	498.3	200' Cont. Cant. pl. girder	2,533	113	418.0	22.0	3 May 1910	(7)
Dallas Co., Cadiz Street	499.1	200' Cont. Cant. pl. girder	2,468	115	418.7	22.7	25 Aug 1914	(7)
Interstate Hwy 35E	499.2	260' Cont. pl. girder	2,439	117	425.0	29.0	30 Sep 1954	1957
Dallas Co., Houston Street	499.5	240' Conc. arch	1,985	60	420.0	24.0	29 Sep 1910	1910
Dallas-Ft.Worth turnpike	499.9	338' Cont. pl. girder	2,233	126	429.2	33.2	17 Aug 1955	
Dallas Co., Commerce St.	500.3	182' Cont. Cant. gr.	1,904	110	423.0	27.0	2 Mar 1916	1931
Dallas Co., Continental St.	500.7	196' Cont. Cant. gr.	1,973	190	424.4	28.4	(8)	1931
Dallas Co., Sylvan Avenue	501.7	250' Cont. I-beam gr.	250	86	404.0	8.0	15 Mar 1951	(7)
Dallas Co., Hampton Road	503.0	367' Cont. pl. girder	3,600	132	431.0	35.0	22 Jan 1951	(7)
Dallas Co., Westmoreland Rd.	504.0	120' thru truss	392	115	411.8	15.8	(8)	(7)
State Hwy Loop 12	507.3	342' Cont. pl. girder	1,143	135	437.0	41.0	23 Jul 1953	1954
Dallas Co. Meyers Road	511.4	221' Cont. I-beam	221	95	434.2	10.2	8 Jun 1953	(7)
State Hwy, Belt Line Road	514.6	285' Cont. W.F. spans	285	106	445.6	21.6	24 Feb 1955	(7)
State Hwy 360	522.4	282' Pres Conc. beam	412	87	463.0	39.0	7 Oct 1957	1958
State Hwy 157 (North)	527.7	230' Cont. I-beam	230	87	469.7	17.7	18 Aug 1954	1955
State Hwy 157 (South)	527.7	100' thru truss	150	87	469.4	17.4	(8)	(7)
Arlington-Bedford Rd (9)	532.2	100' thru truss	220	92	474.0	22.0	(8)	(7)
Arlington-Smithfield Rd (9)	536.2	100' thru truss	223	92	481.9	29.9	(8)	(7)
U. S. Hwy Loop 820	549.7	324' I-beams	658	90	506.0	26.0	7 Aug 1961	
Handley-Ederville Rd (9)	541.4	110' thru truss	217	110	495.6	15.6	(8)	(7)
Fort Worth terminus								
Fort Worth, East First St. (9)	547.2	80' Conc. girders	200	75	507.3	34.1(11)	(8)	1931
Fort Worth, Beach St. (10)	549.6	90' Conc. I-beam	200	87	524.0	44.0(11)	(8)	1961
Fort Worth, Riverside Dr. (North)(10)	551.2	154' Plate girder	333	151	529.6	49.0(11)	(8)	(7)
Fort Worth, Riverside Dr. (South)(10)	551.2	95' Plate girder	292	93	523.7	43.0(11)	(8)	(7)

(1) Includes length of approach spans to river span.
(2) Minimum clearance of river span
(3) Clearance between bridge low-steel elevation and proposed normal elevation of navigation pool
(4) U. S. Highway 190 to be relocated to clear conservation pool, elevation 131.0, of the Livingston reservoir.
(5) U. S. Highway 287 to be relocated to clear flood control pool, elevation 285.0 of the Tennessee Colony reservoir.
(6) Clearance between bridge low steel elevation and top of flood control pool, elevation 285.0, Tennessee Colony reservoir.
(7) Date not determined.
(8) Record not available.
(9) Name of owner - Tarrant County.
(10) Name of owner - City of Fort Worth.
(11) Clearance above normal low water upstream of proposed head of navigation
Note: Interstate highway, U. S. Highways and State highways owned by Texas Highway Department.

EXISTING CORPS OF ENGINEERS' PROJECT

66. PREVIOUS PROJECTS.- The project outlined in House Document No. 409 Fifty-sixth Congress, first session, provided for a 4-foot channel in the Trinity River from the mouth to Dallas, by construction of 37 locks and dams, with incidental dredging and open-channel work. The project was adopted in part by the River and Harbor Acts of June 13, 1902, March 3, 1905, March 2, 1907, June 25, 1910, July 25, 1912 (which increased the project depth to 6 feet), March 4, 1913, and July 27, 1916. Each act authorized the construction of certain-named locks and dams. The portion of the project relating to lock and dam construction was abandoned, as directed by the River and Harbor Act of September 22, 1922. The costs and expenditures for the previous projects total $2,181,408, of which $1,890,406 was for new work and $291,002 was for maintenance. In addition, $252,660 was expended for operation and care of locks and dams under the permanent indefinite appropriation, and $66,000 contributed by local interests was expended for new work.

67. Under the authority of the River and Harbor Act of 1902 and subsequent legislation, the Engineer Department constructed seven locks and dams and one auxiliary dam, and removed obstructions in some reaches of the river. The locks, with lifts varying from 7.4 to 17.5 feet, provided unuable chambers of 50 by 140 feet and a minimum navigable depth of 6 feet over the lower miter sills. Six of the dams were of the Chanoine type, one of the Boule type, and one of the needle type.

68. EXISTING PROJECT.- With abandonment of the lock and dam construction, the improvement of the Trinity River by a channel 6 feet deep and of navigable width from the mouth to Liberty was left as the existing project, being continued as provided for in the River and Harbor Act of July 25, 1912. Maintenance of the six-foot project was suspended in 1930.

69. The six-foot project was modified by the River and Harbor Act of March 2, 1945, which approved a comprehensive plan of development of the Trinity River and tributaries, Texas, in accordance with the recommendations set forth in House Document 403, 77th Congress, 1st session, subject to such future modifications as in the discretion of the Chief of Engineers and the Secretary of the Army may be advisable, but authorize for construction only the section of the channel extending from the Houston Ship Channel to and including a turning basin at Liberty, Texas. That plan would provide for a navigable channel extending from the Houston Ship Channel in upper Galveston Bay to a terminus at Fort Worth, Texas. The plan provided for a channel 9 feet deep and 200 feet wide in Galveston Bay and 150 feet wide upstream of the mouth of the Trinity River with shunting places and suitable widening on curves and 26 locks and dams to overcome the fall of the river, totaling 480 feet. The navigation locks would have clear basin dimensions of 75 feet wide by 400 feet long.

70. The River and Harbor Act of July 24, 1946, further modified the comprehensive plan to provide a 9 × 150-foot channel below Anahuac along the eastern shore of Trinity Bay, in accordance with the recommendations of the Chief of Engineers in House Document 634, 79th Congress, 2nd session.

71. The existing project now provides for a sea-level channel, 9 feet deep and 150 feet wide, below mean low tide, extending easterly from the Houston Ship Channel near Red Fish Bar to and along the east shore of Trinity Bay to Anahuac, Texas, thence generally following the natural Trinity River channel to and including a turning basin at Liberty, Texas, a distance of about 48.9 miles, with a protective (spoil) embankment on the Trinity Bay side of the channel between Smith Point, mile 6.0, and Anahuac, mile 24.3, and a log boom at the head of the Anahuac channel. The project was authorized subject to such future modification thereof as in the discretion of the Secretary of the Army and the Chief of Engineers may be advisable, and to prescribed requirements of local cooperation.

72. The portion of the existing project from the Houston Ship Channel to mile 23.2, about one mile below Anahuac, Texas, was completed to project dimensions including the protective (spoil) embankment in 1950. Sufficient traffic did not use the completed portion of the channel to justify its maintenance. The controlling depth of channel was 3.5 feet in 1952, and 2.5 feet in 1953. Navigation on the Trinity River to and from Trinity Bay now uses the Anahuac Channel that connects with the river at Anahuac, Texas, and extends to 6-foot depth in Trinity Bay, a distance of about 5.5 miles. Some funds have been expended for removal of shoals in the river section of the channel, river mile 9.9 to 10.3, about one mile below the Texas Gulf Sulphur Company's channel. The average annual maintenance cost during the past five years was $4,588. The latest (1952) approved estimate of cost of annual maintenance and operation of the modified project channel is $120,000 as given in House Document No. 634, 79th Congress, 2nd session. The total cost of the existing project to June 30, 1960 was $1,295,741 of which $1,042,660 was for new work, and $253,081 was for maintenance.

73. LOCAL COOPERATION.- Under prior projects the local interests contributed $66,000 for work in the section from East Fork to Dallas and provided lands needed for the locks and dams.

74. The existing project for a navigation channel from the Houston Ship Channel to Liberty is subject to the condition that local interest furnish necessary rights-of-way and suitable areas for disposal of dredged material, make necessary changes in utilities crossing the natural river channel below Liberty, give assurances satisfactory to the Secretary of the Army that they will provide adequate terminal and transfer facilities on the waterway, and hold and save the United States free from claims for damages that may result from construction and operation of the improvements.

75. Local interests have fully complied with the conditions contained in House Document 634, 79th Congress, 2nd session, for the completed portion of the channel below Anahuac, but have not complied with conditions of local cooperation in House Document 403, 77th Congress, 1st session for the portion of the channel above Anahuac. The local interests have refused to cooperate towards completion of the channel above Anahuac because the local rice irrigators allege that the channel would increase the intrusions of salt water into the river and damage the fresh water supply used for rice irrigation.

76. RECOMMENDED MODIFICATION OF EXISTING PROJECT.- Salinity control in the lower river and further advancement of the existing project are included in the plan of improvement for the multiple purpose Wallisville reservoir project recommended by the Acting Chief of Engineers, under date of April 18, 1961, as set forth in House Document No. 215, 87th Congress, 1st Session. The officials of the Trinity River Authority of Texas and the Chambers-Liberty Counties Navigation District, who would be responsible for the local cooperation, have agreed that the recommended plan for the Wallisville reservoir would meet their present needs and requirements and have agreed to provide all proposed items of local cooperation.

77. With respect to navigation the recommended plan proposes the construction of a navigation lock and earth fill dam, a navigation approach channel extending downstream of the lock, minor curve easing of the channel in the vicinity of Interstate Highway No. 10 bridge across the Trinity River near Wallisville and advancement of the existing project channel from its present ending at mile 23.2 to mile 33.8, at the Texas Gulf Sulphur Company's spur channel.

78. The recommended plan also provides that a minimum water surface of one foot above mean sea level should be maintained in the reservoir to aid and assist in preventing salt water intrusion upstream of the lock structure. Accordingly, the existing 9X150 foot project channel upstream of the lock at channel mile 28.3 would be constructed to provide for navigation when conservation storage in the reservoir was depleted to elevation 1.0 above mean sea level. The requirement to maintain minimum water surface at elevation 1.0 constitutes a slight modification of the existing project whereby the project depth of the channel upstream of the lock structure would be based on elevation 1.0 above mean sea level instead of mean low tide, a difference of about 2.36 feet.

79. RELATED NAVIGATION PROJECTS.- There are two existing navigation projects in the vicinity of Anahuac, Texas, which would be affected by completion of additional portions of the authorized channel to Liberty. These projects are: Mouth of Trinity River, Texas, and Anahuac Channel, Texas. These projects will be incorporated in the existing Trinity River and Tributaries, Texas, project, in accordance with the recommendations of the Acting Chief of Engineers as set forth in House Document No. 215, 87th Congress, 1st session. In general the Anahuac Channel

would be maintained as a feeder channel 6 feet deep and 80 feet wide between Trinity Bay and the channel to Liberty. The mouth of Trinity River, Texas, project would become permanently inactive.

80. The channel to Liberty now crosses near the outer end of the Double Bayou, Texas, project, at about channel mile 15.7. The existing Double Bayou project provides for a channel 6 feet deep and 100 feet wide through the bar at the mouth of Double Bayou. Improvement of the channel to Liberty would not adversely affect the Double Bayou channel.

TERMINAL AND TRANSFER FACILITIES

81. EXISTING FACILITIES.- The proposed waterway in the Trinity River will connect with adjacent existing waterways that carry large volumes of seagoing and shallow-draft commerce. Ports on these adjacent waterways have modern public and private terminal and handling facilities that are capable of accepting commodities in barge-load or tow-load quantities for efficient transshipment or local distribution. These facilities are considered adequate to provide for the movement, storage or distribution of existing as well as prospective commerce evaluated for the proposed waterway.

82. TRINITY RIVER.- There are five wharves on the river between the mouth and a point thirty-eight miles upstream at Liberty, Texas. Four of the wharves range from 10 to 20 feet in length and the fifth at Liberty is 150 feet long. All are privately owned and with the exception of one, are free to public use. Four of the wharves have no freight handling equipment although one has a manually operated derrick. There are no rail connections at any of the wharves; however, the wharves are considered adequate for the existing commerce. The Texas Gulf Sulphur Company has constructed a 12- x 100-foot side channel extending about 4,500 feet from mile 11.1 on the river to a 12- x 380- x 1320-foot slip with terminal and handling facilities for the shipment of sulfur from the Moss Bluff mines.

83. There are several small privately owned wharves and slips for local use at Anahuac at the mouth of the Trinity River that are adequate for local commerce.

84. GALVESTON HARBOR AND CHANNEL.- There are no terminals on Galveston Harbor but it is the entrance channel leading to extensive terminal and transfer facilities located on Galveston Channel, Texas City Channel and the Houston Ship Channel, all of which would connect with the proposed waterway in the Trinity River.

85. GALVESTON CHANNEL.- Terminal facilities on Galveston Channel are almost entirely on the south side of the channel. The principal facilities, owned and operated by the city of Galveston, extend from 10th to 41st Streets. Piers, transit sheds, bulkheads and concrete aprons are included in the facilities. Details of the facilities available are contained in Port Series No. 23, revised 1948 and No. 6, part 1.

86. TEXAS CITY CHANNEL.- A privately owned seatrain terminal, completed in 1940, provides water transportation of rail cars to the east coast. Privately owned modern terminal facilities, rebuilt or rehabilitated since the Texas City disaster in April of 1947, are located at the inner end of the Texas City Channel. Details of these facilities are given in Port Series No. 23 revised 1948, Corps of Engineers.

87. HOUSTON SHIP CHANNEL.- The Port of Houston has extensive facilities for handling all types of seagoing, rail and barge commerce. The wharves, warehouses, sheds, equipment and other terminal installations are modern and efficient. The privately constructed facilities have been supplemented by installations constructed by both the city of Houston and the Harris County Houston Ship Channel Navigation District. Terminals, both public and private, have been constructed at many locations along the 20-mile length of the Houston Ship Channel between Baytown and Houston as well as extensive facilities constructed in the turning basin proper. Details of terminals and their equipment are contained in Port Series No. 24, revised 1948, Corps of Engineers. Docks No. 8 and 9, 624 feet and 9,500 feet long, respectively, have been constructed since 1948. These wharves, constructed immediately below the turning basin, are available to the public.

88. GULF INTRACOASTAL WATERWAY.- This waterway, extending the entire length of the Gulf Coast from St. Marks, Florida, to Brownsville, Texas, would connect the proposed Trinity River channel with all of the major waterways and their tributary channels in the Mississippi River system. The Texas section of the waterway, extending from the Sabine River on the east to the Rio Grande on the south, with tributary channels to all major Texas ports has modern adequate terminal and transfer facilities at Orange, Port Arthur, Galveston, Freeport, Port Lavaca, Port Aransas, Corpus Christi, Port Isabel and Brownsville, Texas. These facilities are detailed in Port Series No. 22, revised 1946; No. 23 and 25, revised 1948, Corps of Engineers, and reports on Freeport Harbor, Matagorda Ship Channel, Channel from Pass Cavallo to Port Lavaca, and Brazos Island Harbor, Texas.

EXISTING COMMERCE

89. TRAFFIC BY MAJOR SYSTEMS.- The Trinity River tributary area is well served with various means of transportation. An excellent rail and major highway network covers the entire area which has waterborne access by oceangoing vessel to every major seaport in the world. The Gulf Intracoastal Waterway likewise distributes the products of this area to Gulf ports from Brownsville, Texas, to Florida and also, via the Mississippi River and its system, to ports on the Great Lakes.

90. The major rail lines serving the area offer not only access to existing seaports but connect with lines serving all parts of the continental United States and Mexico. Texas has, according to the Sixty-Ninth Annual Report of the Railroad Commission of Texas, 1960, 12,760 miles of Class I and 2,243 miles of Class II railroads, while Oklahoma, according to the Statistical Abstract of Oklahoma, 1959, published by the University of Oklahoma, has a total of 5,960 miles of railroad not designated by class. These major rail lines are shown on plate 2.

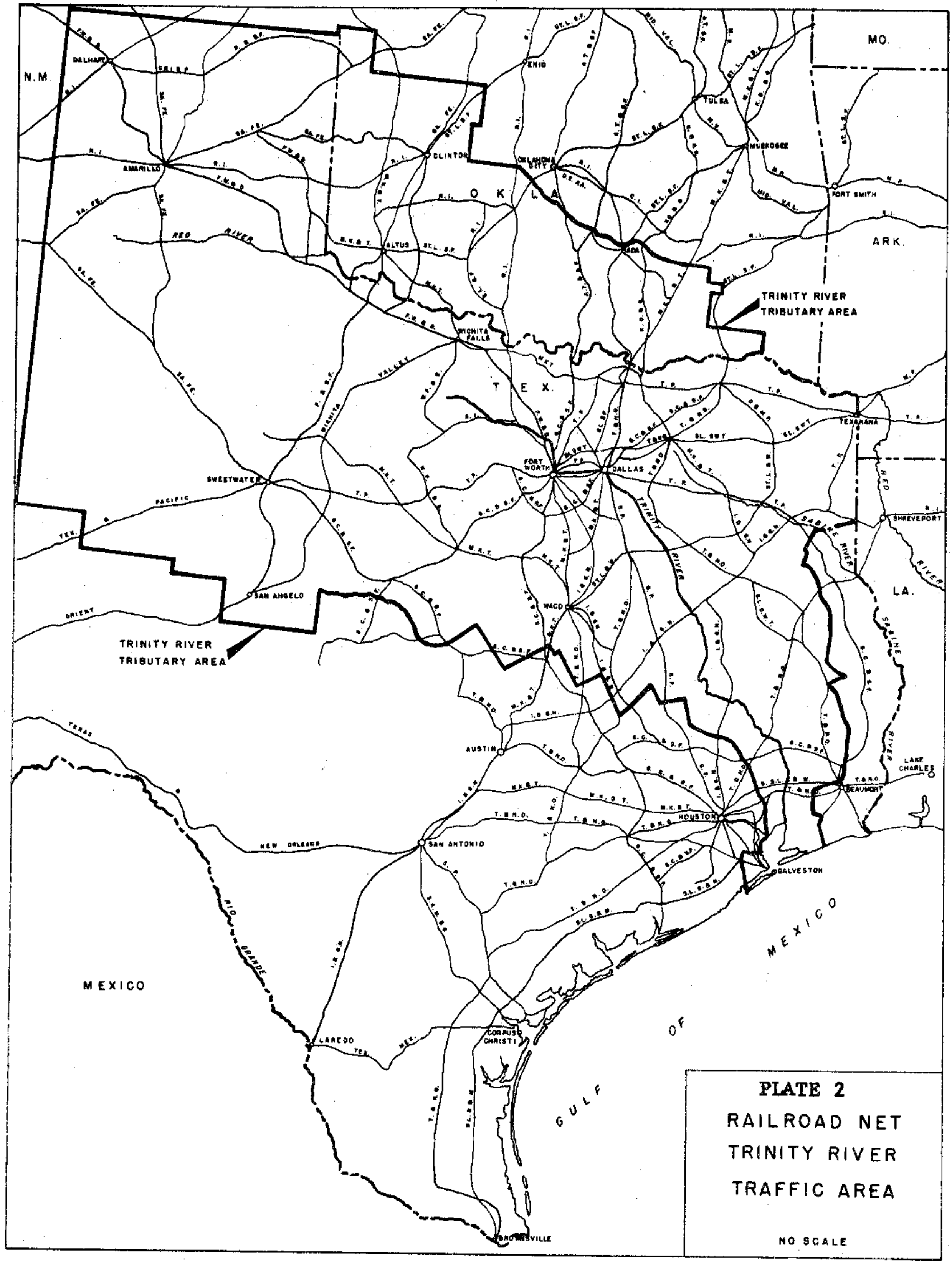


PLATE 2
RAILROAD NET
TRINITY RIVER
TRAFFIC AREA

NO SCALE

91. Rail traffic terminating in Texas, according to the Statistical Section of the Sixty-Ninth Annual Report of the Texas Railroad Commission amounted to over 60,080,666 tons in 1960. The commodities accounting for the greatest tonnages were: sand and gravel, 7,262,568 tons, grains (excluding wheat) 7,151,258 tons, and wheat 5,545,591 tons for Class I Railroads. The total freight carried in Texas with terminations both in and out of Texas amounted to 153,634,461 tons of which 54,698,262 tons originated in Texas. Similar statistics could not be found for Oklahoma, but it is probable that, because of its smaller size and greater wheat production, wheat would account for the largest single item of railroad tonnage in that state. Overall tonnage should be roughly proportional to railroad mileage or somewhat less than half the through freight reported for Texas.

92. Major highways serving the area are a highly developed system of main Federal and state highways extending in all directions and serving port and inland areas. Texas had 55,750 miles of paved highway in 1959 and reported 620,000 commercial motor vehicles that year; while Oklahoma reported 11,556 miles of primary state highway and 139,246 commercial trucks at the end of 1958.

93. WATERWAYS ADJOINING PROPOSED TRINITY RIVER CHANNEL.- Waterborne transportation at the present time is confined exclusively to the Gulf Intracoastal Waterway and oceangoing transportation. The accompanying table 16 shows the increase of over 40 percent in waterborne traffic over the past 12 year period. Some interim fluctuations will be noted that were a result of changing economic conditions, but it will be noted that the long term trend has been increasing. This general increase has been caused principally by the steadily increasing demand for crude petroleum and petroleum products, but other commodities have tended to show increases as exemplified by the wheat traffic in Galveston which amounted to 299,421 tons in 1954 and 2,187,232 tons in 1960 and unmanufactured cotton which, in Galveston, amounted to 230,678 tons in 1954 and 572,420 tons in 1960.

TABLE 16

COMPARATIVE STATEMENT OF WATERBORNE TRAFFIC
TONS OF 2000 POUNDS

	Sabine River to Galveston Gulf Inland Waterway	Vessel Traffic Sabine-Neches	Vessel Traffic Houston	Vessel Traffic Galveston	Vessel Traffic Texas City	Intracoastal & Vessel Traffic Total
1949	13,854,190	51,062,098	36,887,488	38,468,474	11,016,602	151,288,852
1950	14,239,348	48,377,483	40,825,048	41,368,635	10,928,572	155,739,086
1951	15,908,393	54,334,133	43,774,781	45,263,765	14,211,117	173,492,189
1952	19,355,294	54,599,609	46,608,424	46,004,489	16,196,336	182,764,152
1953	18,722,059	56,739,601	44,263,704	40,663,963	14,827,298	175,216,625
1954	16,216,377	53,504,920	43,244,841	40,042,826	14,388,797	167,397,761
1955	17,441,667	56,218,285	47,037,718	43,630,409	14,310,112	178,638,191
1956	20,015,170	62,790,305	52,293,262	48,741,187	14,798,944	198,638,868
1957	22,057,232	62,638,250	54,945,531	49,973,739	14,399,454	204,014,206
1958	20,698,161	60,674,062	55,258,046	49,944,477	14,060,214	200,634,960
1959	23,021,805	62,474,378	60,265,293	51,437,248	13,649,143	210,847,867
1960	24,728,605	68,693,211	57,132,659	50,136,546	15,401,847	212,092,868

94. The Gulf Intracoastal Waterway tonnage between the Sabine River and Galveston shows an increase of over 78 percent during the 12 year period from 1949 to 1960 as contrasted with the 40 percent overall increase in waterborne traffic. This increase has been largely in petroleum and products, chemicals, and seashells. The existence of various industries dealing in bulk low value commodities such as sand and gravel, cement, gypsum, and stone in the inland Trinity River tributary area would probably increase Gulf Intracoastal Waterway traffic if these sources of supply could be tapped by low-cost transportation. Low-cost transportation would extend the marketing areas of many of these products that cannot be exploited profitably with existing means of transportation.

MULTIPLE PURPOSE CHANNEL

95. GENERAL.- The plan of improvement providing for a canalized multiple purpose Trinity River channel to Fort Worth, Texas, as recommended in this report, provides for an improved channel designed primarily for flood control and navigation. The proposed channel would connect with the Houston Ship Channel near Red Fish Bar in Galveston Bay, about 9.9 miles from the Gulf Intracoastal Waterway crossing of the Houston Ship Channel in the lower part of Galveston Bay. From its junction with the Houston Ship Channel, the proposed channel would coincide generally with the authorized channel to Liberty project passing through the recommended Wallisville lock and reservoir to the existing authorized head of navigation at Liberty, Texas. Upstream of Liberty, the channel would extend along the general course of the Trinity River passing through the Livingston and proposed Tennessee Colony reservoirs enroute to its ending at the Riverside Drive bridges over the West Fork in Fort Worth, Texas where the channel would join with the lower end of the existing Fort Worth Floodway. The plan provides for a channel about 369.8 miles long between the Houston Ship Channel and the Riverside Drive bridges in Fort Worth, excluding spur channels extending to the Dallas and Fort Worth terminus. The channel mile distance from the Houston Ship Channel to the Dallas terminus and the Fort Worth terminus would be 328 and 364 miles, respectively.

96. CHANNEL ALIGNMENT.- The plan provides for numerous cut-offs of small river bends and straightening of the river to provide tangent reaches on the general alignment of the river with maximum curvature of 2,500-foot radius between tangent reaches, 2,500-foot tangent approach channels to the proposed locks and 1,500-foot tangent approach channels to bridge structures. The proposed alignment of the channel is shown on the general plan, plates 3 through 10.

97. Investigation reveals that it would be most economical to provide a river cut-off channel at Wallisville, Texas, for prospective traffic on the channel to Dallas and Fort Worth, as shown on plate 3. The proposed channel realignment would save about 1.2 miles of travel and is included in the plan of improvement for the multiple purpose channel project.

98. Alignment of the channel through the South Liberty Oil Field near Liberty, Texas, is shown on the general map, plate 3 and in greater detail on plate 11. Under present conditions there are no oil or gas wells adjacent to the river below river mile 35, but numerous wells exist in this reach along the outer limits of the flood plain which precludes the location of the channel through these areas. Upstream of river mile 35, the selected channel alignment would serve small-size gathering lines and elevated service roads to the wells, but would not require redrilling of any wells. The plan provides for relocating the pipelines and construction of new service roads over the proposed river diversion dams to connections with the existing roads now providing access to the various wells, generally as shown on plate 11.

99. Below the Livingston and Tennessee Colony dams, the multiple purpose channel would divide into two separate channels - one serving navigation and the other serving flood release discharges, as shown on plates 4 and 7, respectively.

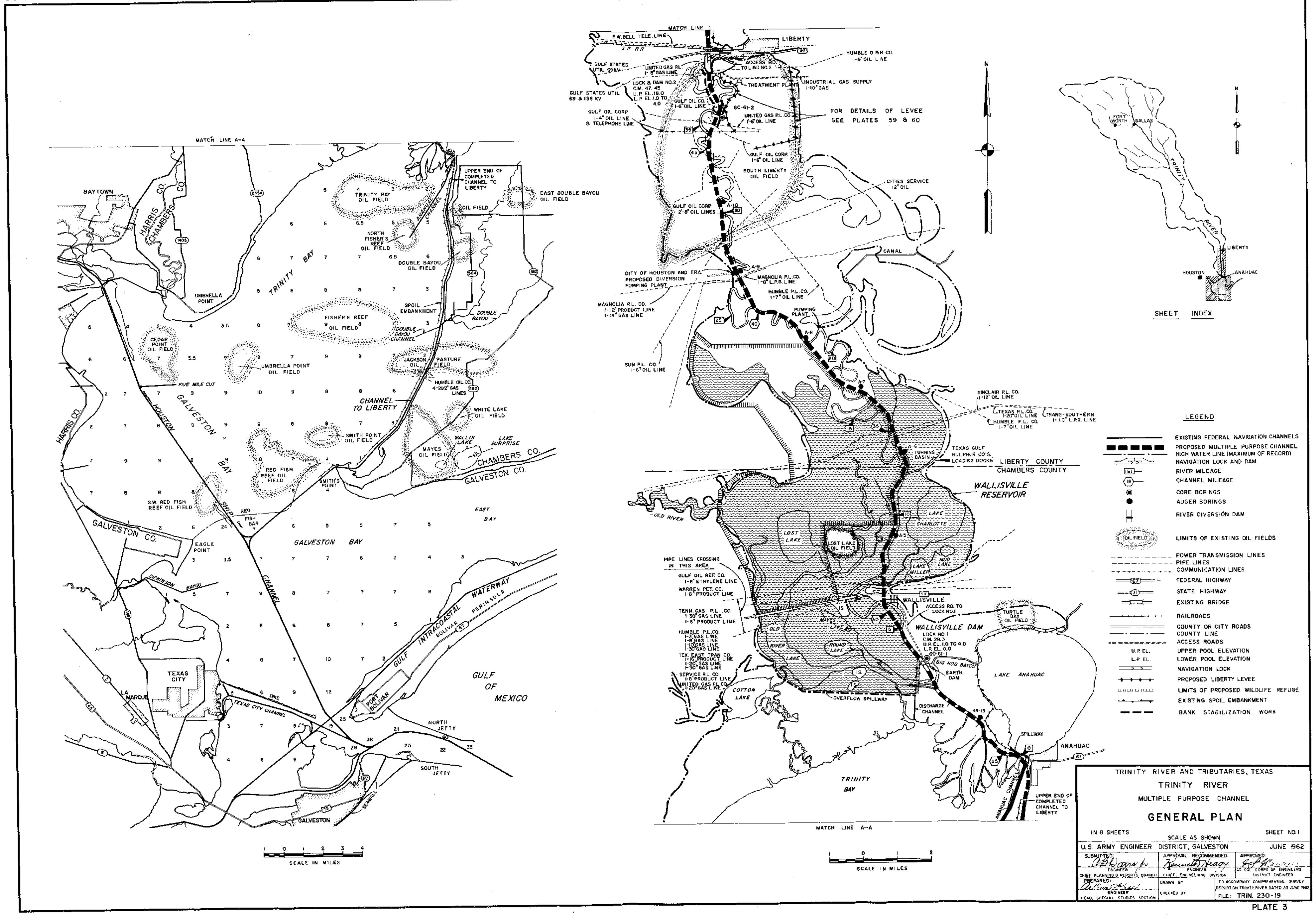


PLATE 3

52-704 O-65 Vol. II (Face blank p. 152) No. 1

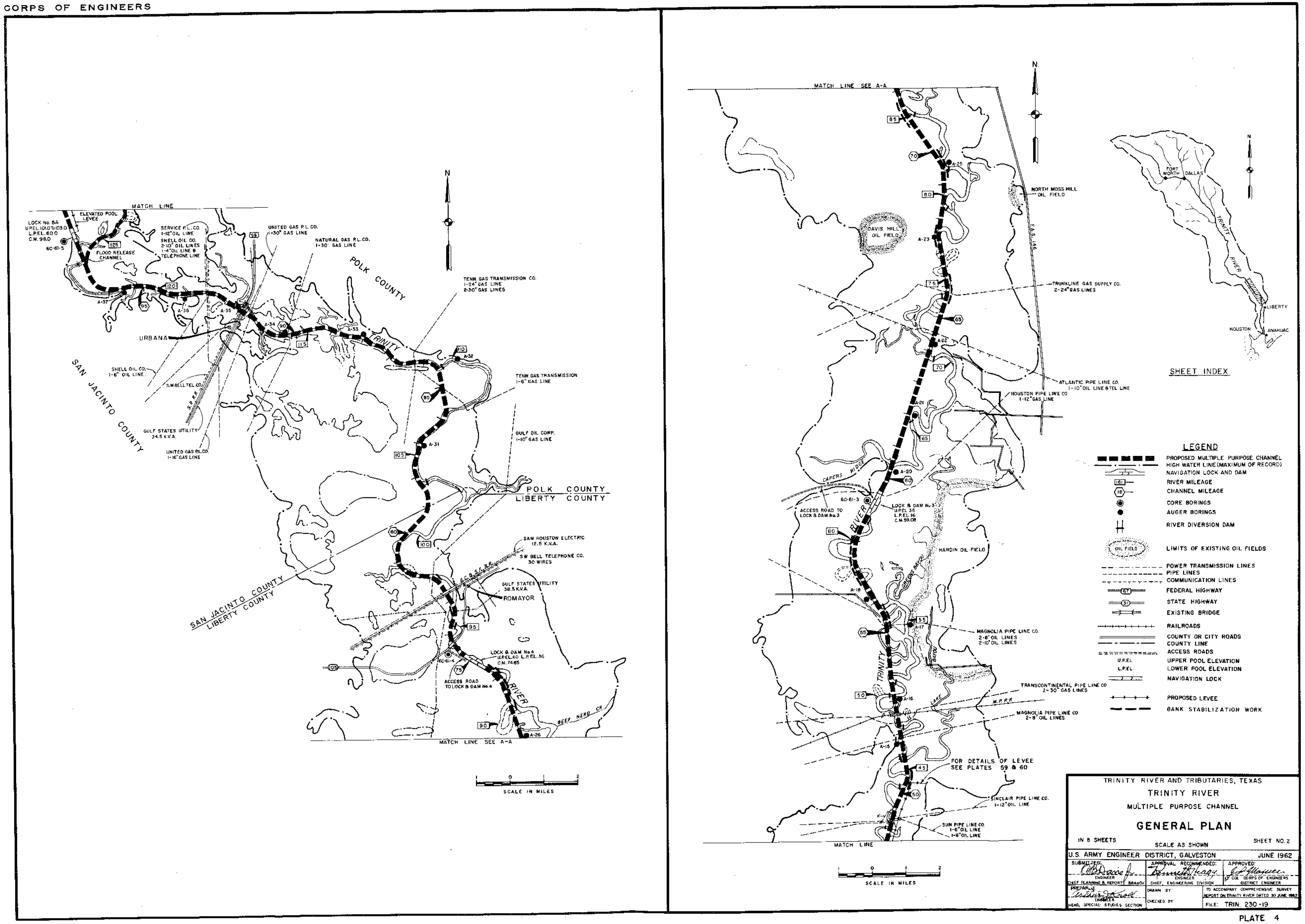

MATCH LINE
LOCK No. 6A U.P.EL.101.0 TO 103.0 L.P.EL.60.0 C.M.98.0
ELEVATED POOL LEVEE
FLOOD RELEASE CHANNEL
SERVICE P.L. CO. 1-12" OIL LINE
SHELL OIL CO. 2-10" OIL LINES 1-4" OIL LINE & TELEPHONE LINE
UNITED GAS P.L. CO. 1-30" GAS LINE
NATURAL GAS P.L. CO. 1-30" GAS LINE
POLK COUNTY
TENN GAS TRANSMISSION CO. 1-24" GAS LINE 2-30" GAS LINES
URBANA
TRINITY
SHELL OIL CO. 1-6" OIL LINE
S.W. BELL TEL. CO.
SAN JACINTO COUNTY
GULF STATES UTILITY 34.5 K.V.A.
UNITED GAS P.L. CO. 1-16" GAS LINE
TENN GAS TRANSMISSION 1-6" GAS LINE
GULF OIL CORP. 1-10" GAS LINE
POLK COUNTY
LIBERTY COUNTY
SAN JACINTO COUNTY
LIBERTY COUNTY
SAM HOUSTON ELECTRIC 12.5 K.V.A.
SW BELL TELEPHONE CO. 30 WIRES
GULF STATES UTILITY 36.5 K.V.A.
ROMAYOR
LOCK & DAM No.4 U.P.EL.60 L.P.EL.36 C.M.74.85
ACCESS ROAD TO LOCK & DAM No.4
RIVER
BEEF NERD CR.
MATCH LINE SEE A-A
SCALE IN MILES
N.
MATCH LINE SEE A-A
NORTH MOSS HILL OIL FIELD
DAVIS HILL OIL FIELD
TRUNKLINE GAS SUPPLY CO. 2-24" GAS LINES
ATLANTIC PIPE LINE CO. 1-10" OIL LINE & TEL LINE
HOUSTON PIPE LINE CO. 1-12" GAS LINE
CAPERS RIDGE
ACCESS ROAD TO LOCK & DAM No.3
LOCK & DAM No.3 U.P.EL.36 L.P.EL.16 C.M.59.08
HARDIN OIL FIELD
RIVER
MAGNOLIA PIPE LINE CO. 2-8" OIL LINES 2-10" OIL LINES
TRINITY
TRANSCONTINENTAL PIPE LINE CO. 2-30" GAS LINES
MAGNOLIA PIPE LINE CO. 2-8" OIL LINES
FOR DETAILS OF LEVEE SEE PLATES 59 & 60
SINCLAIR PIPE LINE CO. 1-12" OIL LINE
SUN PIPE LINE CO. 1-6" OIL LINE 1-8" OIL LINE
MATCH LINE
SCALE IN MILES
FORT WORTH
DALLAS
TRINITY RIVER
LIBERTY
HOUSTON
ANAHUAC
SHEET INDEX
LEGEND
PROPOSED MULTIPLE PURPOSE CHANNEL
HIGH WATER LINE (MAXIMUM OF RECORD)
NAVIGATION LOCK AND DAM
RIVER MILEAGE
CHANNEL MILEAGE
CORE BORINGS
AUGER BORINGS
RIVER DIVERSION DAM
LIMITS OF EXISTING OIL FIELDS
POWER TRANSMISSION LINES
PIPE LINES
COMMUNICATION LINES
FEDERAL HIGHWAY
STATE HIGHWAY
EXISTING BRIDGE
RAILROADS
COUNTY OR CITY ROADS
COUNTY LINE
ACCESS ROADS
UPPER POOL ELEVATION
LOWER POOL ELEVATION
NAVIGATION LOCK
PROPOSED LEVEE
BANK STABILIZATION WORK
TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER
MULTIPLE PURPOSE CHANNEL
GENERAL PLAN
IN 8 SHEETS
SCALE AS SHOWN
SHEET NO. 2
U.S. ARMY ENGINEER DISTRICT, GALVESTON
JUNE 1962
CHIEF, PLANNING & REPORTS BRANCH
CHIEF, ENGINEERING DIVISION
COL. CORPS OF ENGINEERS DISTRICT ENGINEER
HEAD, SPECIAL STUDIES SECTION
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER DATED 30 JUNE 1962
FILE: TRIN. 230-19

PLATE 4

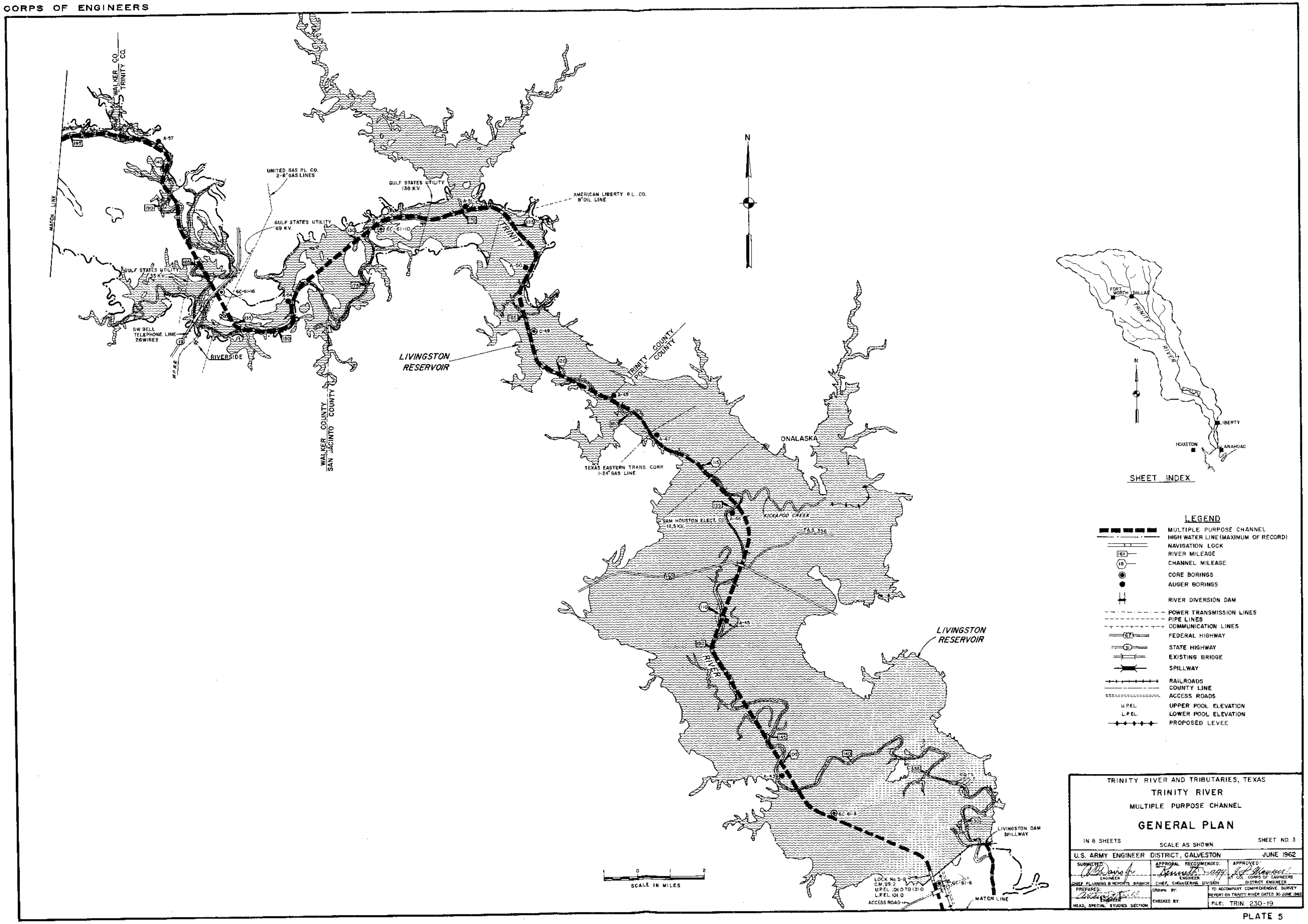


PLATE 5

52-704 O-65 Vol. II (Face blank p. 152) No. 3

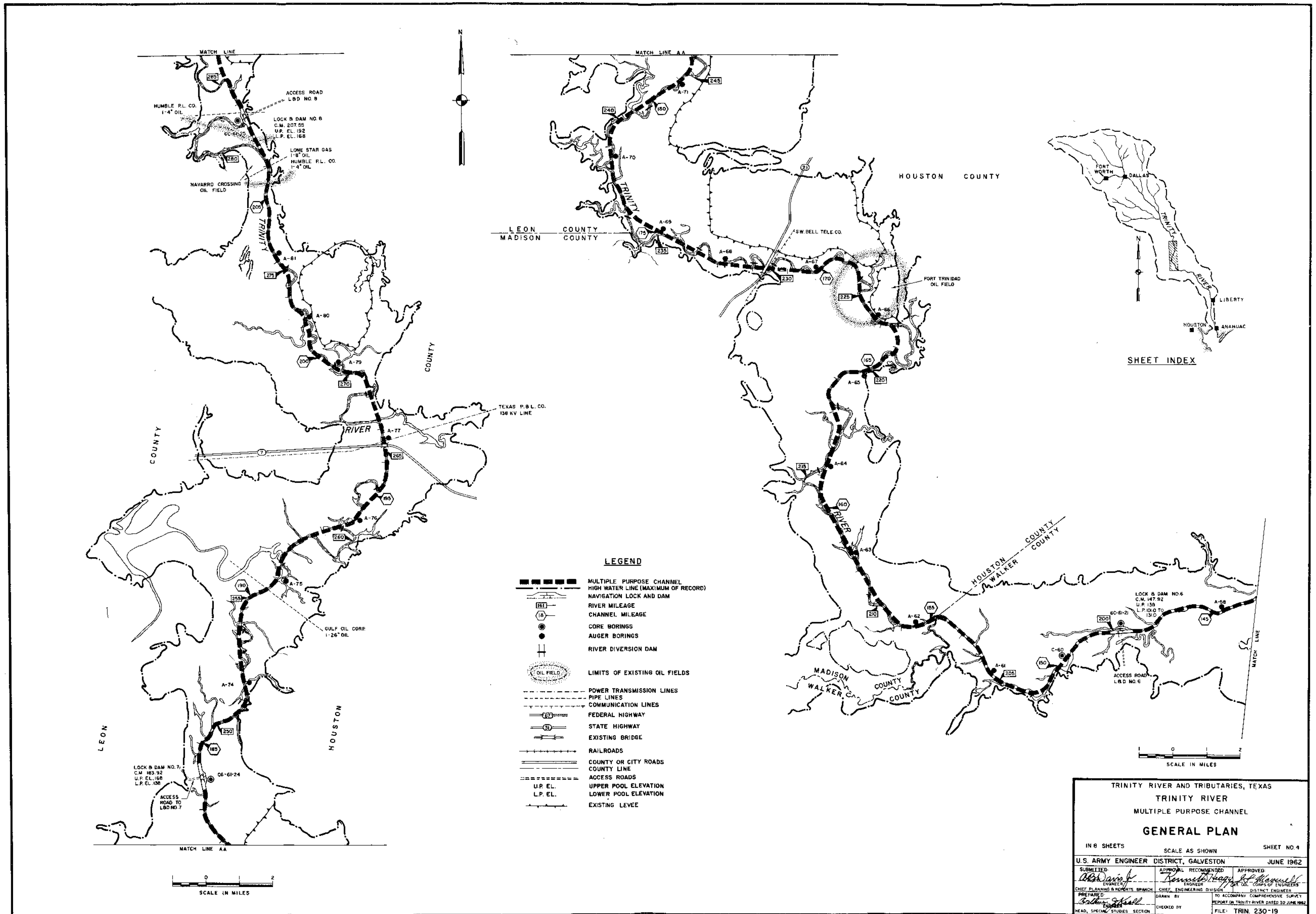
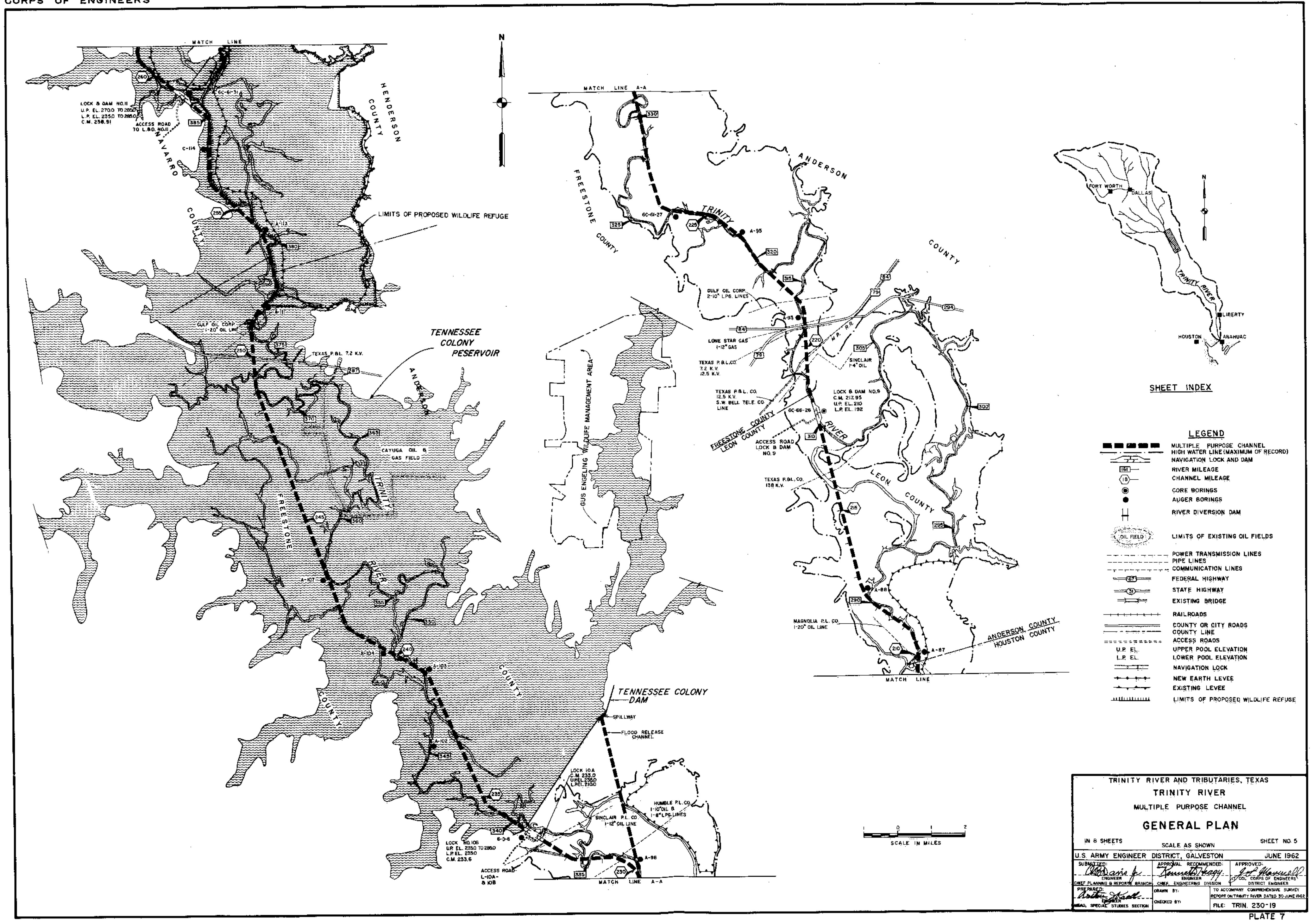


PLATE 6

52-704 O-65 Vol. II (Face blank p. 152) No. 4



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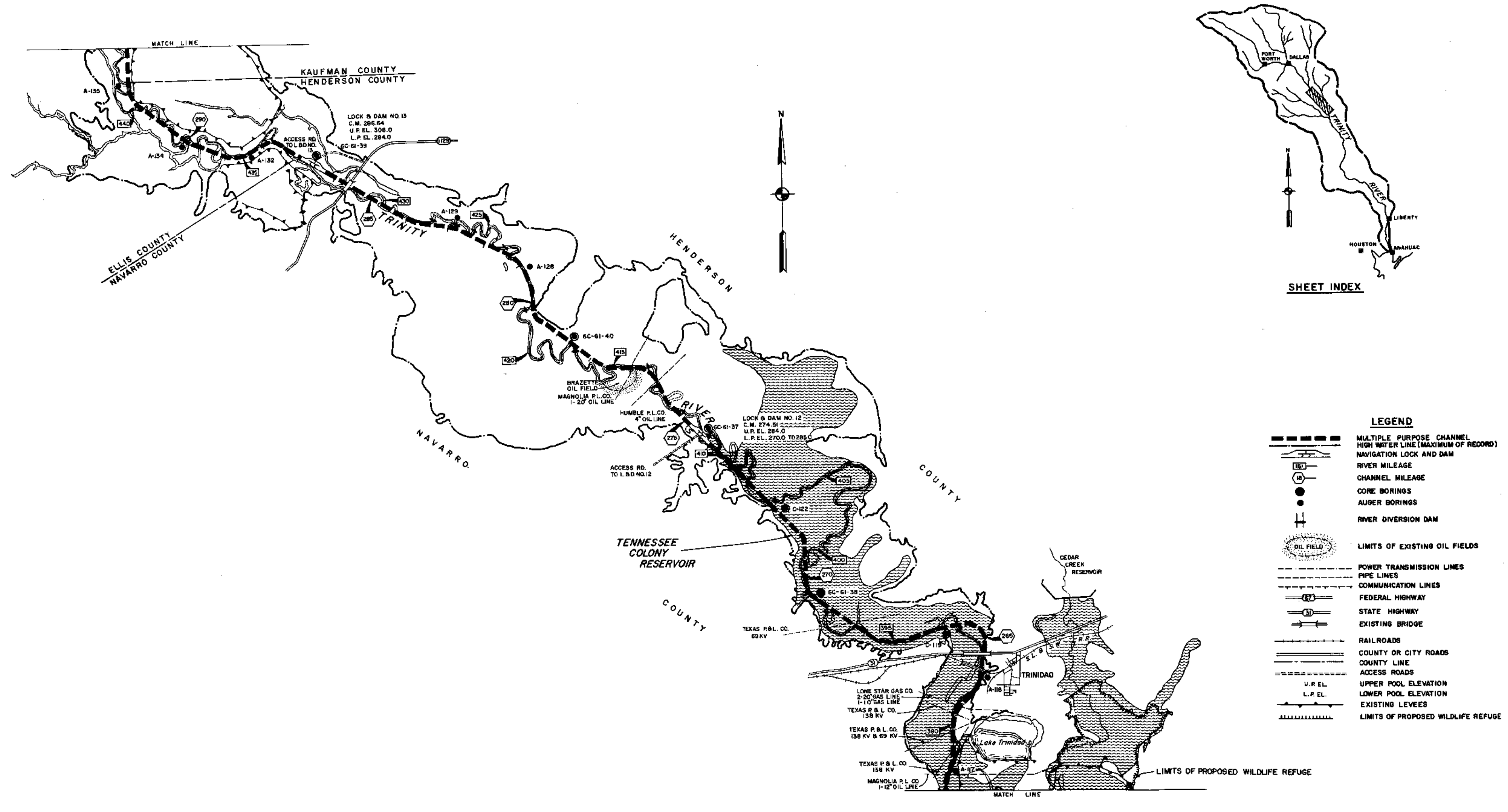
CORPS OF ENGINEERS

U.S. ARMY



TRINITY RIVER AND TRIBUTARIES, TEXAS

TRINITY RIVER

MULTIPLE PURPOSE CHANNEL

GENERAL PLAN

IN 8 SHEETS — SCALE AS SHOWN — SHEET NO. 6

U.S. ARMY ENGINEER DISTRICT, GALVESTON — JUNE 1962

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
ENGINEER, CHIEF, PLANNING & REPORTS BRANCH	ENGINEER, CHIEF, ENGINEERING DIVISION	LT. COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ENGINEER, HEAD, SPECIAL STUDIES SECTION	DRAWN BY: / CHECKED BY:	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER DATED 30 JUNE 1962 / FILE: TRIN. 230-19

PLATE 8

52-704 O-65 Vol. II (Face blank p. 152) No. 6

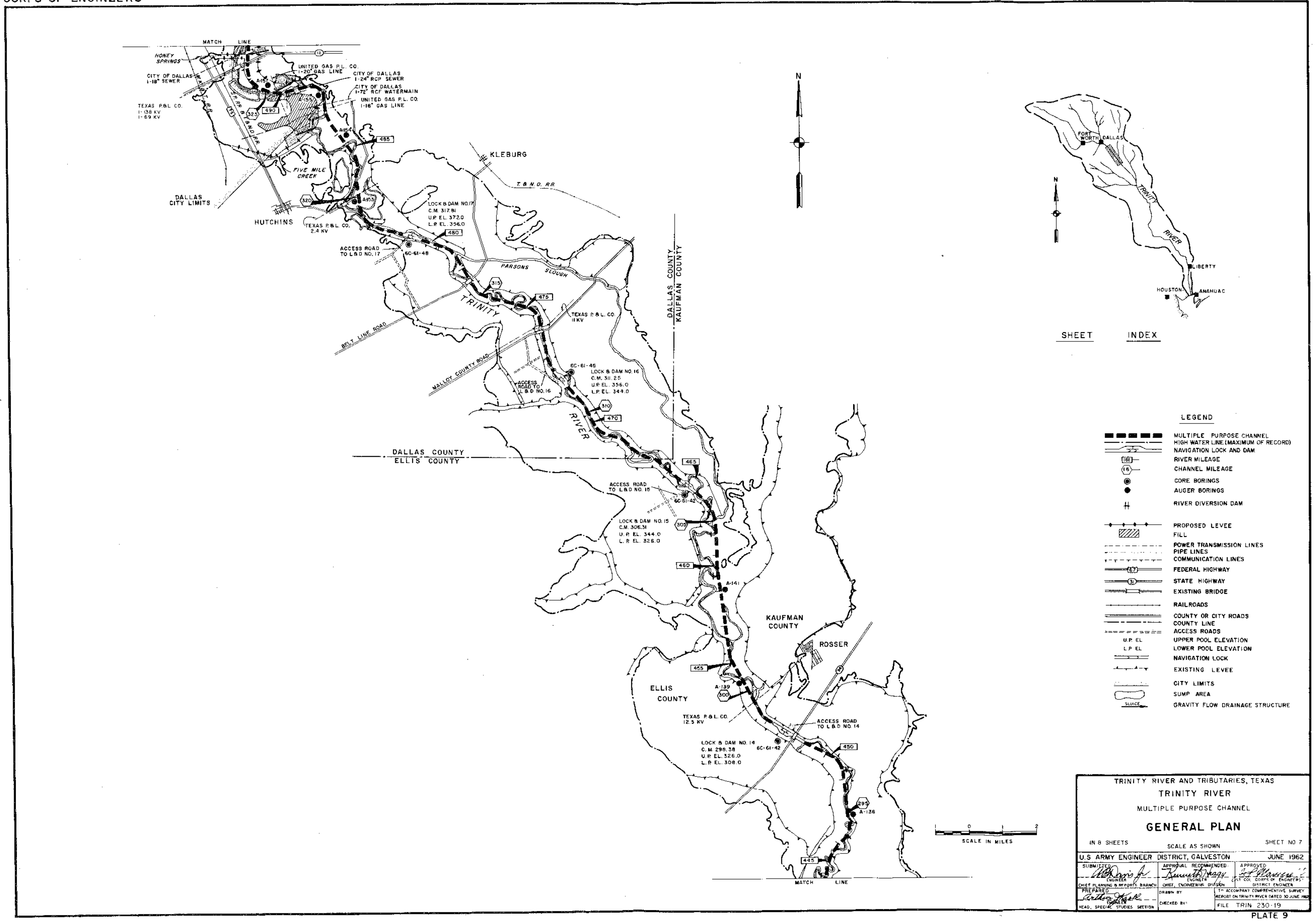


PLATE 9

52-704 O-65 Vol. II (Face blank p. 152) No. 7

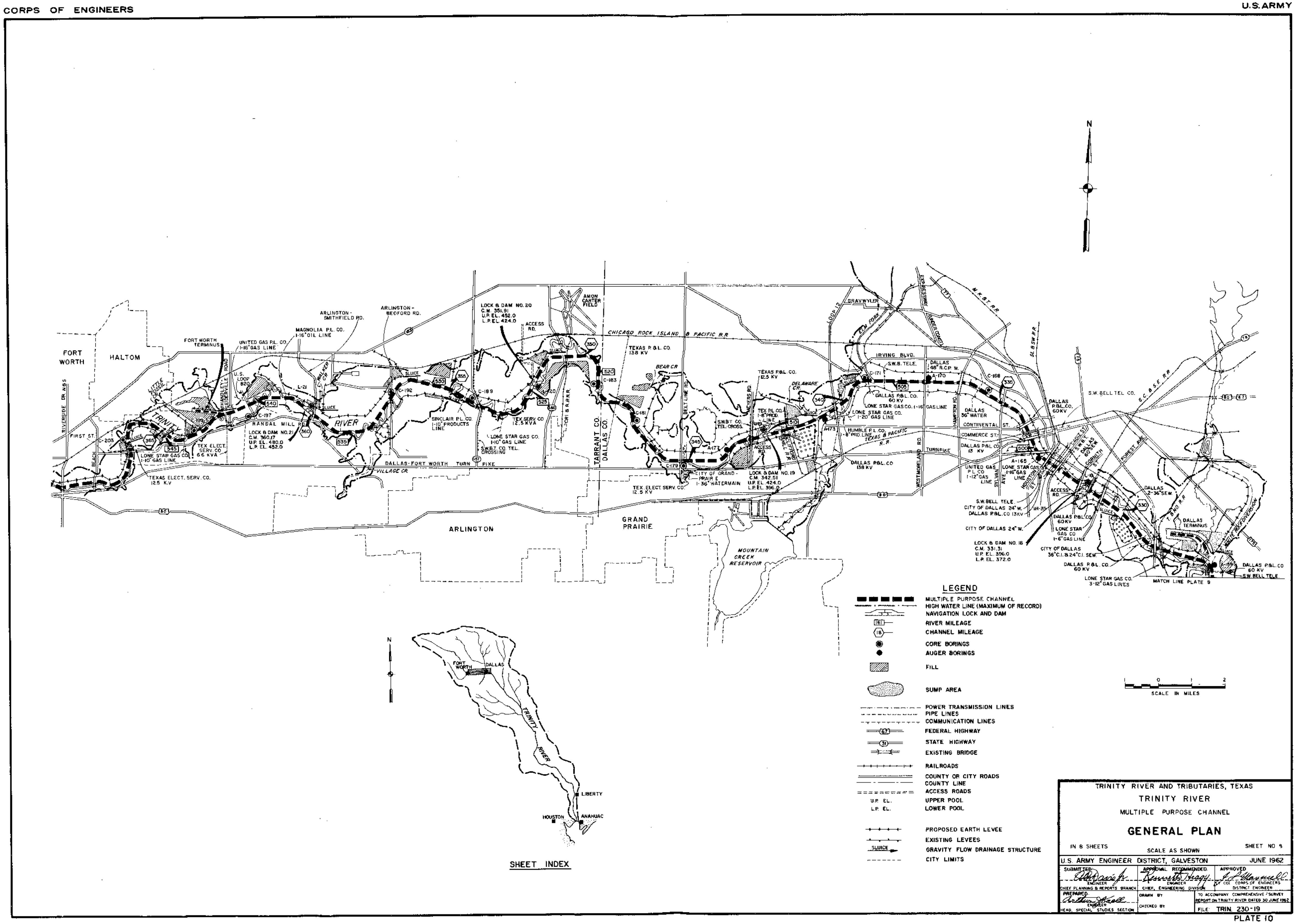
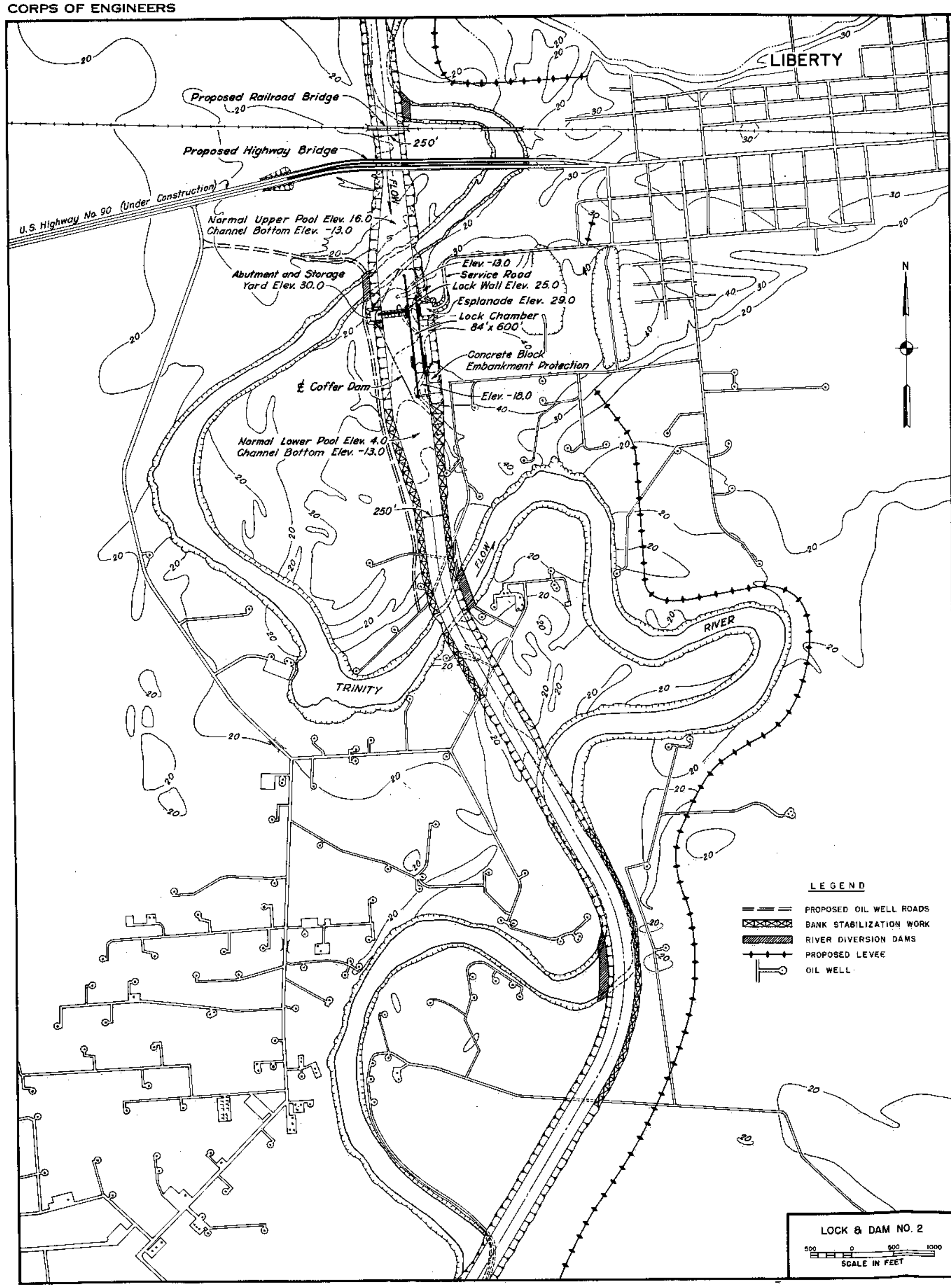
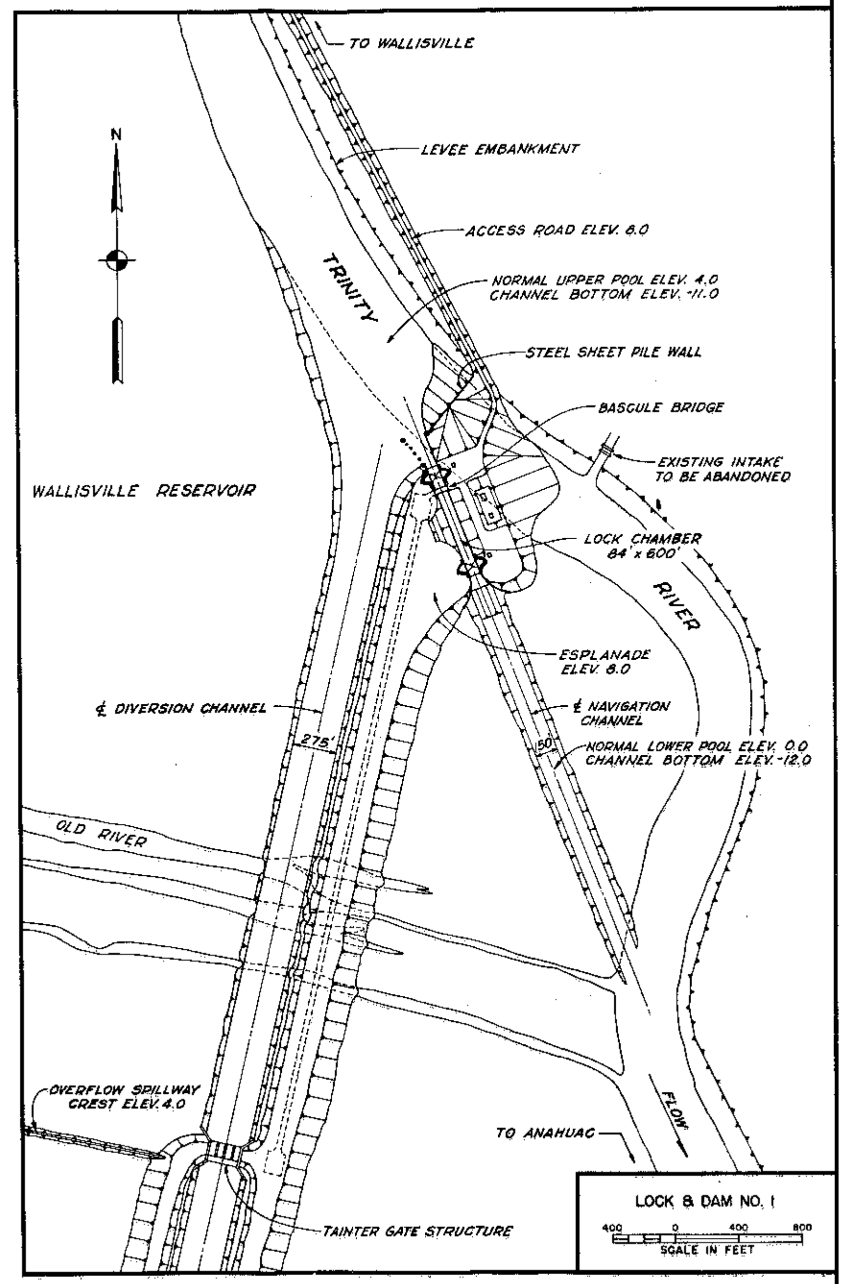


PLATE 10

52-704 O-65 Vol. II (Face blank p. 152) No. 8





TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER

MULTIPLE PURPOSE CHANNEL
SITE PLAN
LOCK AND DAM NO. 1 & NO. 2
SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, GALVESTON

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
ENGINEER, CHIEF, PLANNING & REPORTS BRANCH	ENGINEER, CHIEF, ENGINEERING DIVISION	COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: HEAD, SPECIAL STUDIES SECTION	DRAWN BY W.E.D. CHECKED BY	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRIN RIVER DATED; FILE TRIN. 230-19

PLATE 11

100. The plan also provides for a spur channel to serve the proposed Dallas terminus which would be located about one-half mile northeast of the Texas and New Orleans Railroad bridge over the channel to Fort Worth, as shown on plate 10. The spur channel would extend from channel mile 326.7 for a distance of about 1.7 miles to and including a 400-foot square turning basin at the Dallas terminus.

101. A spur channel would be provided to serve the proposed Fort Worth terminus located near the east limit of Fort Worth and about one mile south of Halton City, as shown on plate 10. The channel would extend from channel mile 362.8 for a distance of 1.2 miles to and including a 400-foot square turning basin at the Fort Worth terminus.

102. The channel between the mouth of the Trinity River at Anahuac and the Riverside Drive bridges at Fort Worth, would have a length of about 345 miles, whereas, the river in this reach has a length of 552 miles (1939 mileage), including the channel and river alignments in the Wallisville, Livingston and Tennessee Colony reservoirs. Table 17 shows for each pool the length of channel in river and cut-off and other pertinent data.

103. CHANNEL DIMENSIONS.- The plan of improvement for the multiple purpose channel is based primarily on the requirements for navigation and flood control. Channel-size formulation studies for navigation show that a channel having dimensions of 12 feet deep and 150-foot bottom width would be the most economical for modern barge navigation required to transport the prospective commerce on the channel. Channel-size studies for flood control reveal that it would be feasible to relocate the navigation channel more on river alignment in certain proposed river bend cut-offs, also enlarge the realignment navigation channel by deepening and/or widening where necessary to provide sufficient capacity for operating discharges from the existing and proposed flood control reservoirs on the watershed and at the same time provide additional capacity for runoff from the uncontrolled drainage areas below the reservoirs. Pertinent information concerning the design of the multiple purpose channel is given in appendix II.

TABLE 17
LENGTH OF MULTIPLE-PURPOSE CHANNEL
IN CUT-OFF AND IN RIVER

Pool No.	Length of channel in cut-off (miles)	Length of channel in river (miles)	Length of channel Total (miles)	Length of river (miles)	Distance saved (miles)	Cumulative distance saved (miles)
Tidal	.80	3.10	3.9	3.9	-	-
1	8.35	10.80	19.15	35.9	16.75	16.75
2	5.87	5.76	11.63	21.6	9.97	26.72
3	9.66	6.11	15.77	32.0	16.23	42.95
4	7.77	15.38	23.15(1)	32.6	9.45	52.40
5A	1.20	-	1.20	3.0	1.80	54.20
5B	20.19	28.53	48.72	70.8(2)	22.08	76.28
6	14.56	21.44	36.00	48.3	12.30	88.58
7	9.89	13.74	23.63	35.4	11.77	100.35
8	8.52	1.88	10.40	26.8	16.40	116.75
9	7.95	7.10	15.05(3)	28.7	13.65	130.40
10A	0.61	-	.61	1.2	0.59	130.99
10B	18.04	7.26	25.30	45.6(4)	20.30	151.29
11	9.22	6.38	15.60	25.3	9.70	160.99
12	7.66	4.47	12.13	20.5	8.37	169.36
13	7.87	3.87	11.74	20.0	8.26	177.62
14	6.08	1.85	7.93	13.9	5.97	183.59
15	2.81	2.13	4.94	6.7	1.76	185.35
16	3.97	2.59	6.56	8.2	1.64	186.99
17	7.62	5.88	13.50	17.8	4.30	191.29
18	3.04	8.16	11.20	11.8	.60	191.89
19	5.40	4.00	9.40	14.8	5.40	197.29
20	2.63	5.63	8.26	11.8	3.54	200.83
21	6.14	3.45	9.59(5)	15.7	6.11	206.94
	175.85	169.51	345.36	522.3	206.94	

(1) Length of pool No. 4 to Lock 5A located in navigation cut-off channel.
(2) Length of river from Livingston reservoir spillway to lock and dam No. 6.
(3) Length of pool No. 9 to Lock 10A located in navigation cut-off chennel.
(4) Length of river from Tennessee Colony reservoir dam to lock and dam No. 11.
(5) Length of channel from lock & dam No. 21 to Riverside bridges in Fort Worth.

104. Accordingly, the plan of improvement provides for deepening to 12 feet, the completed and uncompleted portions of the 9 X 150-foot channel to Liberty project from the Houston Ship Channel to channel mile 35.5, including the channel realignment at and below Wallisville, Texas, proposed in this report. At channel mile 35.5, the 9 X 150 foot authorized (uncompleted) channel to Liberty would be incorporated in the proposed multiple purpose channel which would have a bottom width of 300 feet and a depth of about 27 feet below top of river banks. Upstream of channel mile 35.5, the dimensions of the channel would decrease to a minimum of 150 feet at the Livingston Reservoir dam. Upstream of the Livingston Dam, the channel would have a bottom width of 150 feet excepting three widely separated reaches where the channel width would be 200 feet.

105. The plan provides for a channel, 12 feet deep and 150 feet wide extending through the Wallisville, Livingston and Tennessee Colony Reservoirs. The top of the channel through the reservoirs would be located at the bottom elevation of the conservation pools of the respective reservoirs, and thereby the channel would provide 100 percent navigation through the reservoirs when conservation storages are fully depleted. The plan also provides for a minimum navigable depth of 12 feet below normal pool elevation for various lengths in the navigation pools located generally upstream of the Tennessee Colony Reservoir. Detailed information concerning the channel lengths, depths, gradients and capacity of the various channel sections including analyses of the durations and velocities of the regulated channel discharges to be encountered by navigation on the multiple purpose channel is given in appendix II. Pertinent information regarding the dimensions and capacity of various sections of the multiple purpose channel is given in table 18. Plates 12 through 15 show the bottom gradient of the proposed channel.

TABLE 18
DIMENSIONS AND CAPACITY OF MULTIPLE-PURPOSE
TRINITY RIVER CHANNEL

Channel mile*: From	To	Length (miles)	Bottom width (feet)	Depth (feet)(1)	Recommended operating discharge CFS	Recommended channel capacity CFS
0.0	28.30	28.30	150	13.3	Tidal pool	
28.30	35.50	7.20	150	12.0 to 30.0	Wallisville	Reservoir(2)
35.50	43.50	8.00	300	27.0	35,000	45,000
43.50	55.70	12.20	250	30.0	35,000	45,000
55.70	74.85	19.15	200	34.0	35,000	45,000
74.85	100.88(3)	26.03	150	40.0	35,000	45,000
96.94	147.92	50.98(4)	150	6.0 to 54.0	Livingston	Reservoir
147.92	234.60(5)	85.98	150	45.0	35,000	45,000
229.70	274.51	45.01(6)	150	8.0 to 28.0	Tennessee	Colony Reserv.
274.51	293.0	18.49	200	25.0	25,000	32,000
293.0	304.0	11.00	150	28.0	25,000	32,000
304.0	331.31	27.31	150	26.0	20,000	27,000
331.31	337.30	5.99	150	26.0	20,000	25,000
337.30	342.51	5.21	150	26.0	12,000	15,000
342.51	360.17	17.66	200	26.0	12,000	15,000
360.17	367.83	7.66	150	26.0	12,000	15,000
367.83	369.76	1.93	200	26.0	12,000	15,000

(1) Approximate depth of channel below top of river bank.
(2) Upper reach of inundated reservoir lands.
(3) Upper end of flood release discharge channel at end sill of the Livingston spillway basin.
(4) Length of navigation channel through Livingston Reservoir from its junction with flood release discharge channel below the reservoir dam to lock and dam No. 6.
(5) Upper end of flood release discharge channel at end sill of the Tennessee Colony spillway basin.
(6) Length of navigation channel through Tennessee Colony Reservoir from its junction with flood release discharge channel below the reservoir dam to lock and dam No. 12.

*Miles from HSC

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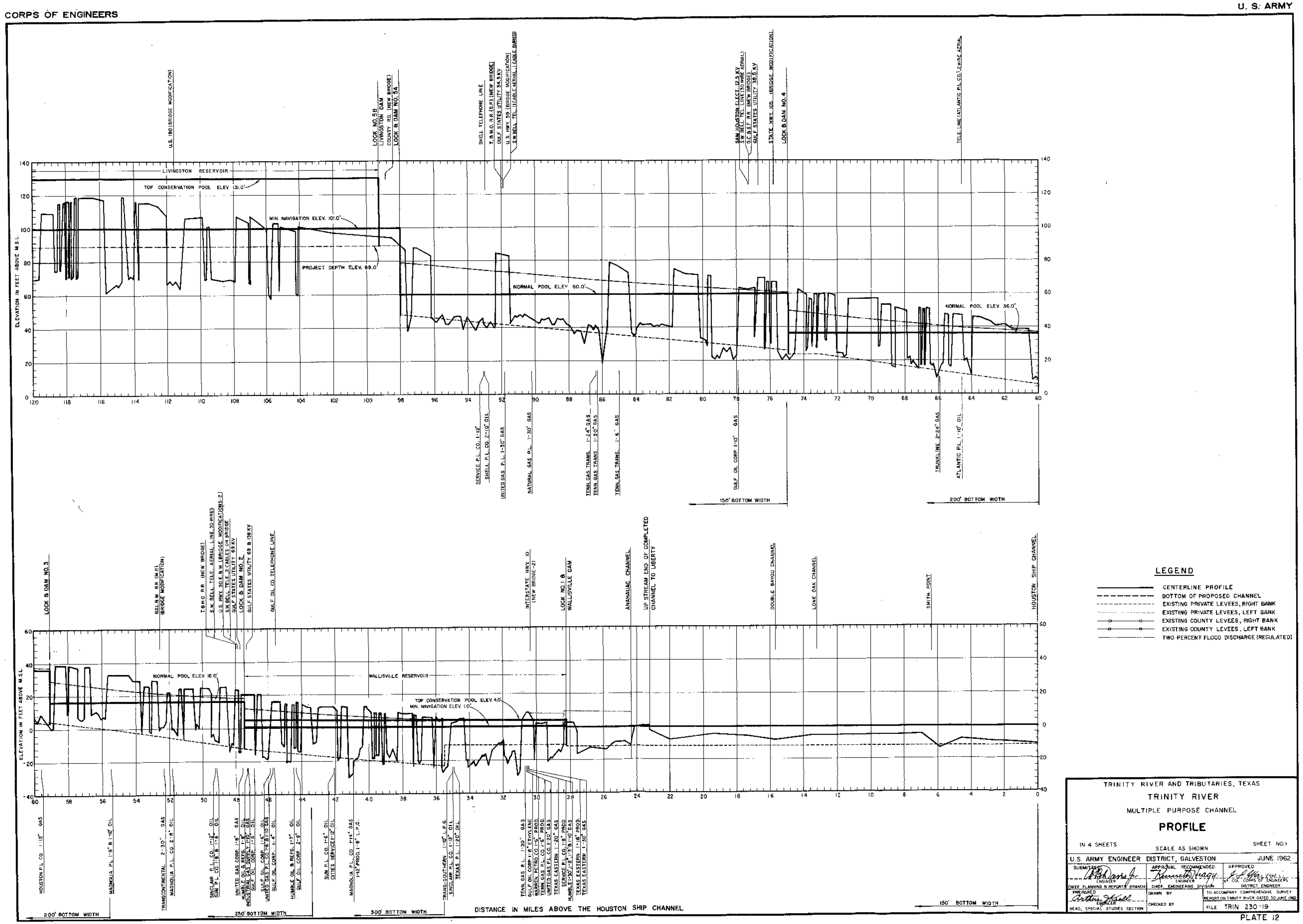


52-704 O-65 Vol. II (Face p. 156) No. 1

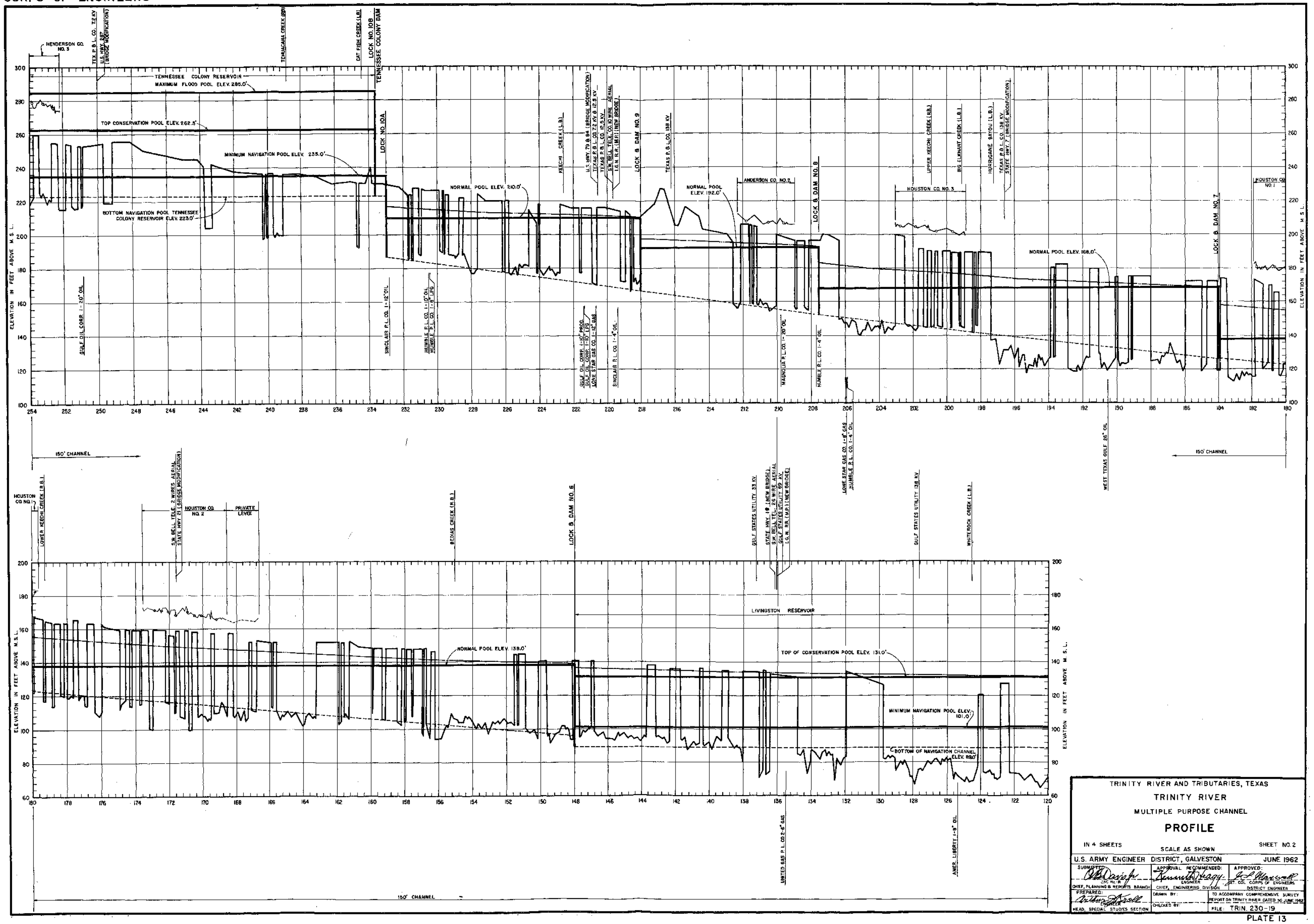
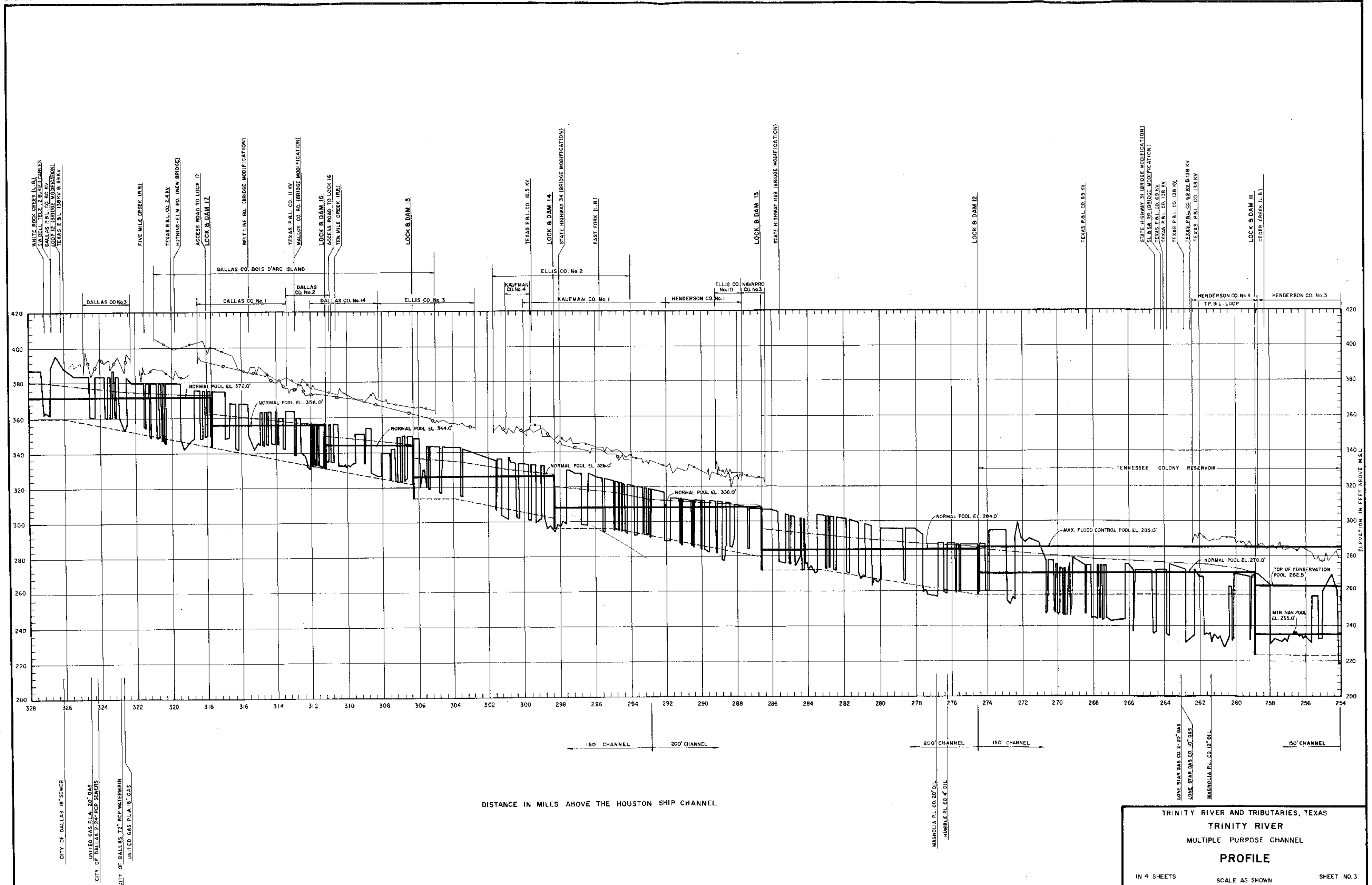

TENNESSEE COLONY RESERVOIR
MAXIMUM FLOOD POOL ELEV. 285.0'
TOP CONSERVATION POOL ELEV. 262.5'
MINIMUM NAVIGATION POOL ELEV. 235.0'
BOTTOM NAVIGATION POOL TENNESSEE COLONY RESERVOIR ELEV. 223.0'
LOCK NO. 10B
TENNESSEE COLONY DAM
LOCK NO. 10A
NORMAL POOL ELEV. 210.0'
LOCK & DAM NO. 9
NORMAL POOL ELEV. 192.0'
LOCK & DAM NO. 8
NORMAL POOL ELEV. 168.0'
LOCK & DAM NO. 7
150' CHANNEL
ELEVATION IN FEET ABOVE M.S.L.
NORMAL POOL ELEV. 139.0'
LOCK & DAM NO. 6
LIVINGSTON RESERVOIR
TOP OF CONSERVATION POOL ELEV. 131.0'
MINIMUM NAVIGATION POOL ELEV. 101.0'
BOTTOM OF NAVIGATION CHANNEL ELEV. 89.0'
TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER
MULTIPLE PURPOSE CHANNEL
PROFILE
IN 4 SHEETS
SCALE AS SHOWN
SHEET NO. 2
U.S. ARMY ENGINEER DISTRICT, GALVESTON
JUNE 1962
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER DATED 30 JUNE 1962
FILE: TRIN. 230-19

PLATE 13

CORPS OF ENGINEERS U.S. ARMY



TRINITY RIVER AND TRIBUTARIES, TEXAS

TRINITY RIVER

MULTIPLE PURPOSE CHANNEL

PROFILE

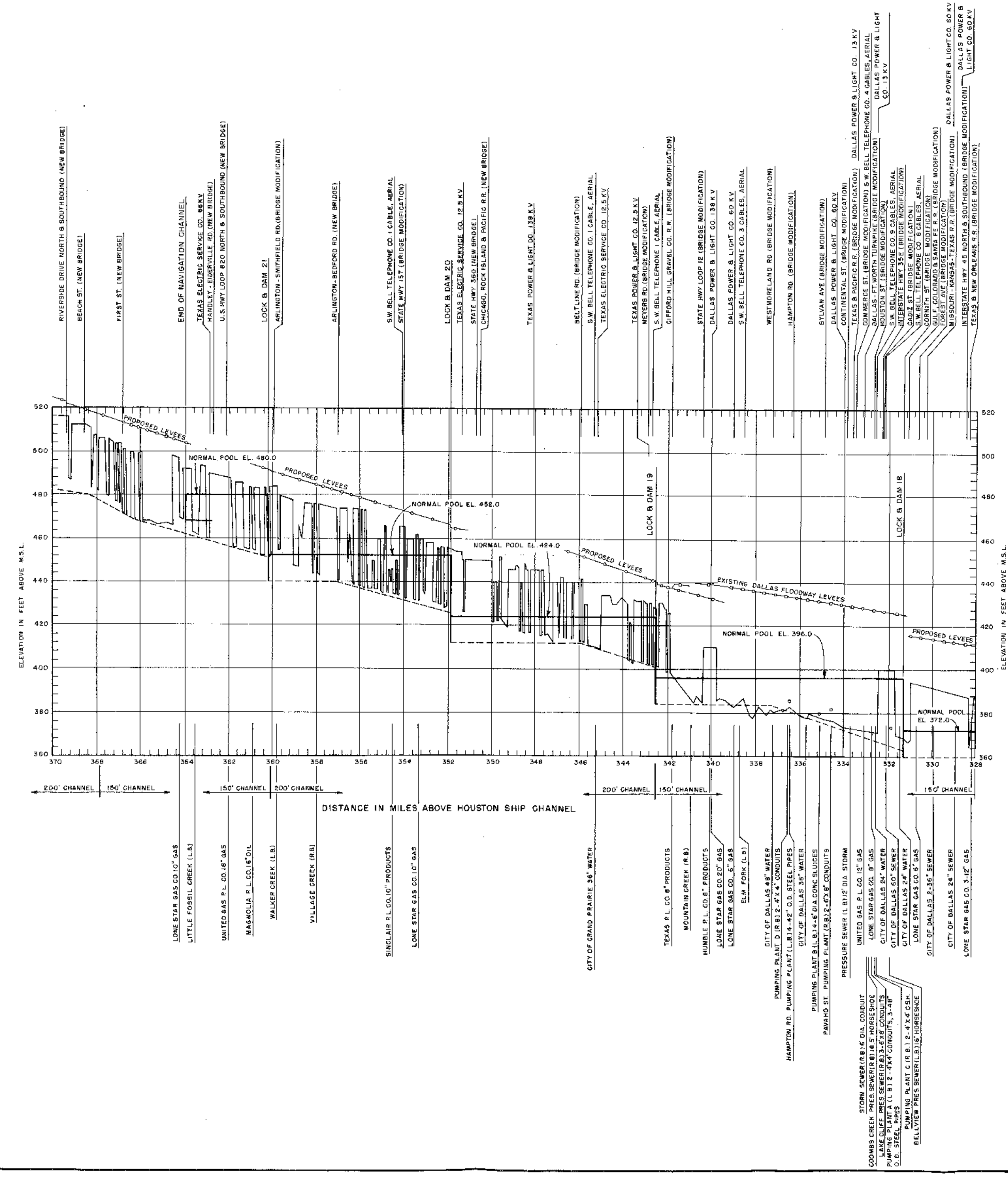
IN 4 SHEETS — SCALE AS SHOWN — SHEET NO. 3

U.S. ARMY ENGINEER DISTRICT, GALVESTON — JUNE 1962

SUBMITTED: ENGINEER, CHIEF, PLANNING & REPORTS BRANCH	APPROVAL RECOMMENDED: ENGINEER, CHIEF, ENGINEERING DIVISION	APPROVED: LT. COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: HEAD, SPECIAL STUDIES SECTION	DRAWN BY: CHECKED BY:	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER DATED 30 JUNE 1962. FILE: TRIN 230-19

PLATE 14

52-704 O-65 Vol. II (Face p. 156) No. 3



TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER

MULTIPLE PURPOSE CHANNEL

PROFILE

IN 4 SHEETS — SCALE AS SHOWN — SHEET NO. 4

U.S. ARMY ENGINEER DISTRICT, GALVESTON — JUNE 1962

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
ENGINEER CHIEF, PLANNING & REPORTS BRANCH	ENGINEER CHIEF, ENGINEERING DIVISION	LT. COL. CORPS OF ENGINEERS DISTRICT ENGINEER
PREPARED ENGINEER HEAD, SPECIAL STUDIES SECTION	DRAWN BY P.K. CHECKED BY J.S.	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER DATED 30 JUNE 1962 FILE: TRIN. 230-19

PLATE 15

52-704 O-65 Vol. II (Face p. 156) No. 4

106. RIVER DIVERSION DAMS.- Diversion dams would be placed across the upstream end of severed river bends. These dams would be provided to confine all flows in the multiple purpose channel. Dams would not be provided for short severed reaches. Eighty-one diversion dams would be required for the multiple purpose channel. Construction of each dam would require an average of approximately 86,000 cubic yards of channel spoil material. Top of dams would be constructed to the elevation of the flood of record and would have a length of two hundred feet greater than the distance between tops of bank of the river measured along the alignment of the channel. Plates 3 thru 9 show the locations of the proposed river diversion dams.

107. CHANNEL BANK REVETMENTS WORK.- The banks of the Trinity River downstream of the Livingston dams are composed of alluvium sands, silts, and clays or mixtures of these materials. The portions of the river to be traversed by the multiple purpose channel between channel miles 35.5 and 46.0, and from channel mile 80 to the Livingston dam have not materially shifted or changed its meandering course. Between channel miles 46.0 and 80, the river has made numerous natural cut-offs and has moderately shifted its position by erosion of the banks within a narrow width of the flood plain area, as indicated on plate 4,
Tide water extends up the Trinity River to Liberty thence the low water slope averages about 0.66 foot per mile for a distance of 55 miles to Romayor. Flooding of the lowlands occurs with flows of 40,000 second-feet at Romayor, 20,000 second-feet at Liberty and about 10,000 second-feet at mile 35.5. The banks of the river at Romayor are about 35 feet above low water stage, about 22 feet at Liberty and about 6 feet at mile 35.5. The proposed multiple purpose channel would eliminate about 40 miles of river channel, and provides for the construction of lock and dams Nos. 2, 3 and 4 in the reach between mile 46 and 80. These structures would create navigation pools and change the river flows in the reach of river under consideration.

108. The plan of improvement proposed that the multiple purpose channel be located along the general course of the meandering river and that river diversion dams be provided at the upper ends of the proposed river cut-offs to confine the flows within the proposed channel. The plan proposes that the channel curves have a minimum radius of 2,500 feet. The proposed channel would have bottom widths of 250 feet from just upstream of lock and dam No. 2 to channel mile 55.7, thence 200 feet to mile 74.85, thence 150 feet upstream of lock and dam No. 4, with bottom gradient of about 1.55 feet per mile for a distance of 27.4 miles between locks Nos. 2 and 4.

109. The multiple purpose channel in this reach is designed to pass a regulated discharge of 35,000 second-feet with an additional capacity of 10,000 second-feet for flood flows from the uncontrolled area below the Tennessee Colony reservoir. Information concerning the mean channel velocities for various flows estimated to occur at the Romayor gage and throughout the multiple purpose channel downstream thereof is given in the following tabulation:

Channel discharges (second feet)	Occurrence (percent)(1)	Mean channel velocity in feet per second
45,000	0.2	5.86
35,000	2.7	4.55
25,000	4.3	3.37
20,000	5.7	2.67
10,000	11.0	1.32

(1) Percent of time discharge is equalled or exceeded.

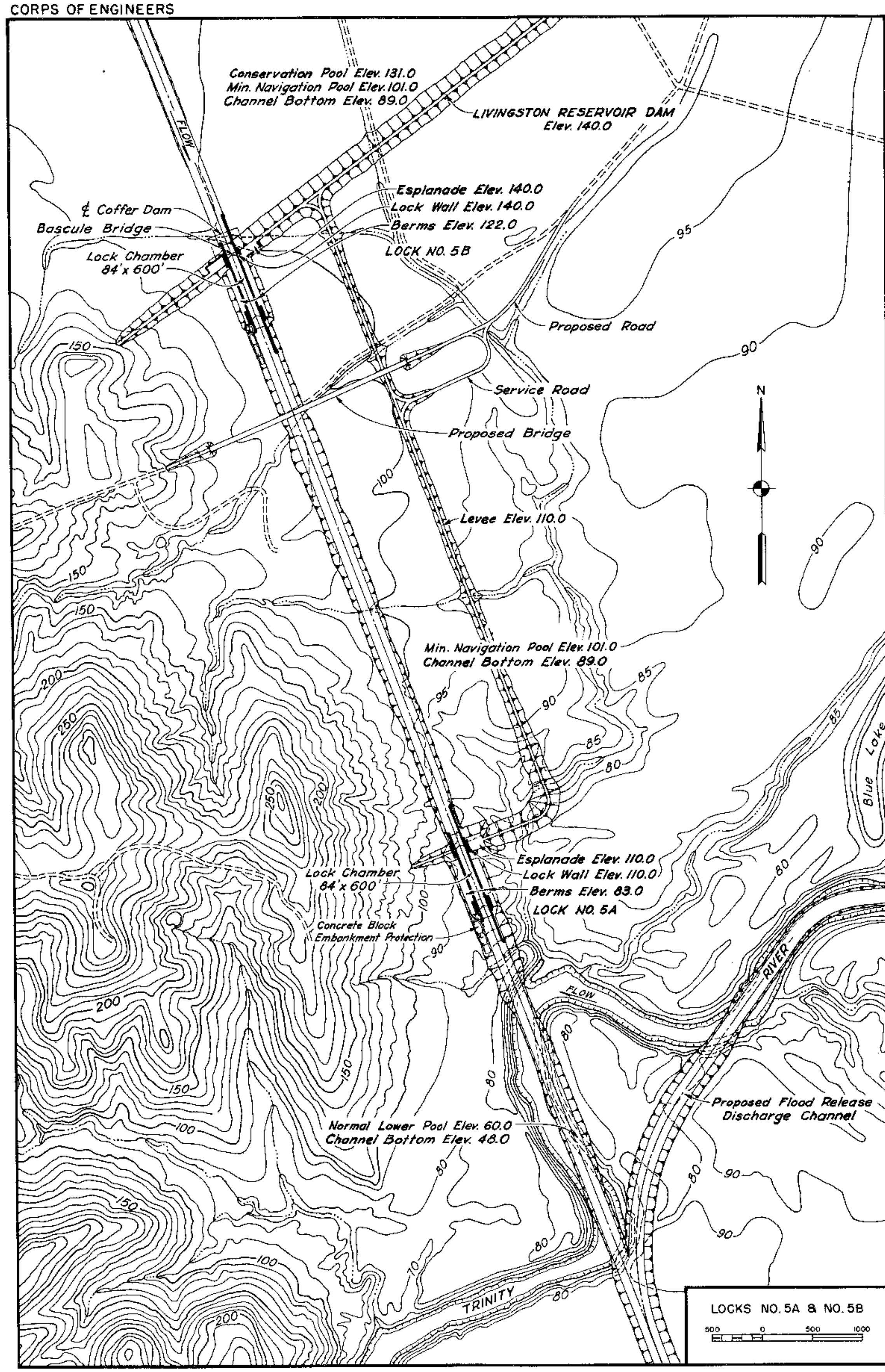
110. The mean channel velocities shown for various channel discharges indicate that eroding of the channel banks would probably occur where the banks are composed of sands and or sandy clay materials. It is apparent from the foregoing that some type of bank revetment works would be required in the reach of channel under consideration. Sodding and seeding of the banks above normal pool elevation would probably suffice to prevent erosion of the upper portion of the banks which would not be subject to frequent inundation. Whereas, some type of permanent revetment would probably be required extending from a few feet above normal pool elevations to the bottom of the channel.

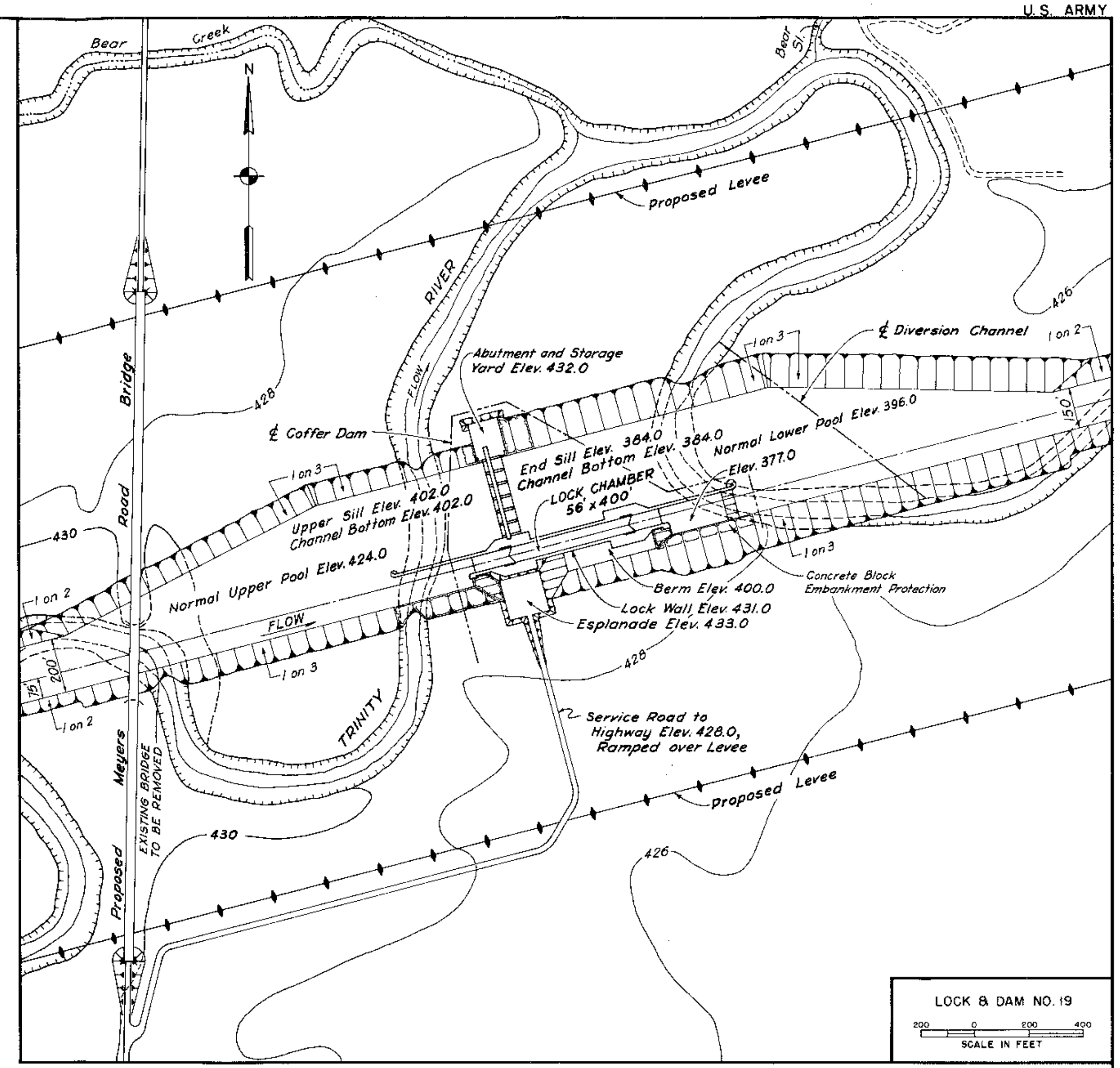
111. Based on available data, it is proposed that the outside banks of the sharper curves and short lengths of tangent bank on each side, located between channel mile 45 and 74, be protected with 24-inch thickness of quarry-run stone ranging from one-half inch to 200 pound stone extending from two feet above normal pool elevation to bottom gradient of proposed channel. The channel from mile 45 to lock and dam No. 2 traverses a reach of the river that is now actively eroding the river banks in this reach. Extensive bank revetment works in this reach are proposed extending for a distance of about a mile below lock and dam No. 2. Plates 3 and 4 show the locations of the proposed bank revetment works.

112. NAVIGATION POOLS 5A and 10A.- The plan of improvement for the multiple purpose channel to Fort Worth provides for navigation pools 5A and 10A to be elevated above natural ground by means of levees extending between locks Nos. 5A and 5B, and 10A and 10B, in order to provide for navigation through the Livingston and Tennessee Colony reservoirs when conservation storage in these reservoirs is fully depleted.

113. The plan provides for navigation pool 5A to be located in a land cut channel extending between lock No. 5A located about 6300 feet below lock No. 5B which would be located in the Livingston Dam, generally as shown on plate 16. The levee would have a top elevation of 110 and be constructed of channel spoil material. In conjunction with the high hills on the opposite side of the channel, the levee would create a small reservoir providing a minimum navigation pool elevation of 101.0 and a maximum elevation of 103.0. Storage between these elevations would provide a water supply for adverse lock operation that may occur at lock No. 5A. When conservation storage in Livingston Reservoir is depleted to below elevation 103.0, the gates in lock 5B would remain open and barge tows would be able to traverse pools 5A and 5B without operation of lock No. 5B.

114. The plan provides for navigation pool No. 10A extending between locks No. 10A and 10B to be contained within a leveed reservoir area as shown on plate 17. The reservoir would be about 1100 feet wide and 2600 feet long providing storage to a minimum navigation elevation of 235.0 and a maximum elevation of 237.0. Storage between these elevations would provide a water supply for adverse lock operation that may occur at lock No. 10A. When conservation storage is depleted to and below elevation 237.0, the gates in Lock No. 10B would remain open and barge tows would be able to traverse pool No. 10A and 10B without operation of lock No. 10B.





TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER
MULTIPLE PURPOSE CHANNEL
SITE PLAN
LOCK NO. 5A & NO. 5B
LOCK AND DAM NO. 19
SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, GALVESTON — JUNE 1962

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
[signature] ENGINEER, CHIEF, PLANNING & REPORTS BRANCH	[signature] ENGINEER, CHIEF, ENGINEERING DIVISION	[signature] COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: [signature] ENGINEER, HEAD, SPECIAL STUDIES SECTION	DRAWN BY W.E.D. CHECKED BY [initials]	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER DATED ___ FILE TRIN. 230-19

PLATE 16

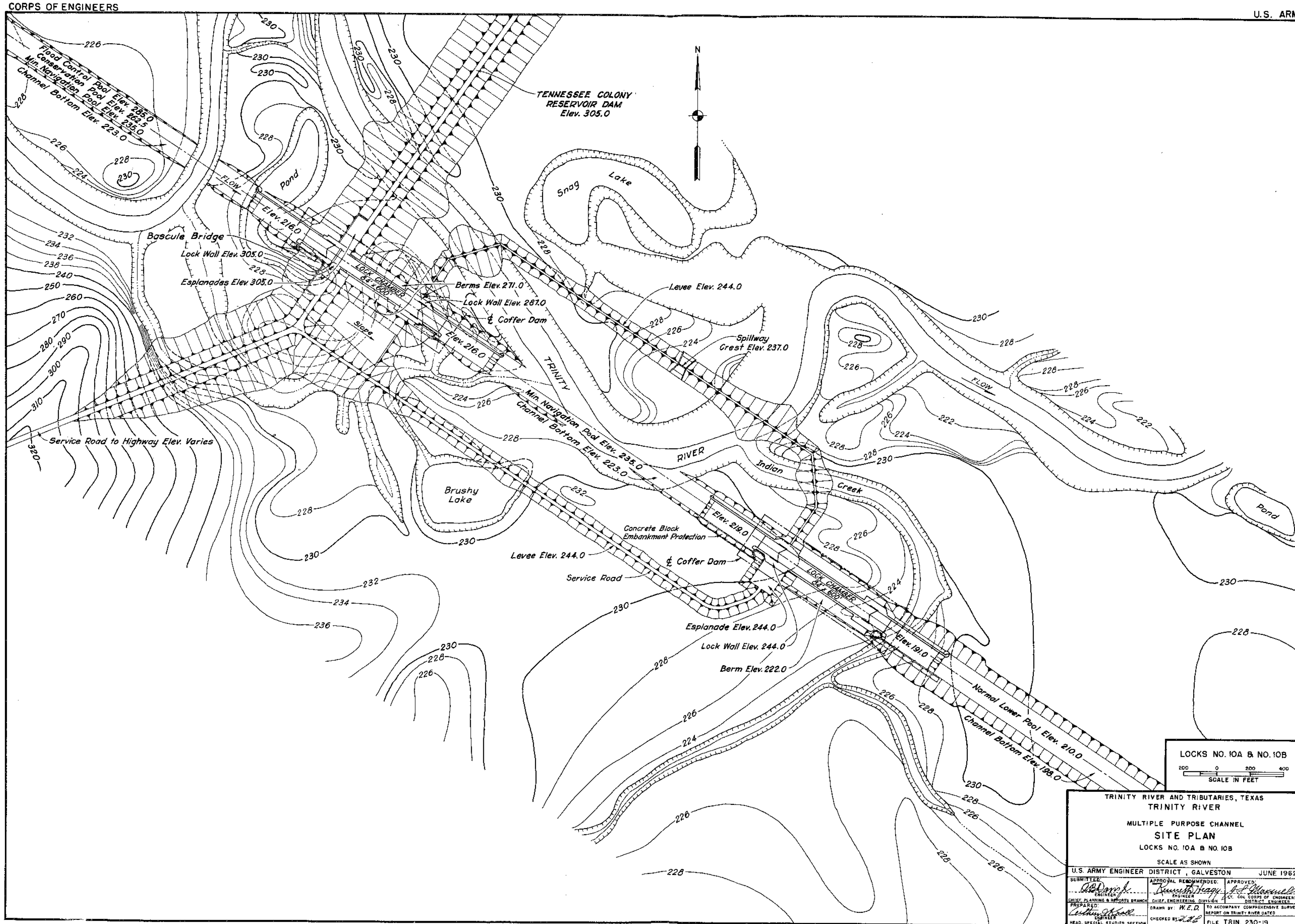


PLATE 17

52-704 O-65 Vol. II (Face blank p. 160) No. 2

115. **BRIDGES, HIGHWAYS AND RAILROADS.-** The plan of improvement for the multiple purpose channel proposes that all bridges over the proposed channel provide a minimum vertical clearance of 50 feet above the water surface elevation of the two percent regulated flood discharge; that all bridges over the channel below Dallas provide a minimum horizontal clearance of 250 feet between bridge fenders, and that all bridges over the channel above Dallas provide a clearance of 225 feet between bridge fenders. The plan also proposes that all bridges extending across floodways adjoining the channel bridges provide a minimum vertical clearance of four feet above the design water surface elevation of the floodway.

116. High-level fixed bridges consisting of a three span continuous plate girder unit over the channel with prestressed concrete beam approach spans and earth embankment approaches are proposed for all highways crossing the proposed channel. Vertical lift bridges are proposed for all railroad crossings of the proposed channel. Table 19 lists the existing bridges over the multiple purpose channel and shows whether modification of the existing bridge or construction of a new bridge is proposed. Plate 18 shows the general design features of the proposed highway and railroad bridges.

117. **UTILITY RELOCATIONS.-** The multiple purpose channel would require the relocation of the following utilities: one hundred and eleven pipelines of various sizes, from a minimum of three-inch gathering lines to a maximum of 30-inch through trunklines which transport crude oil, gas, gasoline, and other petroleum products; 31 electric power transmission lines of various capacity from a minimum of 2.4 kilovolts to a maximum of 138 kilovolts; 17 communication line crossings of various size from a 2-wire aerial crossing to a maximum of 9-cable aerial crossing; 6 water lines of various size from a minimum of 24 inches to a maximum of 72 inches; and 6 sewer lines of various size from a minimum of 18 inches to a maximum of 84 inches.

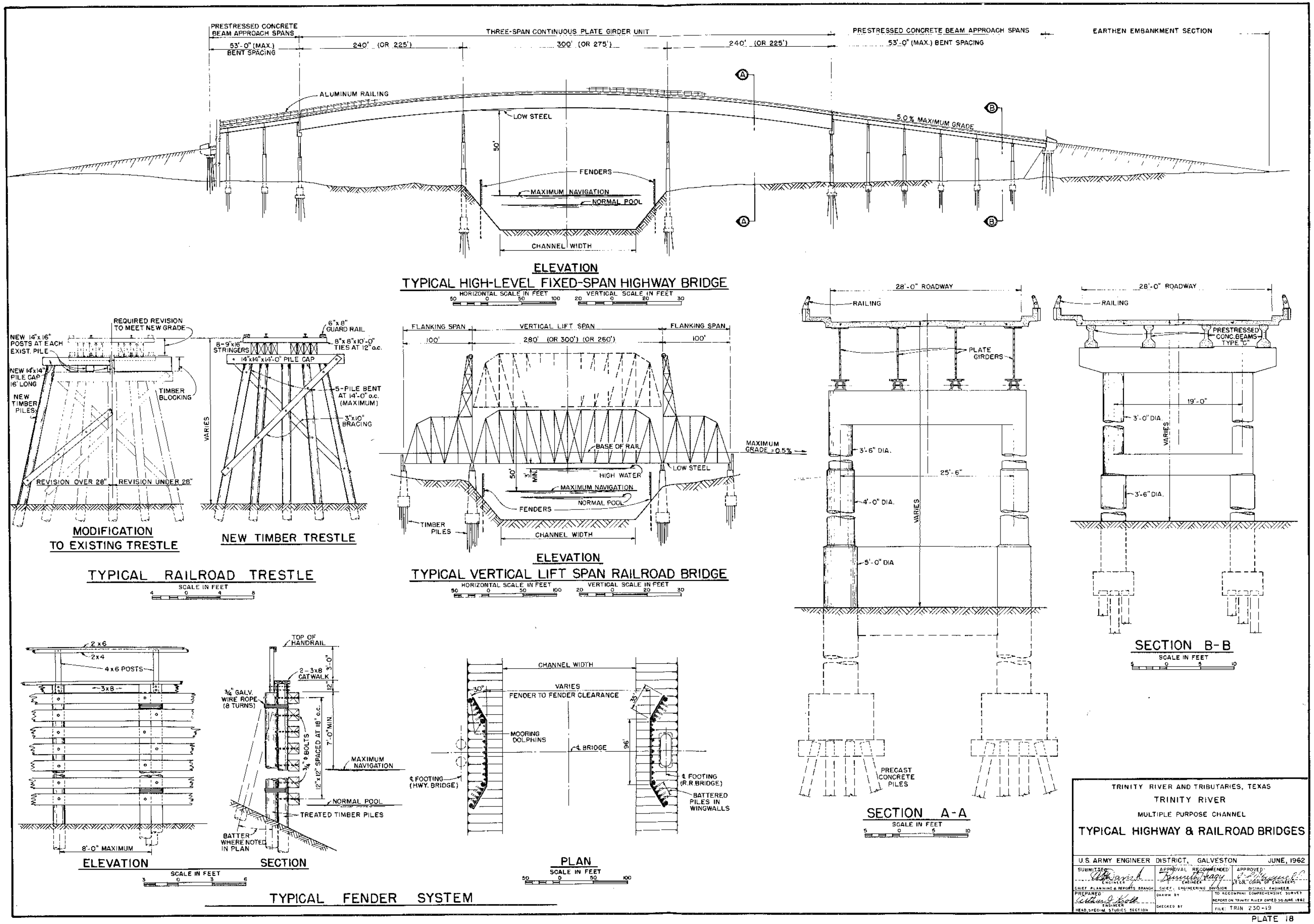
118. **PUBLIC-USE AREAS.-** The plan of improvement for the multiple purpose channel provides for the development of 31 separate public-use areas to be located adjacent to the project channel between Smith Point on Galveston Bay and lock and dam No. 21. The proposed development includes 21 50-acre sites, one 75-acre site and 9 125-acre sites with necessary access and internal roads, requiring a total land area of about 2500 acres. Appendix V gives further information concerning the development of the proposed public-use areas. Cost of facilities to be provided for use by the general public are included in appendix VI.

TABLE 19
SUMMARY OF BRIDGE WORK FOR CHANNEL TO FORT WORTH

Channel Mile	Bridge Designation	Description of proposed bridge work
30.36	Interstate Highway 10(Eastbound)	New bridge over cut-off channel
30.37	Interstate Highway 10(Westbound)	New bridge over cut-off channel
47.84	U. S. Highway 90 (Eastbound)	Modification of existing bridge over cut-off channel
47.90	U. S. Highway 90 (Westbound)	Modification of existing bridge over cut-off channel
47.94	Southern Pacific RR	New bridge over cut-off channel
52.57	Missouri Pacific RR	Modification of existing bridge over cut-off channel
75.78	Texas State Highway 105	Modification of existing bridge over cut-off channel
77.28	Gulf Colorado & Santa Fe RR	Modification of existing bridge over cut-off channel
91.86	U. S. Highway 59	Modification of existing bridge over cut-off channel
91.93	Southern Pacific RR	New bridge to replace existing bridge over cut-off channel
98.90	County Road from Camilla, Texas	New bridge over cut-off channel
111.54	U. S. Highway 190	Modification to existing bridge
136.08	Missouri Pacific RR	New bridge over cut-off channel
136.15	Texas State Highway 19	New bridge over cut-off channel
171.63	Texas State Highway 21	New bridge to replace existing bridge over channel in river
196.68	Texas State Highway 7	New bridge to replace existing bridge over channel in river
219.70	Missouri Pacific RR	New bridge over cut-off channel
220.55	U. S. Highway 79 & 84	New bridges to replace existing bridges over channel in river
249.99	U. S. Highway 287	New bridge over Tennessee Colony Reservoir
264.14	Saint Louis & Southwestern RR	Modification of existing bridge over reservoir
264.52	Texas State Highway 31	Modification of existing bridge over Tennessee Colony Reserv.
285.60	Texas State Highway 1129	Modification of existing bridge over channel in river
298.04	Texas State Highway 34	Modification of existing bridge over channel in river
312.84	Malloy County Road	New bridge to replace existing bridge over channel in river
315.57	Belt Line Road	New bridge to replace existing bridge over channel in river
319.92	Dowdy-Ferry Road	New bridge over cut-off channel
326.19	Texas Highway - Loop 12 (Eastbound)	New bridge over cut-off channel
326.20	Texas Highway - Loop 12 (Westbound)	New bridge over cut-off channel
328.30	Southern Pacific RR	Modification of existing bridge over channel in river
328.46	Interstate Highway 45(Northbound)	Modification of existing bridge over channel in river
328.47	Interstate Highway 45(Southbound)	Modification of existing bridge over channel in river

TABLE 19 (CONT'D)
SUMMARY OF BRIDGE WORK FOR CHANNEL TO FORT WORTH

Channel Mile	Bridge Designation	Description of proposed bridge work
330.28	Missouri Kansas & Texas RR	New bridge replacing existing bridge over channel in river
330.65	Forrest Avenue, Dallas	Modification of existing bridge over cut-off channel
331.09	Gulf Colorado and Santa Fe RR	Modification of existing bridge over channel in river
331.41	Corinth Street Viaduct, Dallas	New bridge to replace existing bridge over channel in river
332.22	Cadiz Street Viaduct, Dallas	Modification of existing bridge over cut-off channel
332.28	Interstate Highway 35E	Modification of existing bridge over cut-off channel
332.61	Houston Street Viaduct, Dallas	Modification of existing bridge over channel in river
333.12	Dallas-Fort Worth Turnpike	Modification of existing bridge over channel in river
333.50	Commerce Street Viaduct, Dallas	Modification of existing bridge over channel in river
333.66	Texas & Pacific RR	Modification of existing bridge over channel in river
333.93	Continental Street, Dallas	Modification of existing bridge over channel in river
334.89	Sylvan Avenue, Dallas	Modification of existing bridge over channel in river
336.33	Hampton Road, Dallas	Modification of existing bridge over channel in river
337.26	Westmoreland Road, Dallas	Modification of existing bridge over channel in river
340.39	Texas Highway - Loop 12	New bridge replacing existing bridge over cut-off channel & floodway
341.86	Gifford Hill Gravel Co. RR	New bridge to replace existing bridge crossing channel in river
342.94	Meyers Road	New bridge to replace existing bridge over channel in river & floodway
345.25	Belt Line Road	New bridge to replace existing bridge over channel in floodway
350.54	Chicago-Rock Island & Pacific RR	New bridge over cut-off channel
350.75	Texas State Highway 360	New bridge over cut-off channel
354.00	Texas State Highway 157	New bridge to replace existing bridge over channel in river & floodway
357.00	Arlington-Bedford Road	New bridge over channel in river
359.95	Arlington-Smithfield Road	New bridge to replace existing bridge over channel in river & floodway
362.11	Interstate Highway 820 (Northbound)	New bridge over cut-off channel
362.12	Interstate Highway 820(Southbound)	New bridge over cut-off channel
362.70	Handley-Ederville Road	New bridge over -cut-off channel
366.80	East First Street	New bridge replacing existing bridge over floodway
368.60	Beach Street	Modification of existing bridge in floodway
369.40	Riverside Drive (Northbound)	Modification of existing bridge in floodway
369.41	Riverside Drive (Southbound)	Modification of existing bridge in floodway



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119. LOCK LOCATION CONSIDERATIONS.- The proposed location of locks and dams on the multiple purpose Trinity River Channel below Dallas were determined largely by the location of four proposed large reservoirs on the main river and the desirability of locating the lock and dam structures upstream of the mouth of large tributaries and on stable reaches of the river wherever feasible. In addition, consideration was given to the selection of the least number of locks and dams to overcome the fall of the river with normal navigation pools established at least four feet below the top of bank at the proposed lock sites to prevent water logging of the lands adjacent to the lock and dam sites. Also, lock lifts were limited to a maximum of 30 feet to prevent deep entrenchment of the navigation channel below the river bed and excessive loading of the foundation materials.

120. At and upstream of Dallas, the lock and dam sites were selected generally by the requirement to provide normal navigation pool elevations whereby storage of water in the pools would not interfere or seriously affect the operation of sewage disposal plants located along the river banks and the storm sewers at Dallas which now discharge into the Trinity River. Consideration was also given to the sites being upstream of the mouth of large tributaries and that the normal navigation pools be established about four feet below the top of banks. The sewage disposal plants and storm sewers are located with reference to channel mile as follows:

a. White Rock sewage disposal plant at Dallas, mile 329.4

b. Gravity and pressure type storm sewers, totaling 10 separate installations through the Dallas floodway levees between miles 331.9 and 336.4.

c. Trinity River Authority plant at Grand Prairie, mile 341.6.

d. Arlington disposal plant, mile 346.7.

e. Amon Carter Airfield plant, mile 351.0.

f. Fort Worth - Village Creek plant, mile 357.8.

g. Fort Worth - Riverside plant, mile 367.8.

121. The selected lock and dam sites were based on available data consisting of 1912-15 survey data, aerial photographs made in November, 1958, and foundation investigations limited to one core boring at the sites. Alternate site studies were made in the selection of several sites. However, based on available data, the studies were non-conclusive as to the better sites. The location of the lock and dam sites proposed for the multiple purpose channel to Fort Worth, Texas, are of preliminary selection only for the purpose of this report.

122. The four reservoir improvements were considered in the planning of a canalized multiple purpose Trinity River channel to Fort Worth, Texas, are as follows:

a. The multiple purpose Wallisville reservoir with dam at river mile 3.9 providing conservation storage between elevation 4.0 and 1.0, recommended for Federal adoption by the Acting Chief of Engineers under date of 18 April 1961 (House Document No. 215, 87th Congress, 1st Session).

b. The proposed Lake Liberty reservoir (Capers Ridge site) with dam at river mile 63 for water conservation purposes between elevation 70 and 50 feet, included in the Trinity River Authority of Texas long-range plan of development.

c. The proposed Lake Livingston reservoir with dam located at river mile 129.2 for water conservation purposes between elevation 131.0 and 101.0, now in preconstruction stage of development jointly by the city of Houston, Texas, and the Trinity River Authority of Texas.

d. The proposed multiple purpose Tennessee Colony reservoir with dam at river mile 339.2 providing for conservation storage between elevation 262.5 and 235 and flood storage between elevation 285 and 262.5 under investigation in connection with this report.

123. The reservoir dams would impound extensive water areas within the Trinity River valley and extend up the natural Trinity River channel for considerable distances under full conservation storage conditions. The extent of storage in the river channel is of considerable importance in determining the location of locks and dams in order that the loss of such storage may be reduced to a minimum compatible with the economic location of the locks and dams. Information concerning the reach of river channel affected by the proposed reservoirs is given in the following tabulation:

Name of reservoir	Elevation of conservation pool: Maximum	Minimum	Limits of reservoir (River Mile): Dam Site	Upstream Limit	Length
Wallisville	4.0	1.0	3.9	48.0	44
Lake Liberty (1)	63.0	16.0	63.0	129.0	66
Livingston	131.0	101.0	129.2	251.0	122
Tennessee Colony	262.5	235.0	339.2	412.0	73
Tennessee Colony	285.0(2)	262.5	339.2	433.0	94

(1) Limited by the Livingston reservoir dam.
(2) Proposed flood control storage.

124. Lock and dam No. 2 at channel mile 47.45 would be located in the upper reach of the Wallisville reservoir contained in the Trinity River channel at about river mile 40, and would exclude about 400 acre-feet of storage in the upper eight miles of the reservoir within the river banks. However, the loss of such storage would not seriously affect or reduce the yield from the Wallisville reservoir having a conservation storage of 42,660 acre-feet between elevations 4.0 and 1.0 above mean sea level.

125. Lock and dam No. 3, at channel mile 59.08, about one mile below the proposed Lake Liberty reservoir (Capers Ridge) dam site at river mile 63, would have no effect on the proposed Lake Liberty reservoir. However, in the event that the reservoir is constructed at a future date, lock and dam No. 3 would serve in conjunction with the lock in the reservoir dam to overcome a total lift of 47 feet.

126. Lock and dam No. 4, at channel mile 74.85, would probably require alteration if the Lake Liberty reservoir were placed in operation with conservation storage to elevation 63.

127. Lock Nos. 5A and 5B, at channel mile 98.00 and 99.20, respectively, are proposed as separate structures to overcome a total lift of 71 feet at the Livingston reservoir dam from a lower pool elevation 60.0 to maximum conservation pool elevation 131.0. These locks also would provide for navigation through the reservoir when conservation storage would be fully depleted to elevation 101. The separate lock structures are proposed in lieu of adjoining tandem locks in order to reduce delays to navigation. A navigation channel, 12 feet deep and 150 feet wide below elevation 101.0 with a length of 6,000 feet would be provided between the lock structures. Barge tows would be able to pass each other in this reach of channel and single lockages would be made at locks 5A and 5B.

128. Lock and dam No. 6, at channel mile 147.92 would be located in the upper reach of the Livingston reservoir contained within the Trinity River channel above river mile 200. Lock and dam No. 6 would affect 51 miles of the upper reservoir in the Trinity River estimated to contain about 16,600 acre-feet. This loss would be partly overcome

by additional storage estimated at 6000 acre feet to be provided in the reservoir by construction of the navigation channel 12 feet deep and 150 feet wide below elevation 101.0 in river cut-off alignments and enlargement of the river section below lock and dam No. 6. The total volume of the Livingston conservation pool between elevation 131.0 and 101.0 is tentatively estimated at 1,750,000 acre-feet. The above data indicates that lock and dam No. 6 would reduce the conservation storage in the Livingston reservoir by about six-tenths percent when the reservoir is full to elevation 131.0. In view of the foregoing, it is considered that lock and dam No. 6 at its proposed location would not materially affect the conservation storage in the Livingston reservoir.

129. Lock Nos. 10A and 10B, at channel mile 233.0 and 233.61, respectively, are proposed as separate structures to overcome a total lift of 75 feet at the Tennessee Colony reservoir dam from a lower pool elevation 210.0 to maximum flood control storage, elevation 285.0. These locks also would provide for navigation through the reservoir when conservation storage would be fully depleted to elevation 235.0. Separate lock structures are proposed in lieu of adjoining tandem locks in order to reduce delays to navigation. A navigation channel, 12 feet deep and 150 feet wide below elevation 235.0 with a length of about 3200 feet would be provided between the lock structures. Barge tows would be able to pass each other in this reach of channel and single lockages would be made at locks 10A and 10B.

130. Lock and dam No. 11 at channel mile 258.91 would be located within the Tennessee Colony reservoir just upstream of the mouth of Cedar Creek and upstream of the land areas to be inundated by the conservation pool at elevation 262.5. Dam No. 11 would consist of an overflow spillway structure with crest at elevation 275.0 extending from the lock structure across the valley lands for a distance of 5700 feet, and would be inundated when flood storage exceeded elevation 275.0. Navigation would pass through lock No. 11 during all flood storage conditions above elevation 262.5. The proposed location of lock and dam No. 11 was considered in determining the conservation storage requirements for the Tennessee Colony reservoir.

131. Lock and dam No. 12, at channel mile 274.51 would be located in the upper reaches of land areas to be inundated by maximum flood storage in the Tennessee Colony reservoir at elevation 285.0. These structures would not be inundated with maximum flood storage in the reservoir, and would exclude flood storage in the adjoining upstream reach of the river. The proposed location of lock and dam No. 12 was considered in determining the flood storage requirements of the Tennessee Colony reservoir.

132. The proposed locations of the locks and dams upstream of lock and dam No. 12 were selected to prevent excessive backwater flooding of the tributaries and interference with the sewage disposal plants and to provide an adequate water surface elevation to serve the needs of the Dallas and Fort Worth turning basins.

133. PROPOSED SYSTEM OF LOCKS.- The plan of improvement for canalization of the multiple purpose channel to Fort Worth proposes a system of 23 locks, 17 movable dams and one non-navigable overflow spillway dam to serve in conjunction with the Wallisville, Livingston and Tennessee Colony Reservoir Dams to overcome a total river fall of 480 feet, maintain normal elevations of the navigation pools and provide for passage of channel flows equal to or less than bankfull stage including floating debris and other drift. The system of locks includes 19 locks having clear basin dimensions of 84 feet wide by 600 feet long on the channel below Dallas and four locks, 56 feet wide by 400 feet long, on the channel at and upstream of Dallas. A plan and profile of the proposed system of locks and dams is shown on plate 19.

134. LOCK SIZE FORMULATION STUDY.- The lock sizes proposed for navigation to Fort Worth were determined by a lock-size formulation study summarized in the following paragraphs. The study gives consideration to several prescribed standard lock sizes listed in engineering manual 1110-2-2603, dated October 23, 1957, the size of barges and makeup of the standard barge tows that were assumed to be used in transporting the prospective commerce tonnage on the channel to Fort Worth, the water demand required for operation of the locks under consideration, the lockage time required for passage of a standard barge tow through the locks and the costs of the several locks.

135. The size of barges and makeup of barge tows considered in the lock size study are assumed to be the same as considered in channel-size formulation study for a single purpose navigation channel to Fort Worth presented in appendix I. The size of channel found most feasible for navigation to Fort Worth by comparison of costs and benefits of four plans of channel improvement was based on the following assumptions:

a. Two sizes of barges would be required for the prospective commerce movement on the channel. Barges 26 feet wide by 175 feet long would be used for sand, gravel and stone commerce, and barges 35 feet wide by 195 feet long would be used for all other commerce movement.

b. On the channel below Dallas, all commerce would move in three-barge tows, in tandem, except the upbound movement of sand and gravel commerce originating below Dallas, which would move in two-barge tows, in tandem, to Dallas and Fort Worth. On the channel above Dallas, all commerce would move in two-barge tows in tandem.

c. A uniform lockage time of 60 minutes including towboat setover was assumed for all three-barge tows on the channel below Dallas. Lockage time of 45 minutes was assumed for the upbound two-barge tows of sand and gravel below Dallas. On the channel above Dallas a uniform lockage time of 45 minutes was assumed for all tows. Lockage time is measured from full approach speed prior to lockage to resumption of full speed after lockage.

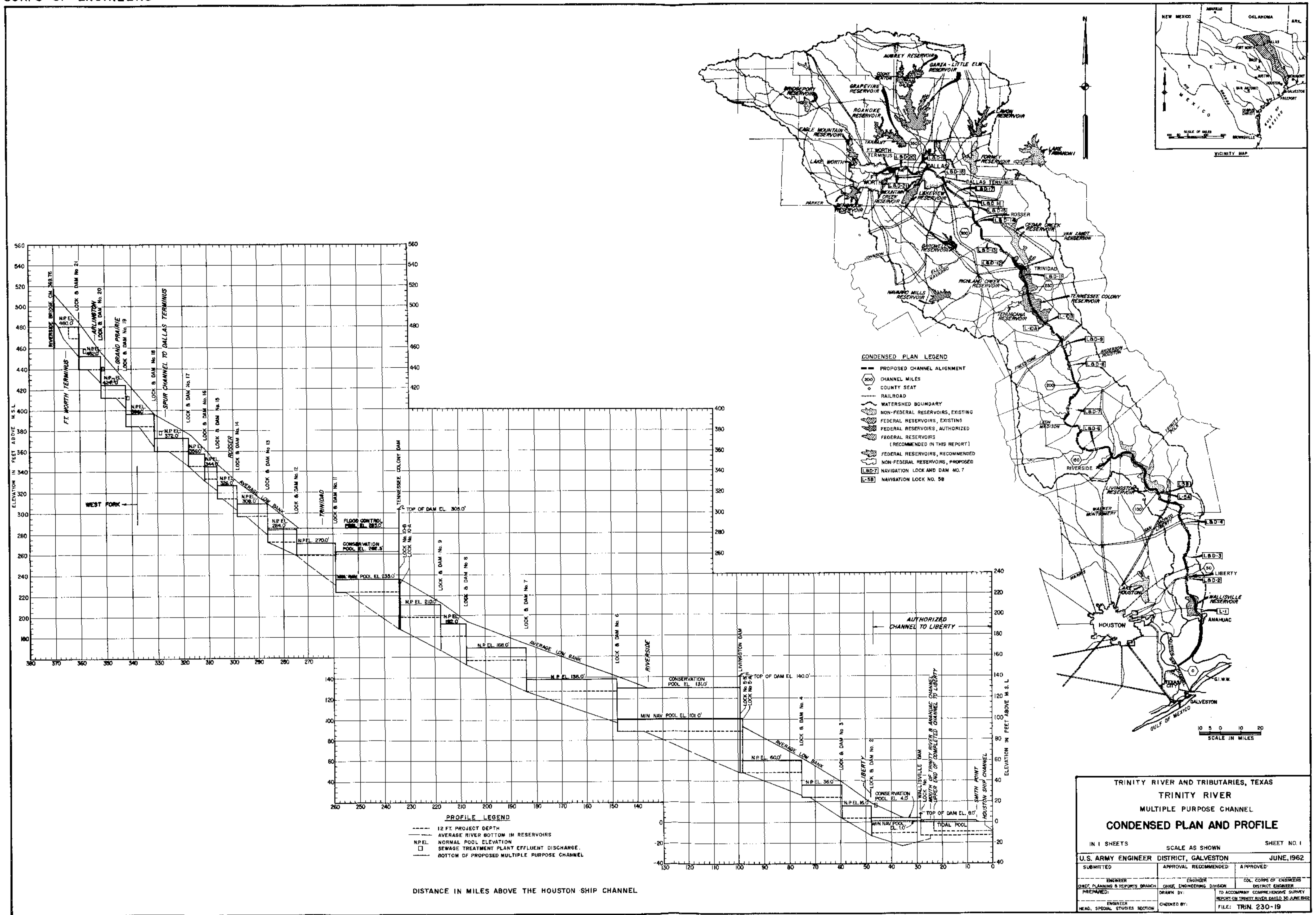

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PLATE 19

d. Towboats of 800-horsepower were assumed for three-barge tows of commerce movement on the channel below Dallas excepting the sand, gravel and stone commerce movement in three-barge tows which would require 600-horsepower towboats. Towboats of 400-horsepower were assumed for the two-barge tows of upbound sand and gravel commerce movement below Dallas and for all commerce movement between Dallas and Fort Worth.

136. Based on the foregoing assumptions, the makeup of standard barge tows on the channel below Dallas would be as follows:

a. Three-barge tows consisting of three barges, each 195 feet long by 35 feet wide, with towboat all arranged in tandem formation for all commerce except sand, gravel and stone.

b. Three-barge tows for sand, gravel and stone commerce consisting of three barges, each 175 feet long by 26 feet wide, with towboat all arranged in tandem formation.

c. Two-barge tows for sand and gravel commerce originating below Dallas consisting of two barges, each 175 feet long by 26 feet wide, with towboat all arranged in tandem formation.

137. On the channel between Dallas and Fort Worth, the standard barge tows would be as follows:

a. Two-barge tows for sand and gravel commerce consisting of two barges, each 175 feet long by 26 feet wide, with towboat all arranged in tandem formation.

b. Two-barge tows for all commerce other than sand and gravel consisting of two barges, each 195 feet long and 35 feet wide, with towboat all arranged in tandem formation.

138. The standard lock sizes considered for canalization of the channel below Dallas included locks having clear dimension as follows: 56x400, 56x600, 84x600 and 84x800.

139. Investigation of pertinent data concerning towboats operating on the Gulf Intracoastal Waterway in the Galveston District listed in Transportation Series 4, dated 1961, reveals that towboats of 800 horsepower generally have beam widths of 22 to 24 feet and that towboats of 600 to 400 horsepower have beam widths of 18 to 14 feet. The standard three-barge tows assumed for commerce movement other than sand, gravel and stone on the channel below Dallas would be moved by towboats of 800 horsepower. It is considered that for economy of barge tow operation, the standard three barge tow should be handled in one lockage operation instead of double lockage operations. Assembling the standard barge in the lock with the three barges in tandem and the towboat set over adjacent to the rear barge, the assembled tow would have a total length of 585 feet and a width of 57 to 59 feet depending on the beam width of the towboat.

140. Accordingly, only the 84×600-foot lock and the 84-×800-foot lock would provide for a single lockage of the standard three barge tow. The larger lock would accommodate the standard three-barge tow without loss of time required for setover of the towboat as would be required for the 600-foot long lock. However, the 84-× 800-foot lock would require about 33 percent more water for lockage than the 84-× 600-foot lock. Accordingly, the 84-× 600-foot lock was selected to be the most feasible size of lock for navigation on the channel below Dallas.

141. The maximum size of barge tow on the channel at and above Dallas would consist of two barges 195 feet long by 35 feet wide powered by a towboat of 400 horsepower having a beam width of 18 to 14 feet. A lock having basin dimensions of 56-× 600-foot would accommodate the barge tow assembled in tandem formation, whereas, the 56-× 400-foot lock would require the towboat to be set over adjacent to the last barge for single lockage operation. Investigation reveals that maximum prospective commerce tonnage movement on the channel could be handled by the 56-× 400-foot lock at less than 50 percent of the yearly lock operation time of 365 days. Furthermore, the 56-× 400-foot lock would use about 50 percent less water for lockage purposes. It is considered that the 56-× 400-foot lock should be provided to serve the needs of navigation on the channel above Dallas.

142. CAPABILITY OF PROPOSED LOCK SYSTEM.- The system of locks proposed for the canalization of the multiple purpose Trinity River channel to Fort Worth consists of 19 84-× 600-foot locks below Dallas and four 56-× 400-foot locks between Dallas and the Fort Worth terminus. Analyses of the capability of the lock system to handle the prospective commerce tonnage movement on the proposed channel to Fort Worth were made to determine:

a. The maximum amount of projected commerce tonnage movement in standard barge tows which could be handled by the locks and the year of such development for the purpose of determining the savings in transportation costs creditable to the multiple purpose channel.

b. The capability of the lock system to provide for prospective movement of miscellaneous commercial craft, work boats, floating equipment, cabin cruisers and other recreational craft requiring lockage in addition to the commercial barge tow movements through the locks.

c. The total number of lockages required to move the projected commerce tonnage through each lock of the system to provide a basis for estimating the water demand for operation of navigation at each lock per year.

143. BASIC COMMERCE TONNAGE.- Analyses of the tonnage capability of the lock system are based on the estimates of (1958) prospective commerce tonnage accepted for the channel to Fort Worth, as set forth in table 27, paragraph 206 of this appendix. The total (1958) prospective commerce is estimated at 6,921,586 tons, of which 2,393,759 tons would

be upbound commerce and 4,527,827 tons would be downbound commerce. The prospective (1958) upbound and downbound commerce tonnages consigned to or originating at various proposed ports along the channel to Fort Worth are given in table 20. A graphic presentation of prospective (1958) commerce tonnage movement on the channel to Fort Worth is shown on the traffic density chart, figure 4, which also shows the tonnage passing each lock. The chart also shows tonnage curves of the projected commerce movement on the channel for the years of 1988 and 2020.

144. The traffic density chart shows that tonnage movements through locks No. 3 and 13 are representative of the maximum lockage requirements in the lower and upper section of the lock system below Dallas. Locks No. 18 and 19 would handle the maximum amount of tonnage on the channel above Dallas. Lock No. 19 is located on the West Fork where the river flows are considerably less than at lock No. 18 and is selected for further analysis of traffic movement between Dallas and Fort Worth. Locks No. 5A, 5B, and 10A, 10B would not be controlling factors in determining the capability of the lock system because these locks would be located separately and individually operated for passage of barge tows.

145. BARGE TOWS AND BARGE LOADING.- The analyses of barge tow transits through the lock system to transport the projected tonnage of each commodity group are based on the same assumptions of barge tow characteristics considered in determining the barge rate factors used in evaluating the savings in transportation costs credited to the channel to Fort Worth, as given in paragraphs 208 to 215 of this appendix. In determining the number of barge tows required to transport each commodity group tonnage, it was considered that the various commodities would be transported in bargeloads with average tonnage as follows:

Commodity	Size of barge	Average barge load tonnage
Petroleum products (bulk liquid)	195 × 35	1200
Grains and products (in bulk)	195 × 35	1200
Iron and steel articles	195 × 35	700
Sulfur, ores and dry chemicals	195 × 35	1200
Scrap iron and steel	195 × 35	700
Commodities, N. O. S.	195 × 35	665
Liquid chemicals and O.B. liquids	195 × 35	1200
Sand and gravel and stone	175 × 26	800

TABLE 20

PROSPECTIVE (1958) UPBOUND AND DOWNBOUND COMMERCE
TONNAGE TO AND FROM VARIOUS PORTS ON MULTIPLE PURPOSE
TRINITY RIVER CHANNEL TO FORT WORTH, TEXAS

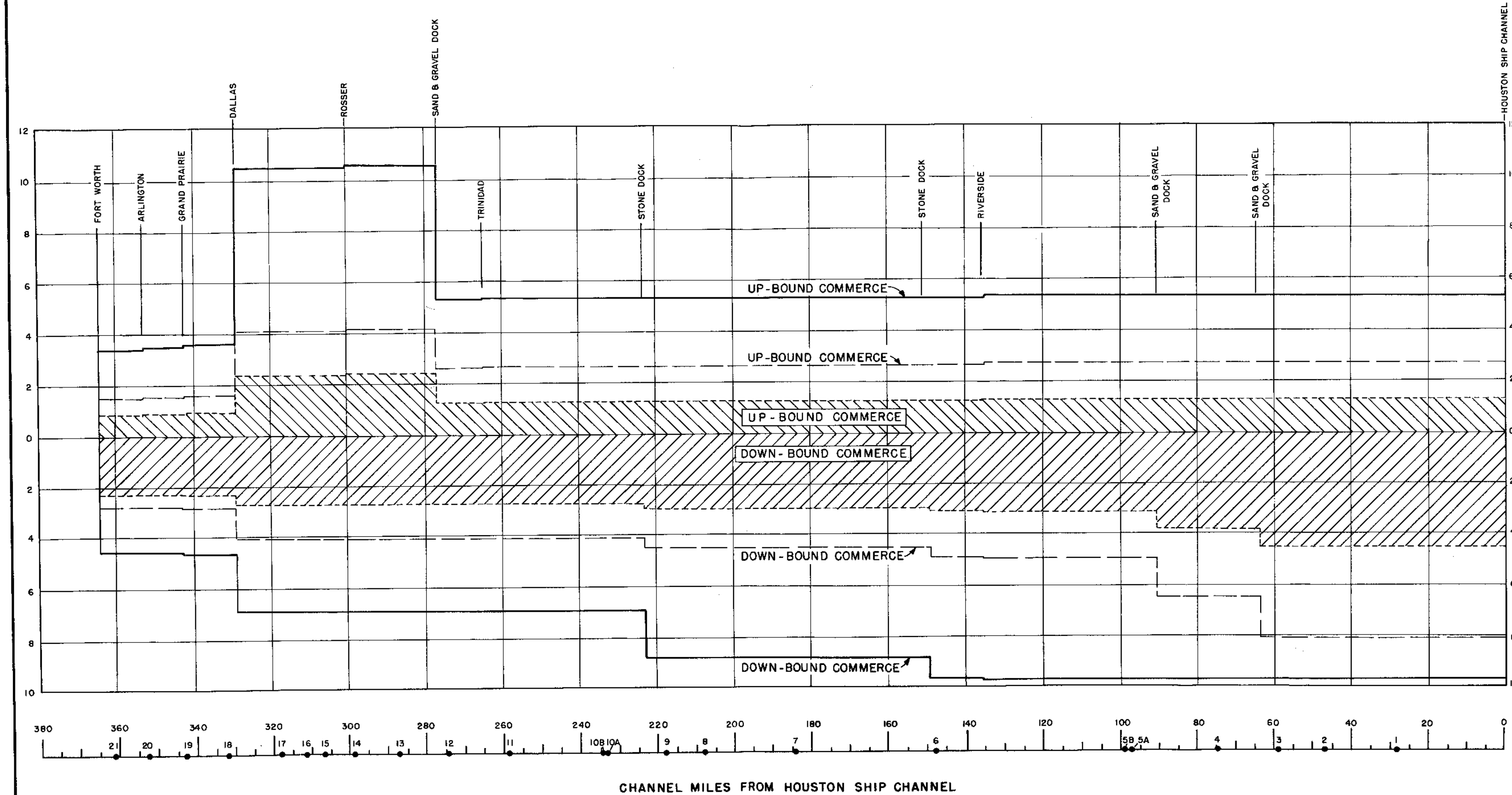
UPBOUND COMMERCE FROM HOUSTON SHIP CHANNEL TO TRINITY RIVER PORTS

Prospective (1958) commerce	Total from H.S.C.(1)	Riverside (C.M.136)	Trinidad (C.M.263)	S & G Dock (C.M.277)(2)	Rosser (C.M.300)	Dallas (C.M.328)	Grand Prairie (C.M.343)	Arlington (C.M.354)	Fort Worth (C.M.364)
Petroleum products (bulk liquid)	28,700					28,700			
Iron & steel articles	709,220	2,500	500		6,700	379,326	16,316	3,750	300,128
Sulphur, Ores & dry chemicals	147,360					94,860	-	-	52,500
Commodities, N.O.S.	296,270				4,550	171,120	-	-	120,600
Liquid chemicals & O.B. Liquids	78,209					15,079	-	-	63,130
Subtotals	1,259,759	2,500	500		11,250	689,085	16,316	3,750	536,358
Sand and gravel				1,134,000		793,000			341,000
Total tonnage consigned to river ports	1,259,759	2,500	500		11,250	1,482,085	16,316	3,750	877,358
Total tonnage consigned beyond river port	1,259,759	1,257,259	1,256,759	2,390,759	2,379,509	897,424	881,108	877,358	877,358

DOWNBOUND COMMERCE FROM TRINITY RIVER PORTS TO HOUSTON SHIP CHANNEL

Prospective (1958) Commerce	Fort Worth (C.M.364)	Grand Prairie (C.M.343)	Dallas (C.M. 328)	Stone Dock (C.M.223)(3)	Stone Dock (C.M.148)(3)	Riverside (C.M.136)	S & G Dock (C. M. 91) (4)	S & G Dock (C.M.63) (4)	Total to H.S.C.
Petroleum products (bulk liquid)						18,000			18,000
Grains & products (in bulk)	2,210,214								2,210,214
Iron & steel articles	2,000		2,200						4,200
Sulphur, Ores & O.B.chemicals			60,000						60,000
Iron and steel scrap	38,200	2,000	273,900						314,100
Commodities, N.O.S.	51,200		70,113						121,313
Subtotal	2,301,614	2,000	406,213			18,000			2,727,827
Sand and grave							715,450	715,450	1,430,900
Stone				184,600	184,500				369,100
Total tonnage originating at river ports	2,301,614	2,000	406,213	184,600	184,500	18,000	715,450	715,450	4,527,827
Total tonnage originating beyond river ports	2,301,614	2,303,614	2,709,827	2,894,427	3,078,927	3,096,927	3,812,377	4,527,827	4,527,827

(1) Tonnage from Houston Ship Channel consigned to ports on the Trinity River Channel.
(2) Shipping dock proposed for sand and gravel commerce upbound to Dallas and Fort Worth.
(3) Shipping dock proposed for downbound movement of stone commerce to Houston Ship Channel.
(4) Shipping dock proposed for downbound movement of sand and gravel commerce to Houston Ship Channel.



NOTES:

The density chart presented above depicts the amounts of prospective and projected up-bound and down-bound commerce tonnage which would be consigned to or originate at the various ports along the proposed canalized multiple purpose Trinity River Channel to Fort Worth, Texas.

The commerce tonnage shown for the year of 1958 by cross-hatching on the chart is the basic prospective up-bound and down-bound commerce tonnage accepted as potential waterway traffic.

The tonnage curves for the years of 1988 and 2015 are based on the projection of 1958 commerce tonnage by means of major economic indications considered in evaluating the future economic activity with the area to be served directly by the proposed water way to Fort Worth, Texas.

The location of the locks proposed for canalization of the multiple purpose channel to Fort Worth are designated on the mileage scale of the density chart.

The total tonnage to be handled by any specific lock during the designated years of either 1958, 1988 or 2015 can be determined from the density chart, as follows:

a. Extend an ordinate line through the lock site to intersect both the up-bound and down-bound tonnage curves of the specific year for which total tonnage is desired.

b. Summate the ordinate values of the up-bound and down-bound tonnage curves of the specific year at their intersection with the ordinate line in terms of the tonnage scale shown on the chart.

LEGEND

140 — 22 — LOCATION OF PROPOSED LOCKS

(cross-hatching) PROSPECTIVE 1958 COMMERCE TONNAGE

(dashed line) PROSPECTIVE 1988 COMMERCE TONNAGE

(solid line) PROSPECTIVE 2015 COMMERCE TONNAGE

TRINITY RIVER & TRIBUTARIES TEXAS
TRINITY RIVER
MULTIPLE PURPOSE CHANNEL
TO FORT WORTH, TEXAS

TRAFFIC DENSITY CHART

COMMERCE TONNAGE 1958, 1988, 2015

U.S. ARMY ENGINEER DISTRICT GALVESTON, TEXAS

TO ACCOMPANY COMPREHENSIVE
SURVEY REPORT ON TRINITY RIVER
DATED 30 JUNE 1962

JUNE 1962 | FILE: TRIN 230-19

FIGURE 4

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146. **PROJECTED COMMERCE TONNAGE.**- Analyses of the prospective (1958) commerce tonnage through locks 3, 13 and 19 reveals that the apparent tonnage capability of these locks is about 15 million tons per year of 365 day lock operation. In order to determine the year when such tonnage would become available at these locks, analysis was made of the tonnage growth trends for five basic economic factors projected over the 100-year life of the project given in paragraphs 247 to 253 of this report. Table 21 shows a summary of the projected commerce tonnage movement through locks No. 3, 13 and 19 for the following years:

1958 - Basic year of complete traffic information

1960 - Economic base-year for projection purposes

1970 - Assumed first year of lock operation to determine water demand for operation of navigation

1988 - Assumed year when sand and gravel commerce resources on the lower channel would be fully depleted

2020 - Assumed 50-year period of operation

2070 - Assumed 100-year period of operation

147. A comparison of the apparent tonnage capacity of locks No. 3, 13 and 19 with their requirement of projected tonnages is shown in the following tabulation:

Year of project tonnage	Projected tonnage requirement at		
	Lock No. 3	Lock No. 13	Lock No. 19
Apparent lock capacity	14,800,000	15,000,000	14,900,000
1960	6,009,000	5,301,000	3,305,000
1970	7,281,000	6,350,000	3,645,000
1988	10,682,000	9,184,000	4,640,000
2020	16,983,000	20,903,000	9,039,000
2070	52,497,000	65,545,000	22,395,000

148. The data in the above tabulation show that the projected 1988 commerce tonnage could be handled by all of the locks at less than 100 percent lock operation time per year. Lock No. 19 would be adequate to handle the projected 2020 commerce tonnage on the channel between Dallas and Fort Worth, but locks No. 3 and 13 would not be adequate to handle the projected 2020 commerce tonnage on the channel below Dallas, based on the (1958) bargeload tonnages considered in determining the apparent tonnage capacity of the locks. It is also considered that none of the locks would be able to handle the projected 2070 commerce tonnage.

TABLE 21
SUMMARY OF PROJECTED COMMERCE TONNAGE
ESTIMATED TO MOVE THROUGH LOCKS NOS. 3, 13 AND 19
DURING YEARS OF 1958, 1960, 1970, 1988, 2020 & 2070

	1958 tonnage			1960			1970 tonnage		
	Upbound	Downbound	Total	Upbound	Downbound	Total	Upbound	Downbound	Total
Lock No. 3									
Petroleum products (bulk liquid)	28,700	18,000	46,700	30,000	19,000	57,000	36,000	23,000	59,000
Grain & products (in bulk)	-	2,210,214	2,210,214	-	2,276,000	2,276,000	-	2,299,000	2,299,000
Iron and steel articles	709,220	4,200	713,420	730,000	4,000	734,000	964,000	5,000	969,000
Sulphur Ores & O. B. Chemicals	147,360	60,000	207,360	159,000	62,000	221,000	220,000	72,000	292,000
Iron and steel scrap	-	314,100	314,100	-	355,000	355,000	-	568,000	568,000
Commodities N. O. S.	296,270	121,313	417,583	309,000	130,000	439,000	369,000	179,000	548,000
Liquid chemicals, & O. B. liquids	78,209	-	78,209	81,000	-	81,000	100,000	-	100,000
Stone	-	369,100	369,100	-	380,000	380,000	-	502,000	502,000
Sand & gravel	-	1,430,900	1,430,900	-	1,474,000	1,474,000	-	1,946,000	1,946,000
Total	1,259,759	4,527,827	5,787,586	1,309,000	4,700,000	6,009,000	1,689,000	5,592,000	7,281,000
Lock No. 13									
Petroleum products (bulk liquid)	28,700	-	28,700	30,000	-	30,000	36,000	-	36,000
Grain & products (in bulk)	-	2,210,214	2,210,214	-	2,276,000	2,276,000	-	2,299,000	2,299,000
Iron & steel articles	706,220	4,200	710,420	727,000	4,000	731,000	960,000	5,000	965,000
Sulphur ores & O. B. chemicals	147,360	60,000	207,360	159,000	62,000	221,000	220,000	72,000	292,000
Iron & steel scrap	-	314,100	314,100	-	355,000	355,000	-	568,000	568,000
Commodities, N. O. S.	296,270	121,313	417,583	309,000	130,000	439,000	369,000	179,000	548,000
Liquid chemicals & O. B. liquids	78,209	-	78,209	81,000	-	81,000	100,000	-	100,000
Sand and gravel	1,134,000	-	1,134,000	1,168,000	-	1,168,000	1,542,000	-	1,542,000
Total	2,390,759	2,709,827	5,100,586	2,474,000	2,827,000	5,301,000	3,227,000	3,123,000	6,350,000
Lock No. 19									
Grain products (in bulk)	-	2,210,214	2,210,214	-	2,276,000	2,276,000	-	2,299,000	2,299,000
Iron & steel articles	320,194	2,000	322,194	330,000	2,000	332,000	436,000	3,000	439,000
Sulphur ores & O. B. chemicals	52,500	-	52,500	54,000	-	54,000	63,000	-	63,000
Iron & steel scrap	-	40,200	40,200	-	45,000	45,000	-	72,000	72,000
Commodities N. O. S.	120,600	51,200	171,800	125,000	56,000	181,000	146,000	85,000	231,000
Liquid chemicals & O. B. liquids	63,100	-	63,100	65,000	-	65,000	76,000	-	76,000
Sand & gravel	341,000	-	341,000	352,000	-	352,000	465,000	-	465,000
Total	897,394	2,303,614	3,201,008	926,000	2,379,000	3,305,000	1,186,000	2,459,000	3,645,000

TABLE 21 (CONT'D)
SUMMARY OF PROJECTED COMMERCE TONNAGE
ESTIMATED TO MOVE THROUGH LOCKS NOS. 3, 13 and 19
DURING YEARS OF 1958, 1960, 1970, 1988, 2020 & 2070

	1988 tonnage			2020 tonnage			2070 tonnage		
	Upbound	Downbound	Total	Upbound	Downbound	Total	Upbound	Downbound	Total
Lock No. 3									
Petroleum products (bulk liquids)	49,000	31,000	80,000	83,000	52,000	135,000	157,000	100,000	257,000
Grain & products (in bulk)	-	2,549,000	2,549,000	-	3,892,000	3,892,000	-	5,053,000	5,053,000
Iron & steel articles	1,555,000	9,000	1,564,000	3,694,000	20,000	3,714,000	12,228,000	67,000	12,295,000
Sulphur ores & O.B. chemicals	375,000	97,000	472,000	1,107,000	158,000	1,265,000	4,414,000	339,000	4,753,000
Iron & steel scrap	-	1,104,000	1,104,000	-	3,945,000	3,945,000	-	17,292,000	17,292,000
Commodities, N. O. S.	514,000	303,000	817,000	927,000	864,000	1,791,000	2,175,000	3,303,000	5,478,000
Liquid chemicals & O. B. liquids	147,000	-	147,000	318,000	0	318,000	1,004,000	-	1,004,000
Stone	-	809,000	809,000	0	1,923,000	1,923,000	-	6,365,000	6,365,000
Sand & gravel	-	3,140,000	3,140,000	-	-	-	-	-	-
Total	2,640,000	8,042,000	10,682,000	6,129,000	10,854,000	16,983,000	19,978,000	32,519,000	52,497,000
Lock No. 13									
Petroleum products (bulk liquids)	49,000	-	49,000	83,000	-	83,000	157,000	-	157,000
Grain & products (in bulk)	-	2,549,000	2,549,000	-	3,892,000	3,892,000	-	5,053,000	5,053,000
Iron & steel articles	1,549,000	9,000	1,558,000	3,679,000	20,000	3,699,000	12,177,000	67,000	12,244,000
Sulphur ores & O. B. chemicals	375,000	97,000	472,000	1,107,000	158,000	1,265,000	4,414,000	339,000	4,753,000
Iron & steel scrap	-	1,104,000	1,104,000	-	394,500	3,945,000	-	17,292,000	17,292,000
Commodities, N. O. S.	514,000	303,000	817,000	927,000	864,000	1,791,000	2,175,000	3,303,000	5,478,000
Liquid chemicals & O. B. liquids	147,000	-	147,000	318,000	-	318,000	1,004,000	-	1,004,000
Sand and gravel	2,488,000		2,488,000	5,910,000	-	5,910,000	19,564,000	-	19,564,000
Total	5,122,000	4,062,000	9,184,000	12,024,000	8,879,000	20,903,000	39,491,000	26,054,000	65,545,000
Lock No. 19									
Grain products (in bulk)	-	2,549,000	2,549,000	-	3,892,000	3,892,000	-	5,053,000	5,053,000
Iron & steel articles	703,000	4,000	707,000	1,670,000	10,000	1,680,000	5,528,000	34,000	5,562,000
Sulphur ores & o. B. chemicals	84,000	-	84,000	138,000	-	138,000	295,000	-	295,000
Iron & steel scrap	-	86,000	86,000	-	500,000	500,000	-	2,193,000	2,193,000
Commodities, N.O.S.	198,000	161,000	359,000	327,000	538,000	865,000	674,000	2,281,000	2,955,000
Liquid chemicals & O. B. liquids	-	105,000	105,000	183,000	-	183,000	441,000	-	441,000
Sand and gravel	750,000	-	750,000	1,781,000	-	1,781,000	5,896,000	-	5,896,000
Total	1,735,000	2,905,000	4,640,000	4,099,000	4,940,000	9,039,000	12,834,000	9,561,000	22,395,000

149. MAXIMUM PROJECTED TONNAGE.- In order to determine the year of maximum tonnage through the lock system further investigation of the growth trend data reveals that the projected commerce tonnage for the year 2015 at locks No. 3 and 13 would amount to 15,009,000 and 18,408,000 tons, respectively. Lock No. 3 would handle 15,009,000 tons of projected commerce including the return empty bargetows at about 93 percent of yearly lock operating time on the basis of the 1958 bargeload tonnages. However, lock No. 13 would not handle the 18,408,000 tons including return empty barge tows on the 1958 basis of barge loadings.

150. The projected (2015) commerce tonnage through lock No. 13 includes 5,128,000 tons of upbound sand and gravel commerce, 3,205,000 tons of upbound iron and steel articles, 3,312,000 tons of downbound iron and steel scrap, and 1,591,000 tons of commodities N.O.S. of which 850,000 tons would be upbound and 741,000 tons downbound, in addition to other commerce tonnage as shown in table 22. It is considered that the waterway operators would undertake to move the above designated large tonnage in the most economical and practical way. Furthermore, it is considered that the commerce tonnage could be stockpiled or held in storage in sufficient quantity to assure loading of the barges to full capacity without undue delay in transportation.

151. The upbound sand and gravel commerce would be most economically transported in the larger barges (195' × 35') averaging about 1200 tons per bargeload in lieu of transporting such commerce in the smaller barges (175' × 26') averaging about 800 tons per bargeload. It is further considered that the shipment of 5,128,000 tons of sand and gravel annually would of necessity require three barge tows in lieu of two barge tows below Dallas. Upstream of Dallas, the locks would limit the movement of such commerce to two barge tows.

152. The availability of large tonnage of iron and steel articles, iron and steel scrap and commodities, N.O.S., would assure heavier loading of the barges without delay. Furthermore, the 195' × 35' barges have a rated capacity of 1500 tons loaded to a draft of 9 feet and 1,100 tons loaded to a draft of 7 feet (plate 8, EM 1110-2-2601). It is considered that the waterway operators would load the barges to full capacity when such commerce is available in lieu of loading to 700 tons as considered in the movement of the 1958 commerce. However, for the purpose of this analysis it is considered that the commerce would be moved in bargeloads averaging 1000 tons.

153. CAPABILITY OF LOCK SYSTEM.- On the foregoing basis of larger barge tow tonnage movement of upbound sand and gravel, and the slightly heavier barge loadings of the iron and steel articles, iron and steel scrap, and commodities, N.O.S., the projected 2015 commerce of 18,408,000 tons could be handled by lock No. 13 at about 95 percent of yearly lock operation time. Pertinent information regarding the barge tows required for transportation of the 2015 commerce through lock No. 13 is given in table 22. Accordingly, the proposed system of locks for the channel to Fort Worth would handle the commerce tonnage projected for the year 2015 estimated at 20,144,000 tons. If the channel were terminated at Dallas the projected commerce of 20,144,000 tons would be developed in the year 2019.

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TABLE 22

BARGE TOWS REQUIRED TO TRANSPORT PROJECT 2015
COMMERCE TONNAGE AT LOCK NO. 13 ON THE MULTIPLE PURPOSE
TRINITY RIVER CHANNEL TO FORT WORTH, TEXAS

Projected 2015 commerce		Barge tows required for commerce tonnage based on on modified bargeload tonnages:					
		Tons per	Number of barges			Barges	No. of
Commodity	Tonnage	bargeload	Loaded	Empty	Total	per tow	tows
Upbound commerce - Lock No. 13							
Petroleum products (bulk liquid)	77,000	1,370	56	-	56	3	19
Grain & products (in bulk)	-	-	-	1,218	1,218	3	406
Iron & steel articles	3,205,000	1,000	3,205	-	3,205	3	1,068
Sulfur ores & O.B. chemicals	948,000	1,200	790	-	790	3	263
Iron & steel scrap	-	-	-	1,891	1,891	3	631
Commodities N. O. S.	850,000	1,000	850	-	850	3	283
Liquid chemicals & O.B. liquids	284,000	1,200	237	-	237	3	79
Sand and gravel	5,128,000	1,200	4,273	-	4,273	3	1,424
Total - upbound	10,479,000		9,398	3,122	12,520		4,173
Downbound commerce - Lock No. 13							
Petroleum products (bulk liquid)	-	-	-	56	56	3	19
Grain & products (in bulk)	3,710,000	1,200	3,092	-	3,092	3	1,031
Iron & steel articles	19,000	1,000	19	-	19	3	6
Sulfur ores & O. B. chemicals	147,000	1,200	123	667	790	3	263
Iron & steel scrap	3,312,000	1,000	3,312	-	3,312	3	1,104
Commodities, N. O. S.	741,000	1,000	741	-	741	3	247
Liquid chemicals & O.B. liquids	-	-	-	237	237	3	79
Sand and gravel	-	-	-	4,273	4,273	3	1,424
Total - downbound	7,929,000		7,287	5,233	12,520		4,173
Grand total	18,408,000						

154. The foregoing analysis of the tonnage capacity of the proposed lock system is based on the assumption that the projected commerce tonnage on the channel below Dallas would be moved in standard barge tows, each consisting of three barges 195 feet long by 35 feet wide. This standard barge tow was used only as a basis for estimating the amount of tonnage that could be moved through the lock system. It is realized, however, that the waterway operators would move the commerce tonnage in the most economical way either in smaller or larger barge tows as may be required to meet the specific needs and demands for the respective commodities.

155. A two-barge tow movement through the locks would not require towboat setover and the average lockage time would be about 45 minutes. A three barge tow would require the towboat to be setover adjacent to the last barge and the average lockage time would be about 60 minutes. Accordingly, the average lockage time per barge would be about 20 minutes for either the two-barge or three-barge tows and approximately the same amount of tonnage would be moved through the locks per year by either the two or three barge tows.

156. Larger barge tows of four or five barges, each 195 feet long and 35 feet wide, could be accommodated in a single lockage through the 84-X600-foot locks below Dallas. The barges and towboat of a five-barge tow could be assembled two abreast and three in tandem forming a compact unit of 585 feet long and 70 feet wide in the lock chamber. The average lockage time for the transit of five-barge tows would be slightly longer than the 60 minutes estimated for the transit of three-barge tows. Barge tows of six barges or more would require double lockage for passage through the locks. In view of the foregoing it is considered that barge tows of various size and composition can be efficiently handled by the proposed system of locks.

157. The foregoing analyses indicate that in about the forty-fifth year of project operation the capacity of locks 13 through 17 would be reached and at that time consideration would have to be given to the advisability of providing additional locks or the enlargement of the presently proposed locks in order to handle the increase in projected commerce tonnage beyond the year of 2015. The construction of additional locks appears to be the most feasible method of increasing the capacity of the waterway. On the basis of the projected development of commerce on the waterway the first measures for increasing the waterway capacity would be construction of additional locks at locks Nos. 13 through 17. Subsequently, the development of projected downbound commerce would reach the capacity of the lower section of the waterway and require an additional lock at the locks in the lower reaches of the channel. Depending on the development of through commerce traffic to Dallas and Fort Worth, it eventually would be necessary to provide an additional lock at each of the other locks on the channel in order to handle the projected commerce tonnage for the year 2070. It is considered that the economy of the basin would be served best by initial construction of 84- X 600-foot locks below Dallas and of 56- X 400-foot locks above Dallas, and subsequently as the need arises give consideration to the most feasible means of providing adequate locks and possible some channel improvement when the projected commerce exceed the capacity of the initial system.

158. LOCKAGES REQUIRED FOR OPERATION OF NAVIGATION.- A summary of the lockages required to transport the projected 1970 and 2015 commerce tonnage through each lock of the system and the percent of lockage time required at each lock on the basis of a 365-day year of lock operation time and bargeload tonnage discussed above for year of 2015 is given in table 23.

TABLE 23
PERTINENT INFORMATION CONCERNING LOCKAGES REQUIRED TO PASS PROJECTED 1970 AND 2015 COMMERCE TONNAGES THROUGH THE PROPOSED TRINITY RIVER LOCK SYSTEM

Lock No.	Projected tonnage 1970	Projected tonnage 2015	Lockages per year 1970	Lockages per year 2015	Lockage time (%) 1970	Lockage time (%) 2015
1	7,281,000	15,009,000	4254	6917	49	79
2	7,281,000	15,009,000	4254	6917	49	79
3	7,281,000	15,009,000	4254	6917	49	79
4	6,308,000	15,009,000	3443	6917	39	79
5A	5,335,000	15,009,000	2632	6917	30	79
5B	5,335,000	15,009,000	2632	6917	30	79
6	5,312,000	14,960,000	2619	6889	30	79
7	5,061,000	14,126,000	2410	6193	28	71
8	5,061,000	14,126,000	2410	6193	28	71
9	5,061,000	14,126,000	2410	6193	28	71
10A	4,810,000	13,292,000	2201	5497	25	63
10B	4,810,000	13,292,000	2201	5497	25	63
11	4,810,000	13,292,000	2201	5497	25	63
12	4,810,000	13,292,000	2201	5497	25	63
13	6,352,000	18,420,000	4128	8345	47	95
14	6,352,000	18,420,000	4128	8345	47	95
15	6,350,000	18,408,000	4128	8345	47	95
16	6,350,000	18,408,000	4128	8345	47	95
17	6,350,000	18,408,000	4128	8345	47	95
18	3,645,000	8,186,000	2852	5532	24	47
19	3,645,000	8,186,000	2852	5532	24	47
20	3,603,000	8,092,000	2852	5532	24	47
21	3,603,000	8,092,000	2852	5532	24	47

159. MISCELLANEOUS COMMERCIAL AND PLEASURE CRAFT.- In addition to the barge tows required for the movement of the prospective traffic on the channel to Fort Worth, there would be movement of work boats and floating plant required for operation and maintenance of the channel, towboats with and without empty barges to serve emergency requirements or breakdown of commercial craft, and a considerable number of cabin cruisers, fishing, hunting and other pleasure craft requiring lockage in various sections of the channel. The lockages required for the miscellaneous craft designated above is unknown; however, it is considered that a large number of water craft could be passed through the lock with each lockage of the 3-barge commercial tows operating on the channel below Dallas and the 2-barge tows operating on the channel between Dallas and Fort Worth.

160. The basic assumptions regarding barge tow movement on the channel below Dallas assume that the 84 × 600-foot locks would accommodate a three-barge tandem tow in one lockage by assembling the three barges in tandem with the towboat setover adjacent to the last barge. Assuming the towboat to be 120 feet long, the lock would provide a water area, 49 feet wide by 480 feet long, ahead of the towboat which could be used for the transit of miscellaneous water craft in connection with each lockage of the standard three-barge tow. The unoccupied water area would accommodate a one-barge tow consisting of a 35' × 195' barge and towboat, 120 feet long, or three towboats, or two 35' × 195' barges or 96 small craft averaging 10 feet wide by 20 feet long. Similarly, the 56 × 400-foot locks on the channel above Dallas would provide a minimum water surface area of 21 feet wide by 280 feet long with each lockage of the standard two-barge tandem tow assembled two barges in tandem with tow-boat setover adjacent to the last barge. This area would accommodate about 28 small craft in addition to the standard two-barge tandem tows, but miscellaneous commercial craft and work boats having beam widths greater than 20 feet could not be accommodated in the lock with the standard two-barge tow. It is also considered that for safety purposes miscellaneous craft would not be permitted for lockage with commercial tows transporting highly combustible commerce, but such commerce movement on the channel would be of small amount and would not materially affect the movement of miscellaneous craft.

161. During the first half of the project life of the channel, commercial barge tow lockages would not require hourly lock operation and small craft could be handled expeditiously providing there would be adequate water supply for such lockages. During low flow periods, it probably would be necessary to limit lockage of small craft with commercial barge tows depending on the availability of lockage water. During the second half of the project life, commerce tonnage movement on the channel would approach a requirement of hourly operation of the locks. On the basis of a 12-hour day, with lockages every hour and an average of only 60 small pleasure boats in addition to the commercial barge tows, the 84 × 600-foot locks would handle a total of 720 small pleasure craft per day. Because of the smaller locks (56' × 400') above Dallas, a total of about 300 small pleasure crafts could be handled during a 12-hour day.

162. Investigation of the small craft passing through the Brazos River floodgates and the Colorado River locks on the Gulf Intracoastal Waterway during the 5-year period, 1957 through 1961, as reported monthly by the lock masters, reveals that an average of about 12 and 52 small craft per day passed through the Brazos floodgates and the Colorado River locks, respectively. Additional information concerning the commercial craft and small craft handled at these facilities on a yearly and monthly basis for each year 1957 through 1961 is given in table 24. These facilities are located within a 60- and 90-mile radius, respectively, from Houston, Texas, and provide access to extensive areas affording some of the best fishing and migratory bird hunting on the Gulf Coast.

163. The proposed canalized multiple purpose Trinity River channel to Fort Worth terminus would have a total length of 364 miles and pass through three large water conservation reservoirs. The navigation locks and dams on the channel would form additional water areas having widths of about 200 and 300 feet within the channel banks. These water areas would be more or less deeply entrenced below the ground level and apparently would not become very popular areas for various small water craft activities because of the confined water areas and disturbance caused by passing water craft. The reservoir areas would be most attractive to pleasure craft and lockage to and from these areas would probably be most demanding partly because of the "thrill" involved in the operation and for fishing below the reservoir dams. The locks at these reservoirs could accommodate a large amount of small boat traffic without detriment to commercial barge operation during the early project life. During the latter part of the project life a total of 90 small boats in addition to the commercial barges could be accommodated on an hourly basis during maximum commerce tonnage movement on the channel. In view of the spare water area available in the locks, it is considered that lockage of miscellaneous commercial and small craft can be coordinated and accommodated with the lockages required for the commercial traffic. Accordingly, no allowance is deemed necessary for individual lockage of miscellaneous craft.

TABLE 24
LOCKAGE OF COMMERCIAL BARGE TOWS AND SMALL CRAFT AT THE
BRAZOS AND COLORADO RIVER CROSSINGS OF THE GULF INTRACOASTAL WATERWAY
DURING FIVE-YEAR PERIOD 1957 - 1961
(BASED ON LOCK MASTERS MONTHLY REPORT)

Year	Number of commercial: Towboats per year	Barges per year	Small craft per year	Number of small craft per month: Jan.	Feb.	Mar.	Apr.	May.	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.	Average per day
Brazos River Crossing - Gulf Intracoastal Waterway																
1957	6621	7417	3487	138	171	214	185	68	142	482	1,020	493	273	125	176	9.6
1958	4856	6550	5024	131	14	129	881	239	797	674	507	845	226	291	290	13.8
1959	5521	6409	4243	155	98	298	415	440	586	826	457	425	227	165	151	11.6
1960	4003	5958	4187	135	78	202	466	530	637	636	443	418	330	195	117	11.5
1961	4243	6851	4103	81	95	145	598	433	388	478	500	878	212	165	130	11.2
Total	25,244	33,185	21,044	640	456	988	2,545	1,710	2,550	3,096	2,927	3,059	1,268	941	864	
Average per year	5,049	6,637	4,209	128.0	91.2	197.6	509.0	342.0	510	619.2	585.4	611.8	253.6	188.2	172.8	
Colorado River Crossing - Gulf Intracoastal Waterway																
1957	7543	8530	20,362	1948	1795	1588	1417	127	306	2060	2440	3529	1852	1614	1686	55.8
1958	6632	8750	18,254	1125	496	502	1390	1295	1364	1664	1929	2190	2172	1835	2292	50.0
1959	6801	8798	16,671	1469	1122	1598	1231	1133	1398	1747	1981	1704	1102	1054	1132	45.7
1960	5439	8280	19,152	1288	776	1184	1659	1527	1558	1712	1936	2981	1607	1630	1291	52.5
1961	5477	9510	20,072	812	976	1297	1476	2336	1709	1673	2762	2188	1930	1632	1281	55.0
Total	31,892	43,868	94,511	6,642	5,165	6,169	7,173	6,418	6,335	8,856	11,048	12,592	8,663	7,765	7,682	
Ave.per year	6,378	8,773	18,902	1,328.4	1,033.0	1,233.8	1,434.6	1283.6	1,267.0	1,771.2	2,209.6	2,518.4	1,732.6	1,553.0	1,536.4	

164. STRUCTURAL FEATURES OF LOCKS.- The lock-size formulation study shows that locks having clear basin dimensions of 84 feet wide and 600 feet long on the channel below Dallas, and that locks, 56 feet wide by 400 feet long, on the channel at and above Dallas are the most feasible size of locks for economical transportation of commerce on the channel to Fort Worth. Accordingly, it is considered that the navigation lock, 56 feet wide by 400 feet long, recommended for the multiple purpose Wallisville Reservoir project in the report of the Acting Chief of Engineers contained in House Document No. 215, 87th Congress, 1st Session, be modified to provide a lock 84 feet wide by 600 feet long as recommended in the report of the district engineer contained in the referenced House Document 215.

165. The proposed 84-x600-foot lock for the Wallisville Dam would consist of an upper and lower sector gate structure of massive gravity-type concrete walls founded on wood piling. The gate sills would be set at elevation minus (-) 16.0 with top of sector gate structure at elevation 8.0. The lock basin would consist of a paved earth basin and would contain a mooring wall of pile and timber construction with top of walkway at about elevation 11.0. Steel sheet pile guide walls would be provided adjoining the up-and downstream ends of the sector gate structures. A single leaf, through plate girder type of bascule lift bridge providing a 12-foot roadway would be provided across the 84-foot lock chamber to provide access to the gated river diversion structure located about 4,400 feet downstream of the lock structure. Appurtenant buildings and facilities would be provided for maintenance and operation of the lock structure. A site plan of the proposed lock No. 1 in the Wallisville dam is shown on plate 11.

166. Limited subsurface investigations were made at lock sites for this report, consisting of one core boring to a depth of about 65 feet below the proposed elevations of lower pools. The borings show that the material underlying the proposed lock sites downstream of lock site No. 16, excluding lock sites No. 6 and 7, consist of sands, clays, silts, or mixtures of these materials. The borings at lock site 6, 7, 16, and upstream thereof indicate moderate depths of sands, clays, and silts to bedrock formations of shale and limestone. Based on the limited boring data and general knowledge of the shale formations in the upper reach of the river, it is considered that these formations are inadequate to serve as rock formations for the proposed locks and dams; however, the limestone formations may prove to be adequate for several lock and dam structures in the Dallas area. For the purpose of this report it is considered that pile foundations be provided for lock and dam structures having 30-foot lifts or less. Lock structures having lifts greater than 30-feet would be designed as a "U" frame type lock.

167. Pertinent information concerning the system of locks proposed for canalization of the channel to Fort Worth is given in table 25. Plates 3 through 10 show the location of the selected lock and dam sites and plates 12 through 15 on Pasters pages show a profile of the proposed canalized channel. Preliminary data concerning the subsurface foundation materials at the various lock sites are shown on plates 20 and 21.

TABLE 25

PERTINENT DATA CONCERNING SYSTEM OF LOCKS PROPOSED FOR CANALIZATION OF THE MULTIPLE PURPOSE TRINITY RIVER CHANNEL TO FORT WORTH, TEXAS

Location Lock (1)	Proposed lock: Lock No.	Size (feet)	Pool elevation: Lower	Pool elevation: Upper	Lift (feet)
28.3	1 (2)	84x600	0	4	4
47.45	2 (2)	"	4	16	12
59.08	3	"	16	36	20
74.85	4	"	36	60	24
98.00	5A	"	60	101	41
99.20	5B (3)	"	101	131	30
147.92	6 (3)	"	131	138	7
183.92	7	"	138	168	30
207.55	8	"	168	192	24
217.95	9	"	192	210	18
233.0	10A	"	210	235	25
233.61	10B (4)(5)	"	235	262.5	27.5
258.91	11 (4)(5)	"	262.5	270.0	7.5
274.51	12 (6)	"	270	284	14
286.64	13	"	284	308	24
298.38	14	"	308	326	18
306.31	15	"	326	344	18
311.25	16	"	344	356	12
317.81	17	"	356	372	16
331.31	18	56x400	372	396	24
342.51	19	"	396	424	28
351.91	20	"	424	452	28
360.17	21	"	452	480	28

(1) Distance in miles from the Houston Ship Channel.
(2) Provides for navigation through all stages of conservation storage (elevation 4.0 to 1.0) in Wallisville reservoir.
(3) Provides for navigation through all stages of conservation storage (elevation 131 to 101) in Livingston reservoir.
(4) Provides for navigation through all stages of conservation storage (elevation 262.5 to 235) in Tennessee Colony reservoir.
(5) Provides for navigation through all stages of flood control storage (elevation 262.5 to 285) in Tennessee Colony reservoir.
(6) Lock No. 12 is not inundated when flood storage in Tennessee Colony reservoir is at elevation 285.

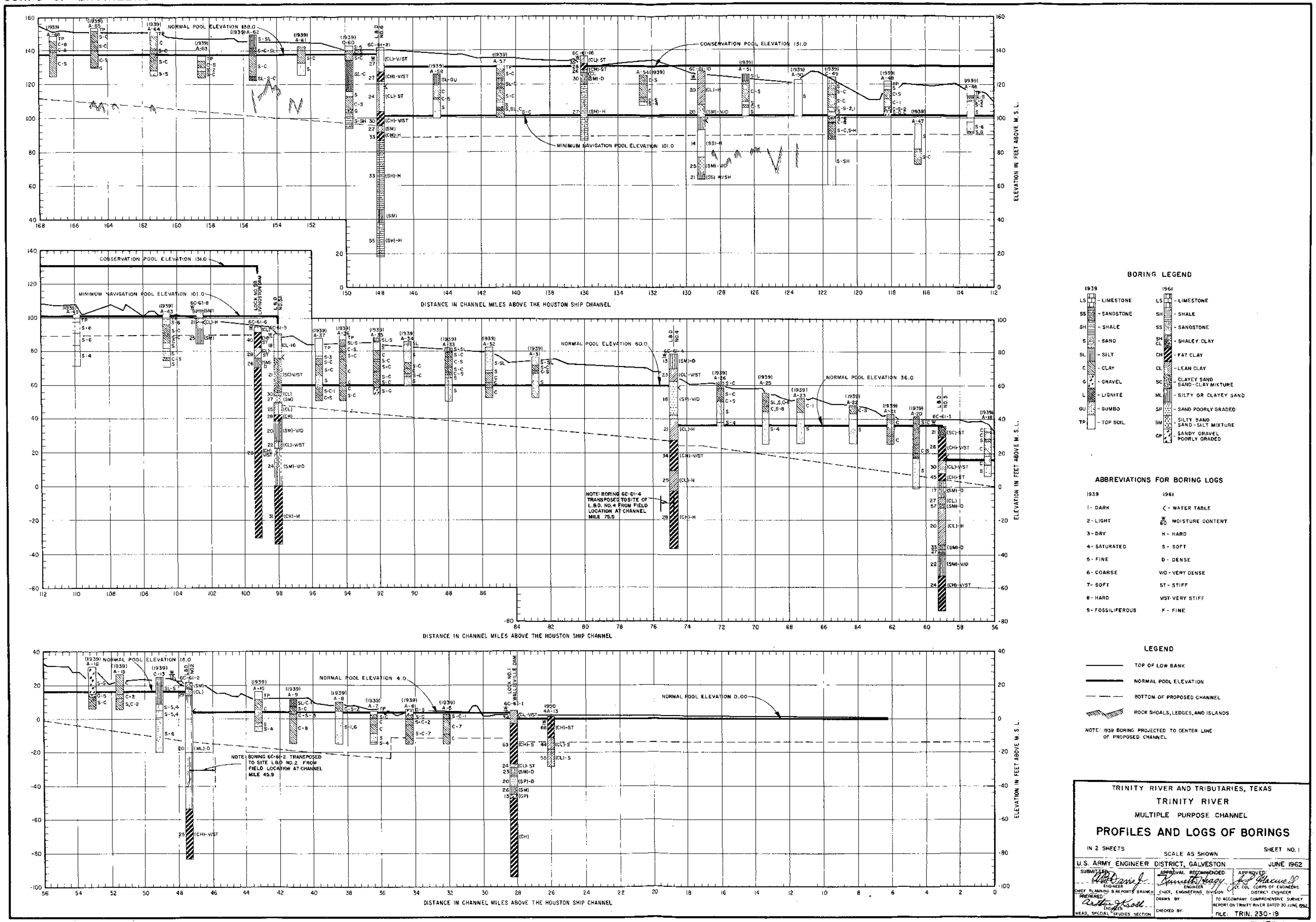

PLATE 20

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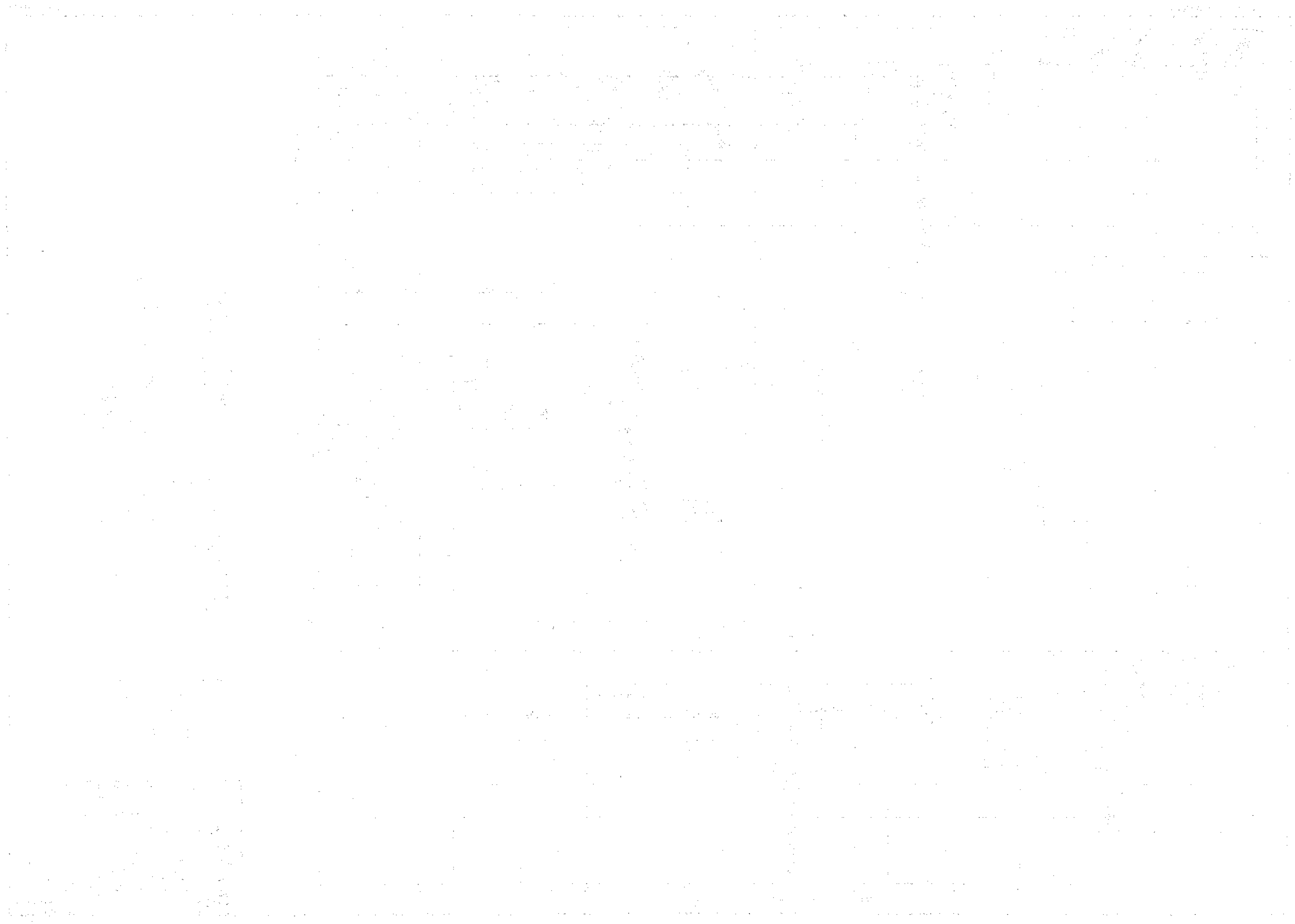

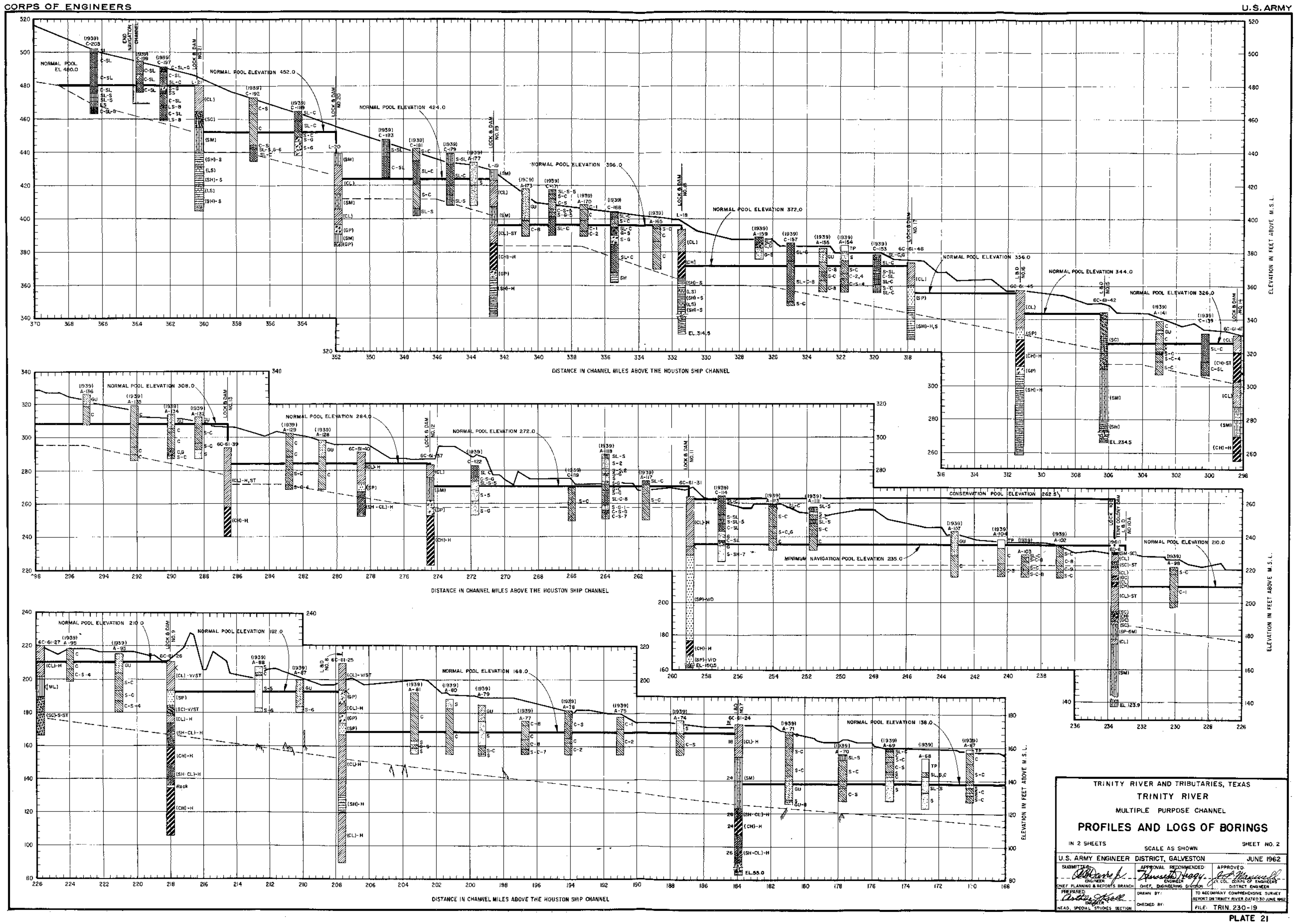

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168. The land and river walls of the proposed locks upstream of lock No. 1 would be massive concrete walls containing a continuous culvert, 12 feet square, with suitable ports for filling and emptying the lock chamber. The lock gates would be of the miter type with both upper and lower miter sills set at a minimum of 15 feet below the respective normal pool elevations. The top of lock gates would provide two feet of freeboard above normal pool elevation which was established at four feet below top of bank at the lock site. The top of lock walls would be seven feet above normal upper pool elevation, or two feet above the flow that occurs 98 percent of time, whichever is the greater. Hydraulic machinery would operate the tainter valves and miter gages with electric motors providing power for the machinery. All locks would be provided with upstream and downstream concrete guidewalls. Each lock would be provided with an explanade and an access road would be provided to each lock site from the nearest improved county or state highway.

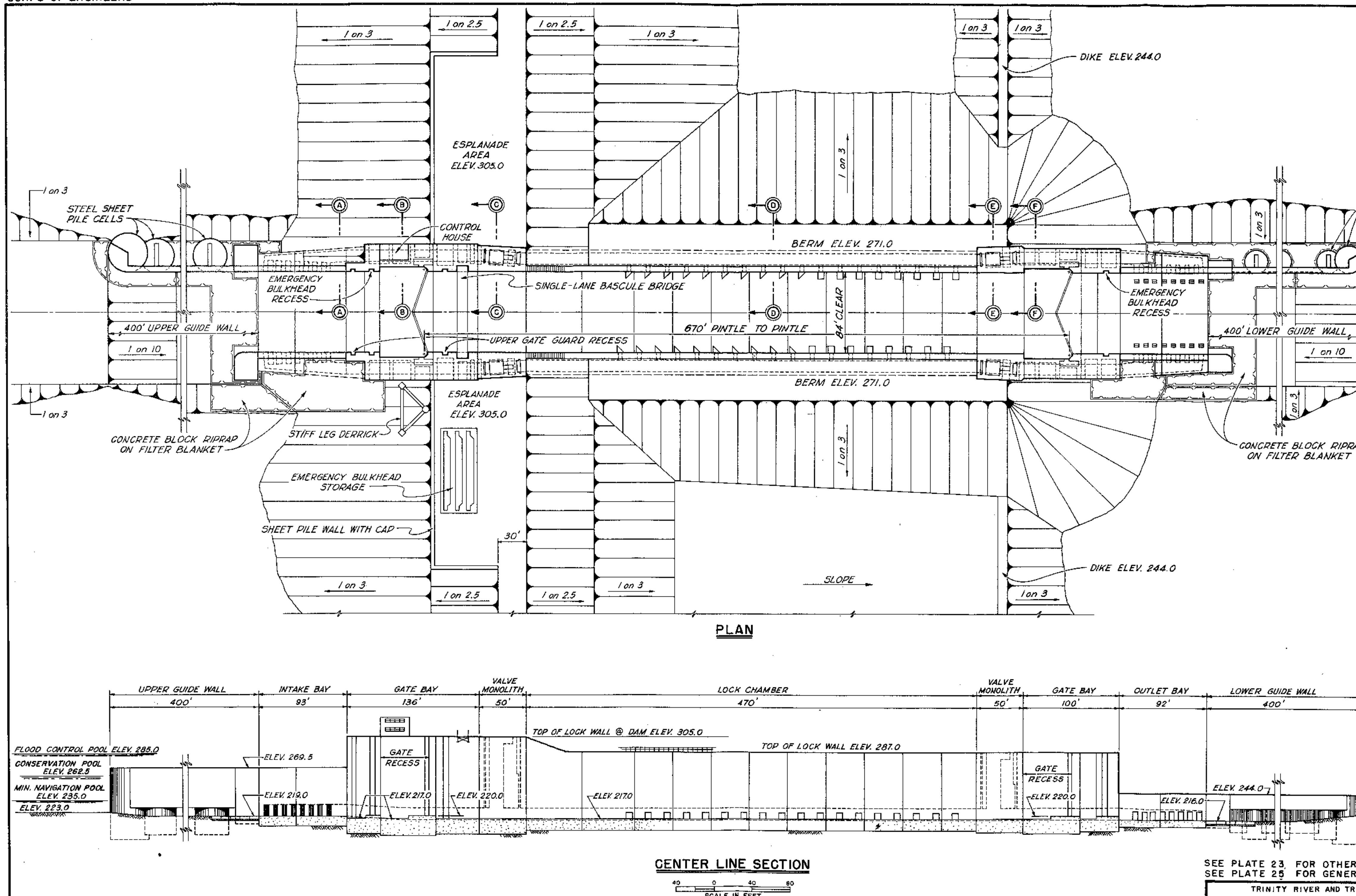
169. Lock Nos. 5A, 6, 10B and 11 would be of concrete "U" frame type similar to the Port Allen lock design. A plan and sectional views of lock 10B are shown on plates 22 and 23, which show the general structural features of the "U" frame type lock design proposed for locks 5A, 6, 10B and 11. Excluding lock No. 1 at the Wallisville reservoir dam and the "U" frame type locks, the other locks would be of massive concrete gravity wall type similar to the Arkansas River lock design. Plates 24 and 25 show a plan and sectional views of the concrete gravity type lock design, founded on batter piling. Site maps of lock No. 1 and 2, 6 and 11 are shown on plate 11 on page 50 and plate 26, respectively. Site maps of locks No. 5 and 5B at the Livingston reservoir dam and Locks 10A and 10B at the Tennessee Colony reservoir dam are shown on plates 16 and 17 on pages 62 and 63. A site map of lock No. 19 is also shown on plate 16.

170. Locks 5B and 10B would be located in the Livingston and Tennessee Colony reservoir dams, respectively. It is imperative that some special means be provided in connection with these locks to prevent the loss of conservation storage from the reservoirs in the event that the lock gates were damaged or sprung apart by accidental collision of barge-tow and gates. Consideration was given to the advisability to provide some type of hinged gage or special designed bulkhead gate which could be installed for the emergency closure or a mechanical operated gate guard installed within the lock to prevent the barge tows colliding with the lock gates. For the purpose of this report, it is proposed that a gate guard be provided in each lock consisting of a structural steel trussed beam, 2.5 feet deep, spanning the full width of the lock between a recess in each wall located 20 feet clear inside the upper gate. The gate guard would be in protective position when upbound barge tows move into the lock and would be mechanically synchronized to be in protective position at the top of the basin pool during filling of the lock chamber. Prior to opening the upper gates, the gage guard would be mechanically controlled to rest on the lock floor during the passage of barge tows out of or into the lock chambers.

The gate guard would be raised to protective position prior to emptying the lock chamber and would be synchronized to be in protective position during emptying of the lock chamber. Details of the gate guard are shown on plate 23.

171. Lock 5B located in the Livingston dam provides for navigation through the reservoir between top of conservation storage at elevation 131.0 and bottom of storage at elevation 101.0. The top of dam is at elevation 140 and has a crown width of 30 feet. The upper gate bay walls of lock No. 5B would extend to the top of dam.

172. Lock 10B located in the Tennessee Colony dam provides for navigation through the Tennessee Colony reservoir during all stages of conservation storage in the reservoir between elevations 262.5 and 235.0, also during all stages of flood control storage between elevation 262.5 and 285.0. The lock walls of lock 10B extend to the top of the Tennessee Colony dam at elevation 303.0 as shown on plate 22.



SEE PLATE 23 FOR OTHER SECTIONS
SEE PLATE 25 FOR GENERAL NOTES

TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER
MULTIPLE PURPOSE CHANNEL
TYPICAL LOCK (U-FRAME TYPE-LOCK 10B)
PLAN AND ELEVATION
SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, GALVESTON JUNE 1962

SUBMITTED: ENGINEER, CHIEF, PLANNING & REPORTS BRANCH
APPROVAL RECOMMENDED: ENGINEER, CHIEF, ENGINEERING DIVISION
APPROVED: LT. COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: HEAD, SPECIAL STUDIES SECTION
DRAWN BY: W.E.D.
CHECKED BY
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER DATED
FILE TRIN. 230-19

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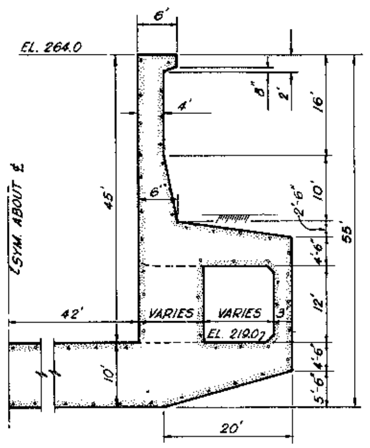
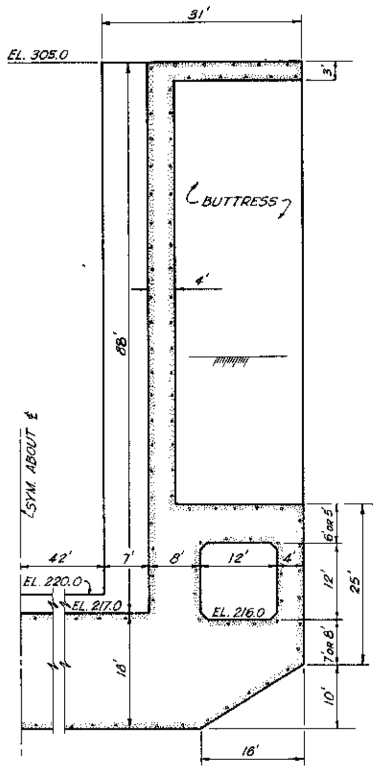


SECTION A-A

10 0 10 20 30
SCALE IN FEET



SECTION B-B

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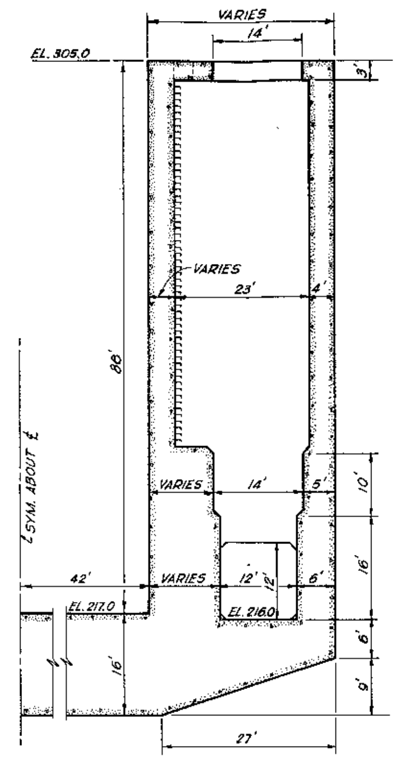
SCALE IN FEET



SECTION C-C

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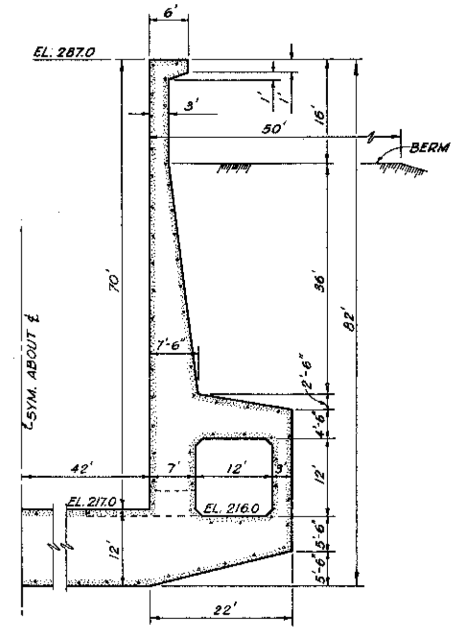
SCALE IN FEET



SECTION D-D

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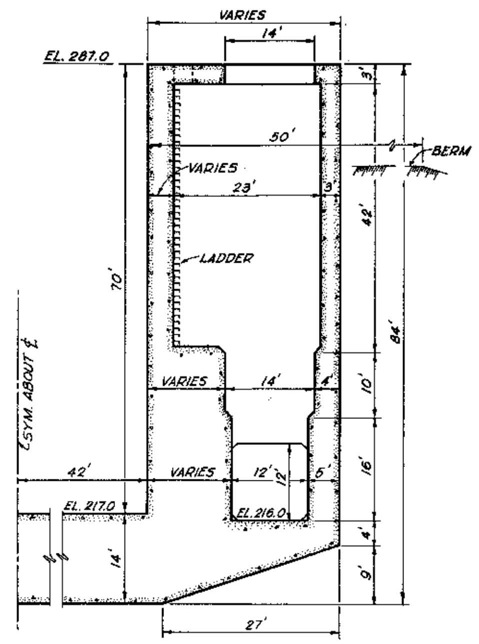
SCALE IN FEET



SECTION E-E

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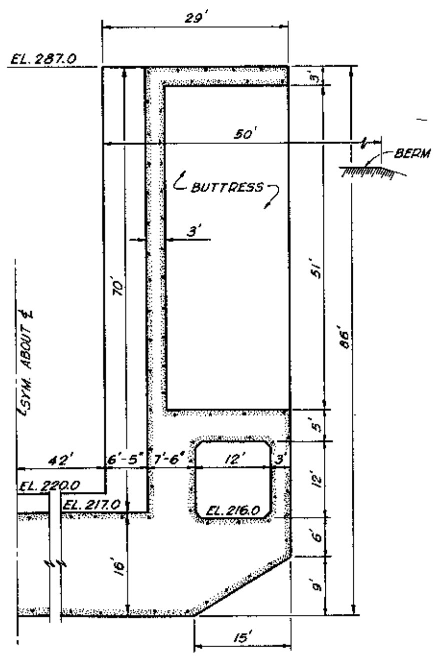
SCALE IN FEET



SECTION F-F

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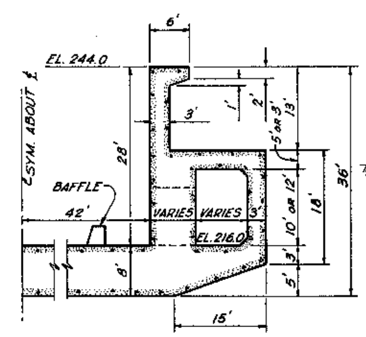
SCALE IN FEET



SECTION G-G

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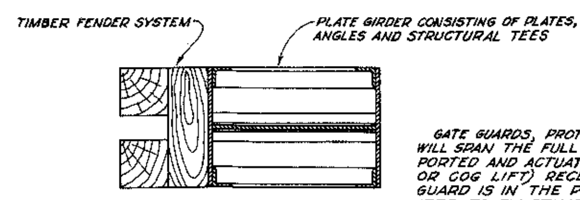
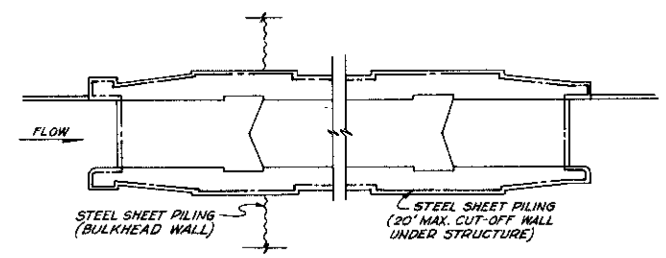
SCALE IN FEET



GATE GUARD SECTION

1 0 1 2 3 4
SCALE IN FEET



SHEET PILE LAYOUT

80 0 80 160 240
SCALE IN FEET

GATE GUARDS, PROTECTING THE UPPER GATES AT LOCKS 5B & 10B, WILL SPAN THE FULL WIDTH OF THE LOCK. THEY WILL BE SUPPORTED AND ACTUATED BY A MECHANIZED DEVICE (HYDRAULIC OR COG LIFT) RECESSED IN EACH WALL. WHEN THE GATE GUARD IS IN THE PROTECTIVE POSITION IT WILL BE MECHANIZED TO FLUCTUATE WITH THE RESPECTIVE POOL LEVEL. WHEN THE UPPER GATE IS IN THE OPEN POSITION THE GATE GUARDS WILL REST ON THE BOTTOM OF THE LOCK. GATE GUARDS WILL BE MECHANICALLY SYNCHRONIZED WITH THE UPPER GATE TO BE IN THE PROTECTIVE POSITION BEFORE AND AFTER THE UPPER GATE IS OPENED.

SEE PLATE 25 FOR GENERAL NOTES

TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER

MULTIPLE PURPOSE CHANNEL

TYPICAL LOCK (U-FRAME TYPE-LOCK 10B)

SECTIONS

SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, GALVESTON — JUNE 1962

SUBMITTED: CHIEF, PLANNING & REPORTS BRANCH | APPROVAL RECOMMENDED: CHIEF, ENGINEERING DIVISION | APPROVED: LT. COL. CORPS OF ENGINEERS, DISTRICT ENGINEER

PREPARED: ENGINEER, HEAD, SPECIAL STUDIES SECTION | DRAWN BY: | CHECKED BY: | TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER DATED | FILE: TRIN. 230-19

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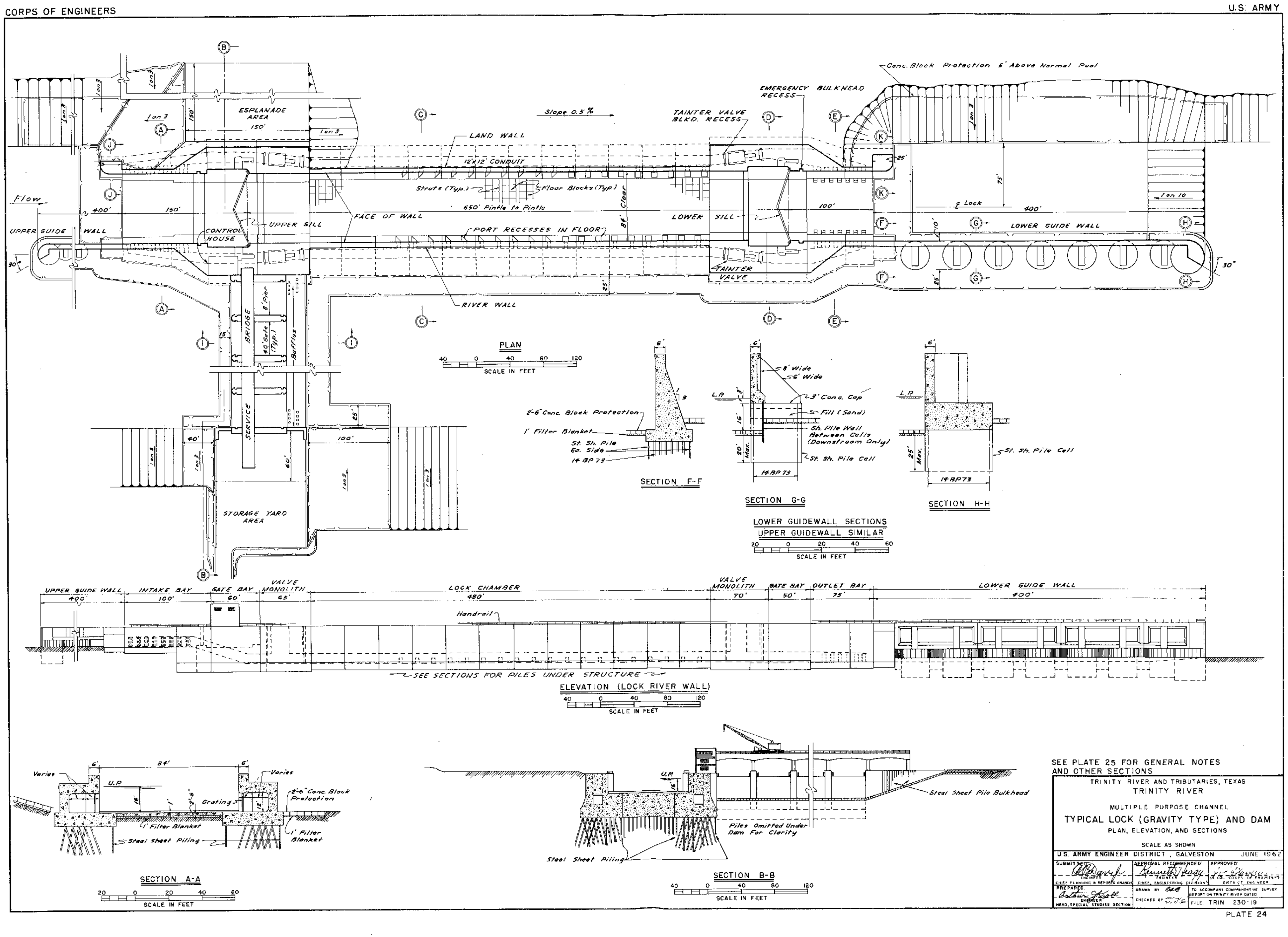

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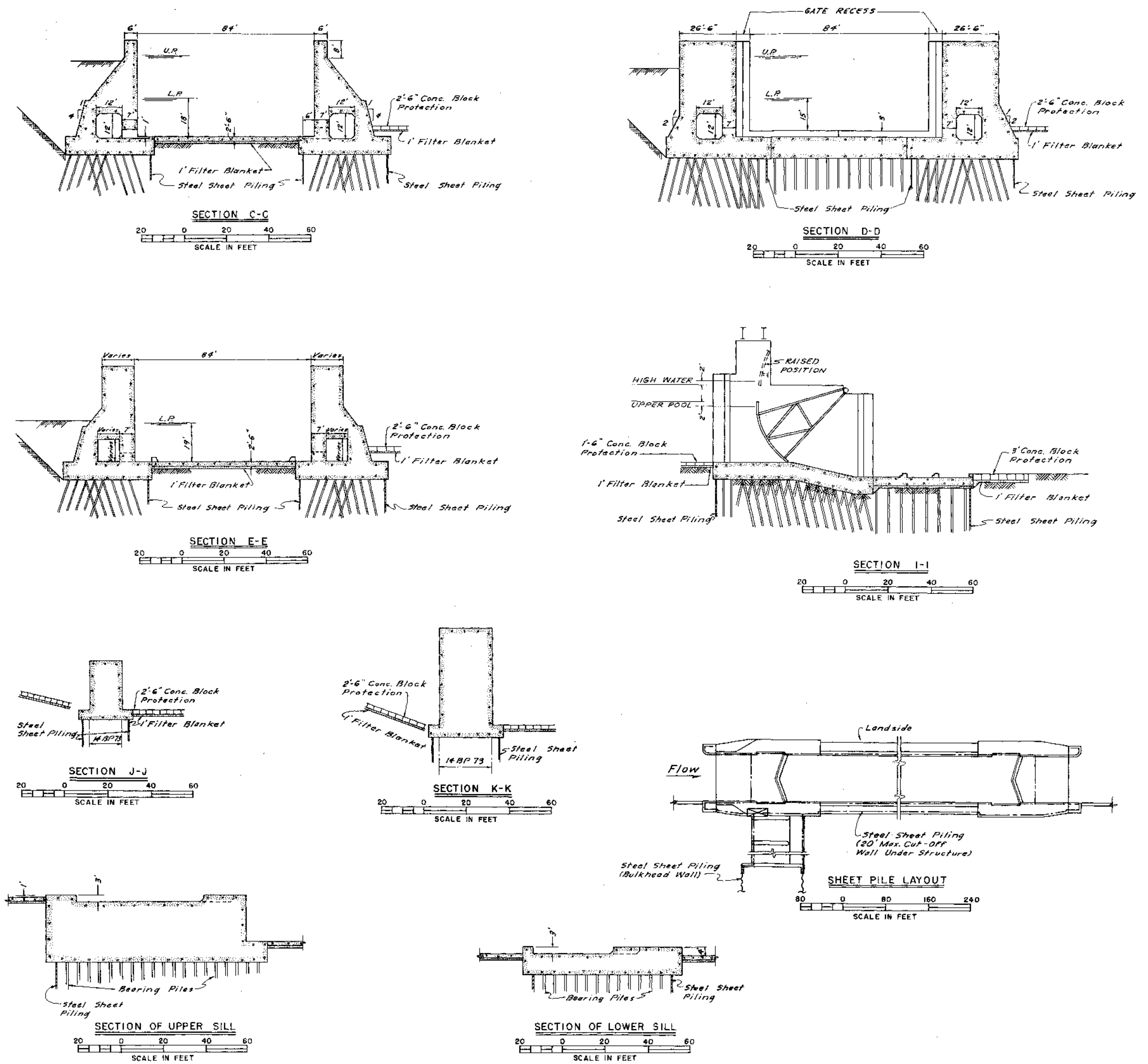

GENERAL NOTES

LOCKS

1. THE 84'x600' LOCK SHOWN ON PLATES 24 AND 25 IS REPRESENTATIVE OF LOCKS 2, 3, 4, 7, 8, 9, 10A, 12, 13, 14, 15, 16, AND 17.
2. OTHER LOCKS ARE SIMILAR EXCEPT FOR THE FOLLOWING FEATURES:
   a. LOCKS 5A, 6, 10B, AND 11 ARE U-FRAME LOCKS (WITHOUT BEARING PILES, SEE PLATES 22 AND 23).
   b. LOCKS 5B AND 10B (REFER TO PLATES 22 AND 23).
      (1) CHAMBER IS APPROXIMATELY 20 FEET LONGER TO ACCOMMODATE THE GATE GUARD.
      (2) A SINGLE LANE BASCULE BRIDGE IS PROVIDED.
      (3) LOCK WALLS AT DAM SECTION ARE EXTENDED TO PROVIDE RETAINING WALLS. UPPER GATE HEIGHTS ARE ADJUSTED ACCORDINGLY.
   c. LOCKS 18, 19, 20, AND 21 - SMALLER LOCKS (56'x 400' CHAMBER IN LIEU OF 84'x 600' AND 300-FOOT GUIDEWALL LENGTHS IN LIEU OF 400-FOOT).
3. THE FOLLOWING CRITERIA APPLIES TO LOCKS 2 THROUGH 21, EXCEPT AS NOTED.
   a. DEPTH AT SILLS - 15 FEET BELOW RESPECTIVE POOLS.
   b. TOP OF WALLS - 7 FEET ABOVE NORMAL UPPER POOL OR 2 FEET ABOVE MAXIMUM NAVIGATION POOL WHICHEVER IS HIGHER, EXCEPT FOR 5B & 10B.
   c. BOTTOM OF CHAMBER FLOOR - 18 FEET BELOW LOWER POOL.
   d. BOTTOM OF CULVERT - 19 FEET BELOW LOWER POOL.
   e. SIZE OF CULVERTS - 12'x 12'.
   f. HEIGHT OF GATES - 1 FOOT BELOW TOP OF SILL TO 2 FEET ABOVE UPPER POOL, EXCEPT UPPER GATES AT LOCKS 5B AND 10B.
4. THE FOLLOWING CRITERIA IS USED WHERE APPLICABLE:
   a. STEEL BEARING PILE CAPACITY - 90 TONS MAX, UNDER EXTREME LOADING.
   b. SHEET PILE CUTOFF WALL LENGTH - 20 FEET MAXIMUM.
   c. EMBANKMENT PROTECTION - 5 FEET ABOVE NORMAL POOL ON EARTH SLOPES OPPOSITE GUIDE WALLS AND AT BASE OF WALLS AS SHOWN
5. GUIDE WALL AND GUARD WALL SECTIONS ARE TYPICAL FOR LOCKS 2 THROUGH 21.
6. GRAVITY TYPE WALLS ON BEARING PILES ARE DESIGNED TO BE INDEPENDENTLY STABLE.

DAMS

1. THE CONTROL DAM SHOWN IS REPRESENTATIVE OF DAMS 2, 3, 4, 6, 7, 8, 9, 12, 13, 14, 15, 16, 17, 18, 19, 20, AND 21.
2. CONTROL DAMS ARE NOT REQUIRED AT SITES 5A, 5B, 10A, AND 10B.
3. A CONCRETE SPILLWAY IS PROVIDED FOR DAM 11.
4. THE FOLLOWING CRITERIA APPLIES TO ALL CONTROL DAMS.
   a. WIDTH OF GATES - 40 FEET.
   b. WIDTH OF PIERS - 8 FEET.
   c. WIDTH OF MONOLITHS - 48 FEET.
   d. TOP OF GATES - 2 FEET ABOVE UPPER POOL.
   e. TOP OF PIERS, ABUTMENTS AND STORAGE YARD - 2 FEET ABOVE HIGH WATER.
   f. SILL ELEVATION - 12 FEET BELOW UPPER POOL ELEVATION OR DESIGN APPROACH CHANNEL BOTTOM, WHICHEVER IS THE LOWER ELEVATION.

TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER
MULTIPLE PURPOSE CHANNEL
TYPICAL LOCK (GRAVITY TYPE) AND DAM
SECTIONS
SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, GALVESTON JUNE 1962

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
ENGINEER, CHIEF PLANNING & REPORTS BRANCH	ENGINEER, CHIEF, ENGINEERING DIVISION	LT COL CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ENGINEER, HEAD, SPECIAL STUDIES SECTION	DRAWN BY [illegible] / CHECKED BY [illegible]	TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER DATED / FILE: TRIN. 230-19

PLATE 25

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CORPS OF ENGINEERS

U. S. ARMY

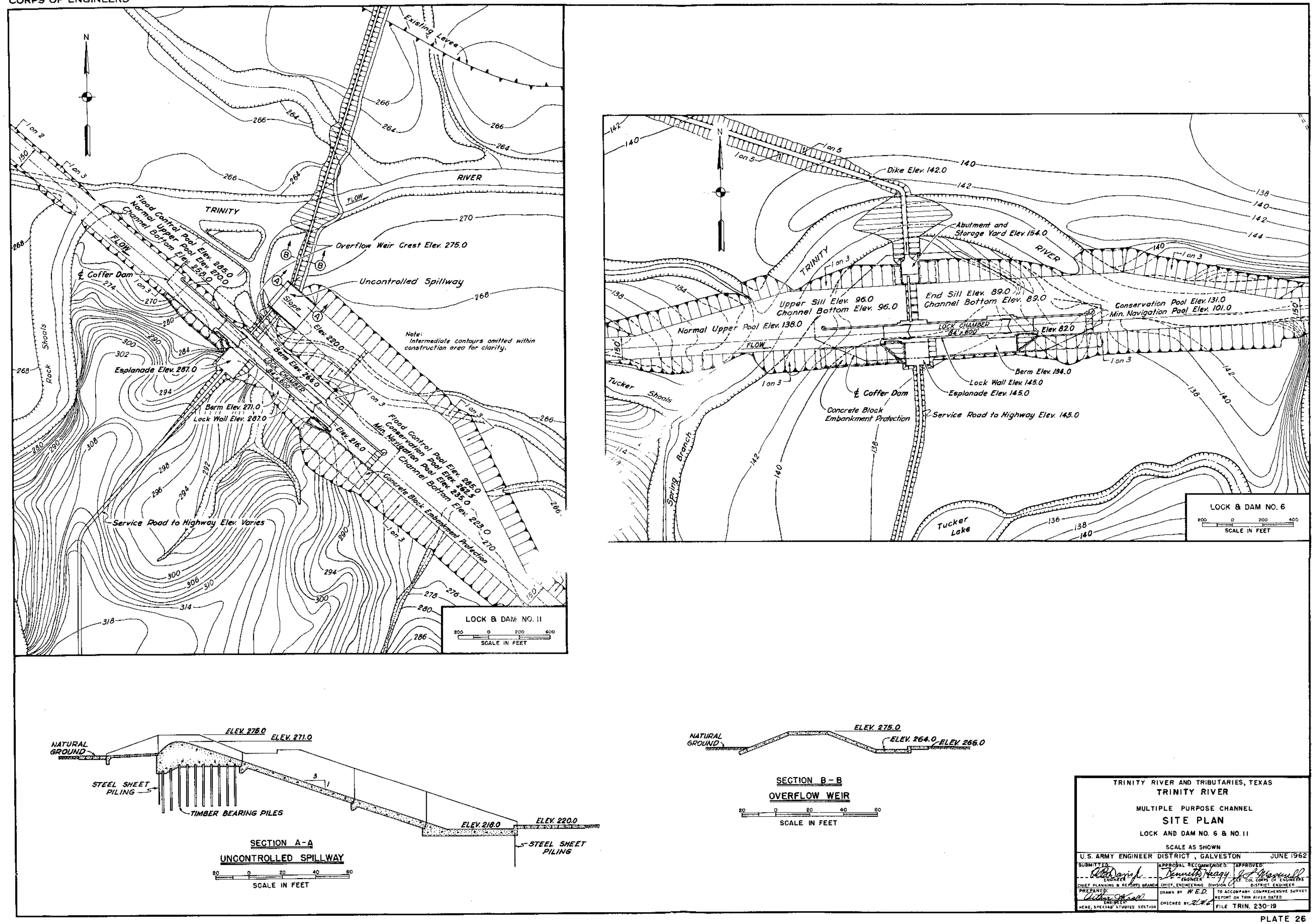
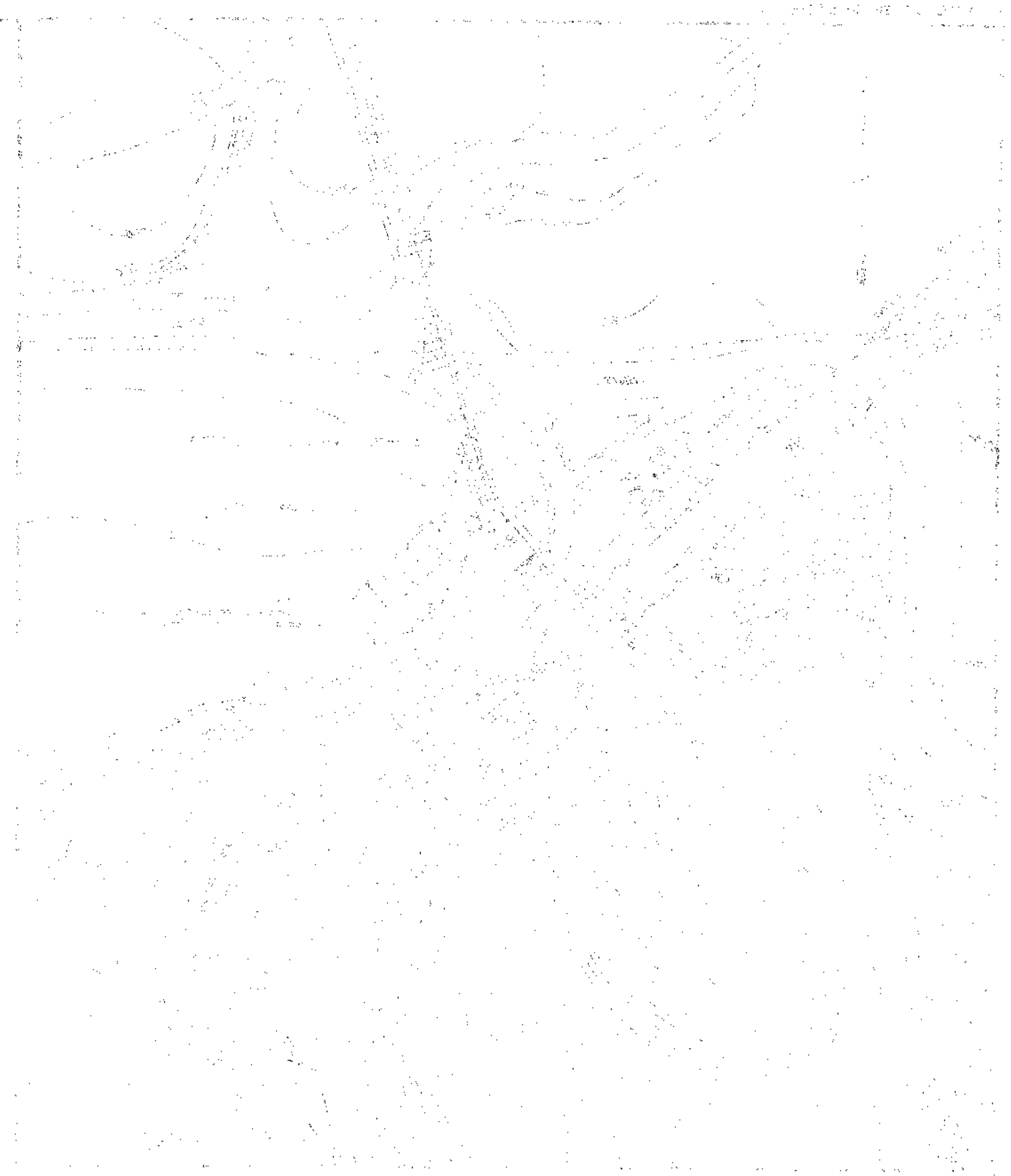


PLATE 26

52-704 O-63 Vol. II (Face p. 188) No. 5



173. STRUCTURAL FEATURES OF DAMS.- All of the 17 movable dams proposed by the plan of improvement for the canalized channel to Fort Worth would consist of non-submersible tainter gates, 40 feet long, with sill set at the design elevation of the multiple purpose approach channel at the dam site. The number of gates at each site was determined by the criterion that the swell head should not exceed one foot when discharging the capacity of the channel at that point. The design provides a free board of one foot on the gates of all movable dams to permit a reasonable amount of storage in the pools, and to meet variations in demand and thereby avoid the unnecessary waste of water. The piers and service bridges are of sufficient height to permit raising the gates 5 feet above the maximum experienced highwater. The dams are founded on bearing piles, battered in two directions to withstand the lateral loads. Steel sheet pile cutoff walls would be provided at the upstream edge of the sill and at the downstream edge of the concrete stilling basin.

174. Further information concerning the design of the movable dams and the overflow dam No.11 is given in appendix VI. The structural features of a typical dam are shown on plates 24 and 25. A site plan of lock and dam Nos. 1 and 2 are shown on plate 11, of lock and dam Nos. 6 and 11 on plate 26, and of lock and dam No. 19 on plate 16. These site maps, excluding ground and channel elevations, illustrate the general features of the proposed lock and dam installations shown on the general maps, plates 3 through 10. Pertinent information concerning the navigation dams is given in table 26.

TABLE 26

PERTINENT DATA CONCERNING NAVIGATION DAMS PROPOSED FOR CANALIZATION OF THE MULTIPLE PURPOSE TRINITY RIVER CHANNEL TO FORT WORTH, TEXAS

Location	Proposed dam					
	Normal Pool elevation:			Elevation: 2 percent:	Sill eleva-:	Number & size
Dam (1)	Lower	Upper	Lift (feet)	flow(2)	tion	of gates
28.3	0	4	4	5.0	-16.0	4-40x21
47.45	4	16	12	17.0	-13.0	7-40x31
59.08	16	36	20	37.0	3.5	6-40x34.5
74.85	36	60	24	61.0	26.0	6-40x36
98.00	60	101	41	(3)		
99.20	101	131	30	(3)		
147.92	131	138	7	139.0	96.0	5-40x44
183.92	138	168	30	169.0	126.0	5-40x44
207.55	168	192	24	193.0	152.0	5-40x42
217.95	192	210	18	211.0	166.0	6-40x46
233.0	210	235	25	(4)		
233.61	235	262.5	27.5	(4)		
258.91	262.5	270.0	7.5	Notched overflow spillway dam		
274.51	270	284	14	286.0	258.0	5-40x28
286.64	284	308	24	309.0	278.0	6-40x32
298.38	308	326	18	327.0	302.0	5-40x26
306.31	326	344	18	345.0	322.0	5-40x24
311.25	344	356	12	357.0	331.0	5-40x27
317.81	356	372	16	373.0	344.0	5-40x30
331.31	372	396	24	397.0	363.5	5-40x34.5
342.51	396	424	28	425.0	402.0	6-40x24
351.91	424	452	28	451.0	426.0	6-40x28
360.17	452	480	28	481.0	451.0	6-40x31

(1) Distance in miles from the Houston Ship Channel.
(2) Elevation of two percent flood discharge (regulated).
(3) Livingston reservoir spillway controls river flows.
(4) Tennessee Colony reservoir spillway controls river flows.

175. ACCESS ROADS TO LOCK SITES.- An access road would be provided from the nearest improved all weather state or county road to each lock site, excepting lock No. 1, which would be provided for under the recommended Wallisville reservoir project. The access roads were selected during a field reconnaissance and consultation with local persons familiar with roads in the vicinity of each lock site. Existing graded roads would be used where favorably located. One access road would be provided to serve locks Nos. 5A and 5B, similarly for locks Nos. 10A and 10B.

176. BUILDINGS, GROUNDS AND UTILITIES.- In general the locks and dams proposed for canalization of the multiple purpose channel to Fort Worth would become readily accessible to local communities on completion of the access roads to the lock sites. It is considered that reasonable living quarters could be found in the communities and that it would not be necessary to provide quarters at the lock sites for lockmen and other personnel, excepting the lockmaster. Accordingly, the plan of improvement provides for a lock master's quarter to be constructed on the lock reservation area including a combination garage and storage shed and other utilities.

177. PERMANENT OPERATING EQUIPMENT.- It is proposed that each lock installation be provided with a set of operating equipment, except locks No. 1, 5A, 5B, 10A and 10B. Lock No. 1 would be provided with operating equipment in connection with the recommended Wallisville reservoir project. One set of operating equipment would be provided to serve both locks Nos. 5A and 5B, and similarly for locks Nos. 10A and 10B. Twenty sets of operating equipment would be required for the system of locks and dams.

178. A river observation system would be required for the collection of basic precipitation and river stage data required to forecast the operation of the navigation dams on the multiple purpose channel to pass flood rises and reservoir releases and at the same time maintain normal pool elevation for navigation. The existing precipitation and stream recording gages on the basin would be augmented by 26 standard precipitation gages and 40 waterstage recorders for navigation forecasting purposes.

179. AIDS TO NAVIGATION.- The Commander, Eighth Coast Guard District, New Orleans, Louisiana, by letter dated October 30, 1961, advises that aids to navigation for the multiple purpose channel to Fort Worth would consist of single pile daybeacons installed on the channel bank at the lower ends of river cut-offs and along the channel route as may be necessary, and that 3rd class radar reflecting buoys would be used to mark the channel through the Livingston and Tennessee Colony Reservoirs. In addition, a light attendant station complete with wharf, vehicles and a 45-foot buoy boat would be provided at each reservoir. Two sites of approximately two acres each would be required for the light attendant stations. Aids to navigation through the Wallisville Reservoir are provided for in the Wallisville Reservoir project.

180. DIFFICULTIES ATTENDING NAVIGATION.- The only existing Federal project for navigation on the Trinity River is the authorized channel to Liberty. This channel was completed to one mile below Anahuac, Texas, but has not been maintained. The controlling depth of the channel is reported to be two and one-half feet. Some navigation on the upper portion of the completed channel to and from Trinity Bay, limited to small mud-shell barges, oil exploration boats and pleasure boats, is feasible via the Double Bayou channel extending to Trinity Bay and crossing the project channel at about mile 15.

181. Traffic movement on the lower Trinity River is feasible via the Trinity River to about river mile 20. Under favorable flow conditions in the river, occasional movement of small mud-shell barges is feasible to Liberty, Texas, at about river mile 40. Tide water extends in the river to Liberty and shoals in the river upstream of mile 20 obstruct navigation during low-flow periods.

182. The natural low-water depth in the Trinity River upstream of Liberty, being only a few feet over the bars and shoals, is inadequate for small fishing and pleasure craft to navigate extensive reaches of the river. The narrow widths of the river including sharp curves and range in stream flow with long durations of low flows prevent commercial navigation on the river.

183. The proposed multiple purpose channel improvement of the Trinity River would permit year-round navigation to Fort Worth, Texas. Barge-tow crossing of the open waters of Galveston Bay at Red Fish Bar would be difficult and hazardous during storms and periods of rough weather and fog. The occurrence of these adverse weather conditions would probably cause infrequent minor delays to navigation.

184. Investigation reveals that some minor delays to navigation on the multiple purpose channel would occur upstream of the Tennessee Colony Reservoir during the recurrence of major floods of record on the Trinity River under 2020 conditions of modified reservoir regulation on the basin. It is considered that regulated discharges equal to or exceeding the proposed bankfull capacity of the channel at the respective gaging stations would cause cessation of navigation during the period the discharges exceeded bankfull channel capacity. A summary of the number of days navigation would probably be delayed at various locations on the channel during a recurrence of these major floods of records under modified 2020 conditions in the Trinity River basin is shown in the following tabulation:

Gaging station	Location (channel miles)	Channel capacity(1)	Days of navigation delays during flood Apr-July (1942)	Feb-May (1945)	Apr-July (1957)
Grand Prairie	345.3	15,000	0	1	1
Dallas	333.9	25,000	4	1	1
Rosser	298.0	32,000	6	2	0
Oakwood	220.6	45,000	0	0	0
Riverside	136.1	45,000	0	0	0
Romayor	75.8	45,000	0	0	0

(1) Designed bankfull capacity in cubic feet per second.

185. Investigation was made of the delays to navigation that probably would be experienced on a single purpose navigation channel to Fort Worth during the recurrence of the three major floods of record under modified existing conditions in the basin which excludes any improvement of the natural river channel in the interest of flood control. It is also considered that the single purpose navigation channel would not materially increase the natural capacity of the river, and that navigation on the single purpose channel would not be safe and feasible when flows exceed flood stage at the various stream gaging stations. A summary of the number of days navigation would probably be delayed on the single purpose channel to Fort Worth during a recurrence of the three major floods of record under modified existing conditions is shown in the following tabulation:

Gaging station	Discharge at flood stage (c.f.s.)	Days of navigation delays during flood of Apr-July (1942)	Feb-May (1945)	Apr-July (1957)
Grand Prairie	7,000	22	6	25
Dallas	13,000	21	10	28
Rosser	9,000	114	81	75
Oakwood	24,000	42	39	60
Riverside	53,000	6	7	24
Romayor	40,000	12	26	47

186. The difference in the number of days of navigation shown in the above two tabulations for modified-2020 conditions and modified existing conditions indicates the beneficial effect on navigation that would result from the ultimate development of the Trinity River basin water resources. Analyses of the three major floods of record indicate that the recurrence of smaller floods of record under modified-2020 conditions apparently would not result in many days of delay to navigation. Whereas, under modified existing conditions, additional days of delay to navigation would probably be experienced during the smaller floods, and in the aggregate would be considered detrimental to navigation on the single purpose navigation channel.

187. In view of the foregoing, it is considered that regulated flood discharges in the multiple purpose channel under 2020-conditions would not cause serious delays to navigation and that the channel would provide for dependable navigation to Fort Worth.

188. The multiple purpose channel to Fort Worth would be subject to occasional freezing temperatures throughout its full length. However, it is considered that freezing or below freezing temperatures would not cause ice formations on the channel which would seriously interfere with navigation. The longest period of freezing or below freezing temperature at Dallas, Texas, occurred during the 16-day period, January 9-24, 1918 according to reports of the United States Weather Bureau. It is further reported that the average number of nonconsecutive days of freezing or below freezing temperatures at Dallas are as follows: four days in November, eight days in December, twelve days in January, six days in February and three days in March. In view of the foregoing only minor delays to navigation would result from adverse winter weather conditions.

NAVIGATION ECONOMICS

189. GENERAL.- This section of the appendix is to provide basic supporting data, analyses and computations that form the basis for estimating the savings to navigation that would be derived from a shallow-draft navigation channel for barge transportation in the Trinity River from the Houston Ship Channel to Dallas and Fort Worth, Texas. The study, of survey scope, is based on current economic and transportation conditions in the area that would be served by the proposed navigation channel in the Trinity River.

190. TRAFFIC STUDY.- The report contained in House Document 403, 77th Congress, 1st Session, submitted by the District Engineer in November 1939, is the last comprehensive traffic study made by the Corps of Engineers of existing traffic in the area that would be served by a waterway in the Trinity River terminating at Fort Worth, Texas. The current traffic study is based on data developed on current economic and transportation conditions in the traffic area and not on an adjustment of information contained in the 1939 report. The traffic survey was completed in 1959 and amounts of commodities and other basic data are as of November 1958.

191. Traffic available for transportation by barge on the proposed waterway would consist of traffic now moving by other modes of transportation between the traffic area and other sections of the United States served by connecting waterways as well as of traffic moving within the immediate area served by the proposed waterway. An extensive field canvass of shippers and receivers of freight; a study of available traffic statistics; and a traffic rate analysis were necessary to identify the commodities and their amounts that could be moved over the proposed waterway at a saving in transportation costs.

192. TRAFFIC AREA.- The traffic area, described in paragraph 20, was determined by analyzing the existing transportation rates and charges of all modes of transportation to determine the geographic extent that the proposed waterway would affect commodity traffic moving in the area adjacent to the Trinity River. The traffic area shown in figure 2 represents the maximum areas inland from the proposed waterway which could be served more economically by the Trinity River barge canal than by land routes or by combination of existing and authorized water and land routes. This area is the aggregate territory to, from, and through which prospective commodity traffic was considered in the survey. This area was used as a basis to develop a comprehensive list of traffic contacts for field canvass.

193. FIELD CANVASS OF TRAFFIC.- The field canvass of traffic consisted of interviews and correspondence with about 2,000 shippers and receivers of commodities in the traffic area. The field canvass and follow-up correspondence was accomplished during the period January - May 1959. All estimates of traffic are based on conditions existing in 1958, the latest traffic year for which data were available. Canvass of the traffic area was supplemented by interviews and correspondence with major shippers in

the extended traffic area described in paragraph 22. Principal cities in the extended traffic area in which major shippers were contacted include Tampa, Mobile, Birmingham, Chicago, Toledo, Cleveland, Youngstown, St. Louis, New York, New Orleans, Lake Charles, Oklahoma City, Bethlehem, Pittsburgh, Philadelphia and adjacent towns in their areas. Guides used to compile lists of concerns to be canvassed included state and city industrial guides; chambers of commerce and other civic organizations membership lists; directory of commercial traffic executives, Poor's Register of Directors and Executives, and other sources.

194. Field surveyors soliciting traffic information in the canvass of traffic included two traffic specialists, each a practitioner before the Interstate Commerce Commission and State Regulatory Commissions, two transportation specialists and Corps personnel. The field study developed information on commodities moving in the area; origin and destination; present mode of shipment; transportation rates; costs of transfer of commodities between different modes of transportation; switching charges; and related information pertaining to actual commerce in the area. Related information was also developed from operators of terminals and barge lines on terminal costs, towing operations and practices and requirements of regulations on inland waterways. Questionable items of traffic developed in the traffic study were resolved by correlation with applicable published statistics.

195. SPECIAL STUDIES.- A special study was made of the sand, gravel and crushed stone that could reasonably be expected to move on the proposed waterway. Industry practices, lack of available market records, the highly competitive nature of the sand and gravel business, and the unwillingness of sand and gravel companies to release exploratory information on extent and location of proven deposits of these materials precluded a conventional approach for study of these commodities. The special study included an examination and evaluation of geologic reports from the University of Texas; the Stanford report prepared for the Trinity Improvement Association; the traffic study prepared by the Trinity Improvement Association, and reports and reference material by the United States Bureau of Mines. In addition field survey teams contacted Texas State Highway officials and engineering personnel, numerous companies dealing in sand and gravel throughout the area, and large consumers of these materials to determine how these materials are now moving, the transportation cost, present sources of supply, the estimated life of these deposits, and the destination of these materials. Data developed from the foregoing sources were utilized in a requirement study to identify the nature of the market for these materials. Conventional studies were then conducted on a comparative transportation cost basis of alternate sources of these materials on the Trinity River. The findings of the special sand and gravel study are that over 32 million tons of sand and gravel and over 36 million tons of crushed stone were produced in Texas in 1958. Resources developed in the special study indicate a reserve of about 639.6 million tons of sand, gravel, and stone available at several locations on the Trinity River. Requirements estimated for these materials in the tributary

area amount to over 6 million tons annually in the Dallas-Fort Worth area and over 4,700,000 tons annually in the Houston-Galveston area. The quantities of these materials accepted as prospective waterway traffic amount to 2,934,000 tons for the study of the channel to Fort Worth. The reserves are considered to be adequate to meet the demand for these materials over the life of the project. Reserves of sand, gravel, and stone were identified and estimates were made of the pattern of use of these materials both in the Dallas-Fort Worth area and the Houston area. Traffic in these commodities was estimated on the use of deposits nearest the market areas and moving to more distant reserves as the nearer supply points become depleted. The average savings are estimated on the basis of the difference in weighted average costs of transportation from presently available alternative sources having the lowest transportation costs by truck or rail and the weighted average costs of moving sand, gravel, and stone by water from sources on the Trinity River. The annual savings in transportation costs of the movement of sand, gravel, and stone are estimated at about $764,000 for the channel terminating at Fort Worth, Texas. The average unit saving amounts to about 26¢ per ton.

196. A special study was also made of grain traffic. The movement of grain sorghums (milo) and wheat is governed by factors not ordinarily involved in the movement of general commerce. Detailed data on the producing areas, quantities, origins and destinations in the movement of grains, and the method and cost of transportation now used were developed by a special field canvass of producers, elevator operators, brokers and shippers. These data were analyzed to establish production and distribution patterns for wheat and milo, and to determine what portion of the 5,654,000 tons of wheat and 7,646,000 tons of milo produced in Texas and Oklahoma is exported. The special study on grain is limited to export grain since it was determined that export grain is the component of the overall grain movement that is susceptible to waterway movement. An allocation was made of wheat and milo to the transportation system that moves the export grain to establish the portion moved by truck. Findings of the special grain study indicate that about 2 million tons of these commodities would move through the ports of Houston, Galveston, and Port Arthur, Texas, and that truck transport is the most economical alternate method of movement. To determine truck haul costs to Fort Worth and Dallas, published truck rates, independent trucking costs, and unregulated truck charges obtained from the grain shippers and truckers were used to construct a scale of mileage rates for application from producing points of origin to Gulf ports. The study indicates that about 22 percent of the total grain shipments to Texas ports in 1958 was transported by truck at an average saving of $1.76 per ton under comparable rail rates. Since the constructed truck rate offers a more conservative rate for measuring waterway benefits, these rates were used. Estimates of savings on 1958 grain traffic amount to about $2,428,000 on traffic to Fort Worth and about $2,140,000 on traffic to Dallas, Texas. The findings of the special grain study relative to the truck movement of grain were corroborated substantially by a report entitled "Competitions in Grain Transportation" presented at the Purdue Marketing Clinic, Purdue University, by Robert C. Haldeman of the Transportation and Facilities Research Division, Agricultural Marketing Service, U. S. Department of Agriculture, on 24 February 1960.

197. BASIC ASSUMPTIONS.- Prospective commerce developed by the traffic study was accepted on the basis of the following assumptions:

a. That a minimum navigable depth of 12 feet for year-round navigation would be available on the proposed waterway.

b. That adequate common-carrier and contract-carrier barge service would be established.

c. That adequate terminals would be available at all important shipping and interchange ports.

d. That joint traffic would move on port-to-port rates with transfer charges and rail or truck charges added.

e. That reasonable and compensatory rail or truck charges would be established between river ports and inland shipping or receiving points for joint traffic where substantial traffic movements are indicated.

198. BASIC RATE STUDIES.- Initial traffic developed for the Trinity River project was subjected to screening to eliminate all commodity movement not considered as sound potential waterway traffic. The balance of the prospective traffic was then subjected to a detailed analysis of applicable rates and charges to ascertain the lowest transportation charges via available alternative routes. These rates and charges were then compared with estimated rates and charges for shipment in connection with and via the proposed Trinity River route. Where portions of the joint land-water hauls of the alternative routes involved movement of traffic via such currently authorized waterways as the Arkansas and Red Rivers via the proposed Trinity River route, probable ports of interchange were determined; and, as there is neither present traffic nor rate structure, constructed rates and transfer charges were used in arriving at the total transportation charges. These constructed rates reflect the average revenue level applicable to similar traffic moving in regular volume, between points representing identical distances within the same general area. The fact that so many exempt commodities for which rates were either unknown or unpublished were handled by water carriers made constructed rates necessary for the water portion of the hauls. The constructed rates, applied to the waterway movements of traffic, reflect the weighted average level for like hauls and like distances on other comparable operating waterways, based upon extensive studies of barge operating costs and services on these waterways. Transfer, handling, switching or trucking charges used where plant locations are not directly accessible to the water routes, reflect the average level of such charges applicable to the same commodities at existing regular interchange points or ports. These charges are based on an examination of available published tariffs and terminal operators' data where similar transportation conditions exist at the principal ports along the Gulf Coast, the Mississippi, Ohio, Illinois, Cumberland, Trinity, and other waterways.

199. UNIT TRANSPORTATION SAVINGS.- The unit saving on each commodity movement was computed as the difference between estimated transportation charges from origin to destination via the proposed Trinity River waterway and charges via the least expensive alternate practicable route available, regardless of whether or not the shipper actually uses the alternate route, such as rail, truck, pipeline, existing and authorized waterway routes or combinations thereof. Transportation costs via the proposed waterway include the port-to-port rate, transfer, switching and overland charges in comparison with the costs of a point-to-point movement of a commodity now carried by existing transportation facilities.

200. WATER CARRIER RATES.- Water-carrier rates applicable to barge transportation on the proposed waterway and available alternatives and feeder systems were derived from a study of the 1958 vessel costs and operations of a large group of common, contract and private carriers using the Mississippi; Ohio; Illinois; and Cumberland River systems as well as the Gulf Intracoastal Waterway. Estimates of these rates, adapted to the proposed waterway, include allowances for investment in equipment and the annual operating costs incidental to providing waterway transportation for the commerce estimated for the proposed waterway. These annual costs include profit, amortization of investment, interest, maintenance, operating overhead, plus an allowance for down time for repairs. The constructed rates are based on the use of tow boats ranging from 600 to 800 horsepower moving a tow of three 35- by 195-foot barges on the project channel to Dallas and a 400 horsepower towboat moving a tow of two 26- by 175-foot barges on the project channel between Dallas and Fort Worth. Reserve equipment for operating contingencies is also included. Estimates of barge transportation cost provide for the disassembly of the units making up the tows on the proposed waterway and the reassembly of these units into larger tows in the vicinity of Fort Worth for further movement below Dallas to the Gulf Intracoastal Waterway. Line haul rate factors for the proposed waterway were developed from an analysis of the costs of operating a fleet of towboats of sufficient capacity to transport the tonnage comprising the prospective commerce. The line haul rate factors used in the traffic study reflect the estimated time schedule on the waterway, including allowance for lockages and barge terminal time. Carrier charges for alternative movement over authorized but not yet constructed waterways for computing combination rates were derived in a similar manner.

201. COMBINATION RATES.- The estimated rates on waterway movements of commodities from origins or to destinations that are beyond the port switching limits include all accessorial charges such as cost of transfer between barge and rail cars or trucks and switching or drayage charges to or from shipping points within the port area not directly accessible to waterways. The appropriate rail, truck, or pipeline rate between the port and interior origin or destination were added in those movements outside the port switching limits.

202. Combination rates include the estimated charges for cargo handling divided between barge and rail car, truck or pipeline transportation. The transfer charges were based on published tariffs in effect at existing

terminals on the waterways to be connected, or on cost records maintained for industrial terminals. There were about 2,000 tariffs and 65 terminal cost records examined during the field study. In some movements the actual transfer cost for the specific movement was furnished from the shippers' company records. Handling charges ranged from $.29 to $1.14 according to the commodity and the load capacity and type of rail car used for the movement.

203. Switching charges between plants and river terminals were estimated from data available in published tariffs on principal ports along the Texas Gulf coast, the Mississippi; Ohio; Illinois; and Cumberland Rivers. Generally these charges ranged from $.56 to $1.13 per ton according to commodity and load capacity of the type of rail car used for the movement. In traffic movement between river ports and inland points, published rates were applied unless large volume movements were indicated. Where there is little or no present traffic and class rates only prevail, commodity rates were constructed between points, with a prospective large volume movement on the proposed waterway, by applying comparable rail or estimated trucking charges between these points. Officials of common carrier motor lines, truck rental services, and contract truckers were interviewed, and specific truck rates were studied to derive estimated trucking charges and average ten-mile rates for truck transport.

204. OVERLAND RATES.- Rail, truck and pipeline rates used in this study were obtained from tariffs in effect as of December 1958. In some commodity movements actual truck charges were obtained from shippers' records. In those cases where a class rate only applied, a commodity rate was constructed from comparable available commodity rates between similar points.

205. RATE ANALYSIS.- All of the estimated prospective traffic accepted for analysis was analyzed on specific movements of commodities. Each commodity movement was entered on detailed rate analysis (DA) sheets for computation of unit savings. The analysis sheets contain information on commodity, origin, destination, annual tonnage, overland rates, estimated barge rate or combination rate via the Trinity River, and the lowest available alternative as well as the authority for freight rates used.

206. ACCEPTED WATERBORNE COMMERCE, 1958 CONDITIONS.- There was a total of about 45 million tons of traffic reported by shippers and receivers to the field surveyors. A summary statement by commodities, of all tonnage estimated collected from all sources of information and tonnages eliminated to derive the 1958 commerce accepted for a waterway channel to Fort Worth is given in table 27.

207. The same procedure was used to derive the traffic accepted for all channels investigated. Total traffic developed was screened and subjected to rate analyses in order to determine the most efficient channel size in terms of benefits from savings to navigation.

TABLE 27

CHANNEL TO FORT WORTH

SUMMARY OF TRAFFIC DEVELOPED, SCREENED, ANALYZED, AND ACCEPTED AS PROSPECTIVE TRAFFIC BY COMMODITIES - 1958 COMMERCE

(Tons of 2,000 pounds)

Commodity	Total reported	Total developed	Duplication	Not barge adaptable	Excessive circuity	Insufficient volume	Other	Total accepted for rate analysis	No savings	Insufficient savings	Other	Total accepted
Animal & Animal Products, Inedible												
Fish Meal & Scrap	34,325	34,325				75		34,250	900	2,850		30,500
Hides, Green Salted	2,950	1,800		1,800				0				0
Oyster Shells & Poultry Grits	1,526,497	208,800			175,400	1,200		32,200	1,000			31,200
Sub-Total	1,563,772	244,925		1,800	175,400	1,275		66,450	1,900	2,850		61,700
Vegetable Food Products and Beverages												
Barley	36,058	27,600			4,500	2,100	21,000(1)	0				0
Beer and Wine	23,411	14,690		14,140		550		0				0
Canned Goods	7,966	1,540				1,540		0				0
Coffee, Green	10,760	5,410				3,160		2,250	2,250			0
Corn	113,952	27,900					27,900(1)	0				0
Flour & Bran Hulls	205,575	133,350				2,350	131,000(1)	0				0
Fruit Juices, Canned	4,752	4,752				752		4,000			4,000(2)	0
Fruits & Vegetables, Canned	1,630	1,630				1,630		0				0
Milo	2,883,630	1,854,900					160,100(3)	1,694,800			915,387(1)	779,413
Milo Gluten	3,680	1,680		1,680				0				0
Oats	20,928	8,500			2,500	1,000	5,000(1)	0				0
Rice Bran & Hulls	141,160	205				205		0				0
Sorghum & Brewers Grain	349,600	46,100	18,000		26,800	1,300		0				0
Sugar	248,780	189,600	125,900		1,500	7,700		54,500	54,500			0
Syrup	5,440	5,140				2,740		2,400			2,400(2)	0
Wheat	2,956,318	2,578,540					10,724(3)	2,567,816			1,137,015(1)	1,430,801
Vegetables & Preparations, N.E.C.	32,686	26,185		24,835		1,350		0				0
Sub-Total	7,046,326	4,927,722	143,900	40,655	35,300	26,377	355,724	4,325,766	56,750		2,058,802	2,210,214
Vegetable Products, Inedible												
Bagasse	1,200	1,200				1,200		0				0
Cotton Seed, Cake & Meal	736,578	2,100		2,100				0				0
Cotton Seed Oil	125,367	47,920		46,780		1,140		0				0
Feed & Meal	209,785	99,040				240		98,800	79,800	4,000		15,000
Linseed Oil & Pine Oil	2,100	2,100				2,100		0				0
Molasses, Blackstrap	163,785	158,359	66,000			2,845		89,514	9,580	1,000	15,334(2)	63,600
Rubber, Natural & Synthetic	25,650	25,650	650	1,000		1,000		23,000	7,000	10,000		6,000
Rubber Products, N.E.C.	4,920	4,920		3,120	1,440	360		0				0
Soybean Meal	66,310	48,500					10,000(4)	38,500	2,500			36,000
Vegetable Products, Inedible, N.E.C.	42,792	5,775				2,775		3,000			3,000(2)	0
Sub-Total	1,378,487	395,564	66,650	53,000	1,440	11,660	10,000	252,814	98,880	15,000	18,334	120,600

TABLE 27 (Cont'd)

CHANNEL TO FORT WORTH

SUMMARY OF TRAFFIC DEVELOPED, SCREENED, ANALYZED, AND ACCEPTED AS PROSPECTIVE TRAFFIC BY COMMODITIES - 1958 COMMERCE

(Tons of 2,000 pounds)

Commodity	Total reported	Total developed	Duplication	Not barge adaptable	Excessive circuity	Insufficient volume	Other	Total accepted for rate analysis	No savings	Insufficient savings	Other	Total accepted
Textile Fibers & Manufactures												
Burlap & Jute Bagging	28,936	20,013				2,563		17,450		6,700	4,300(2)	6,450
Cotton	370,993	290,593					290,593(5)	0				0
Cotton Linters	100,911	33,720					33,720(5)	0				0
Rags	12,400	2,700				700		2,000				2,000
Textile Fibers & Manufactures, N.E.C.	4,400	4,400				4,400		0				0
Sub-Total	517,640	351,426				7,663	324,313	19,450		6,700	4,300	8,450
Wood and Paper Products												
Paper Bags	30,949	560				560		0				0
Paper Boxes & Containers	13,964	2,160				1,200		960			960(2)	0
Paper Board	59,390	55,050	10,800			1,650		42,600				42,600
Wrapping Paper	31,097	19,380				1,320		18,060			1,800(2)	16,260
Insulating Board	4,620	4,570				970		3,600				3,600
Paper, Printing	41,702	14,722				3,522		11,200	7,000		4,200(2)	0
Newsprint Paper	214,410	76,281	750		22,530	4,841		48,160	3,720	9,960	1,030(2)	33,450
Scrap Paper	230,410	23,500				900	600(4)	22,000	4,000	2,400		15,600
Paper Products, N.E.C.	15,820	37,975			30,000	3,425		4,550				4,550
Lumber	131,460	30,350			16,600			13,750	13,750			0
Mahogany Lumber	31,020	1,020				1,020		0				0
Pulpboard	89,395	59,060			4,000	6,000		49,060			12,400(2)	36,660
Pulpwood	434,798	425,760	110,400					315,360		315,360		0
Wood Manufactures, N.E.C.	123,578	14,640			8,000	600	2,500(4)	3,540	3,540			0
Sub-Total	1,452,613	765,028	121,950		81,130	26,008	3,100	532,840	32,010	327,720	20,390	152,720
Non-Metallic Minerals												
Asbestos & Asbestos Products	21,925	20,725				825		19,900	2,400		17,500(2)	0
Asphalt & Asphalt Products	285,622	73,820			70,000	1,220		2,600			2,600(2)	0
Brick & Tile	328,326	75,581		10,271		300	30,000(4)	35,010	31,010	1,000	3,000(2)	0
Cement	1,405,116	9,500			4,200			5,300			5,300(2)	0
Clay & Clay Products	140,673	9,750		4,750		5,000		0				0
Coke	111,324	19,880						19,880	19,480	400		0
Gasoline & Kerosene	201,946	7,128				1,188		5,940			5,940(2)	0
Glass & Glass Products	2,335	1,520				1,520		0				0
Lime & Limestone	260,752	10,280		400				9,880	3,640	6,240		0
Lubricating Oils & Greases	62,921	62,921				18,921		44,000			21,200(2)	22,800
Roofing Material, Asphalt	257,795	69,150				100		69,050	58,550		4,500(2)	6,000
Salt	21,215	11,010				3,430		7,580	1,320	2,660	3,600(2)	0

TABLE 27 (Cont'd)

CHANNEL TO FORT WORTH

SUMMARY OF TRAFFIC DEVELOPED, SCREENED, ANALYZED, AND ACCEPTED AS PROSPECTIVE TRAFFIC BY COMMODITIES - 1958 COMMERCE

(Tons of 2,000 pounds)

Commodity	Total reported	Total developed	Duplication	Not barge adaptable	Excessive circuity	Insufficient volume	Other	Total accepted for rate analysis	No savings	Insufficient savings	Other	Total accepted
Non-Metallic Minerals (Cont'd)												
Sand, Gravel & Crushed Stone	9,437,729	3,300,000						3,300,000	366,000			2,934,000
Sand, N.E.C.	2,073,150	40,800			1,800			39,000	39,000			0
Stone, N.E.C.	601,092	10,400		400				10,000	10,000			0
Sulphur, Dry	266,090	137,000					125,000(6)	12,000	2,000		10,000(2)	0
Sulphur, Liquid	311,500	311,500			125,000		150,000(6)	36,500			36,500(2)	0
Non-Metallic Minerals, N.E.C.	115,673	10,525				4,325		6,200	6,200			0
Petroleum Products, N.E.C.	376,389	54,875			1,850	2,725		50,300			4,000(2)	46,300
Sub-Total	16,281,573	4,236,365		15,821	202,850	39,554	305,000	3,673,140	539,600	10,300	114,140	3,009,100
Metals and Manufactures												
Alloys	8,070	7,890				1,970		5,920			5,920(2)	0
Aluminum, Pig	12,325	7,010				1,010		6,000	3,000			3,000
Aluminum Products	4,240	4,240				4,240		0				0
Brass, Ingot & Scrap	5,779	1,700			1,000	700		0				0
Cast Iron Pipe	21,400	3,400				400		3,000				3,000
Finished Iron Products	26,064	3,564				564		3,000				3,000
Copper	6,695	285				285		0				0
Non-ferrous Metals	24,580	8,790				290		8,500			1,500(2)	7,000
Pig Iron	22,794	12,174				2,674		9,500	7,000		2,500(2)	0
Pig Lead	40,170	19,020				1,620		17,400		4,200	2,500(2)	10,700
Scrap Lead	80,100	5,500				1,500		4,000			4,000(2)	0
Scrap, Non-ferrous	19,240	19,240				240		19,000			5,000(2)	14,000
Scrap Iron and Steel	2,021,060	433,403	45,000			5,825		382,578	38,713	29,765		314,100
Steel Castings & Forgings	12,740	5,870			800	1,170		3,900	3,900			0
Steel Pipe & Tubing	822,175	442,060				11,320		430,740	198,600	17,500	1,650(2)	212,990
Steel Wire, Mesh & Fencing	109,956	22,935				2,075		20,860			800(2)	20,060
Rolled & Finished Steel Products	5,364,918	810,787	205,000	8,100		29,162		568,525	44,375	6,500	43,280(2)	474,370
Spelter & Antimony	34,080	34,080				180		33,900	31,500		2,400(2)	0
Tin Cans	4,650	4,650				530		4,120			4,120(2)	0
Tin Plate	60,400	31,000				300		30,700	22,100	8,600		0
Ferrous Metals	165,647	15,000						15,000				15,000
Sub-Total	8,868,583	1,892,598	250,000	8,100	1,800	66,055		1,566,643	349,188	66,565	73,670	1,077,220
Machinery & Vehicles												
Machinery, Oil Well	29,050	12,750				2,000		10,750			10,750(2)	0
Tractors & Farm Equipment	5,640	5,640			240	5,400		0				0
Vehicles & Equipment, N.E.C.	27,790	19,910		18,000		1,910		0				0
Sub-Total	62,480	38,300		18,000	240	9,310		10,750			10,750	0

TABLE 27 (Cont'd)

CHANNEL TO FORT WORTH

SUMMARY OF TRAFFIC DEVELOPED, SCREENED, ANALYZED, AND ACCEPTED AS PROSPECTIVE TRAFFIC BY COMMODITIES - 1958 COMMERCE

(Tons of 2,000 pounds)

Commodity	Total reported	Total developed	Duplication	Not barge adaptable	Excessive circuity	Insufficient volume	Other	Total accepted for rate analysis	No savings	Insufficient savings	Other	Total accepted
Chemicals & Related Products												
Alcohol	22,100	21,100				16,725		4,375	4,375			0
Anhydrous Ammonia	29,450	6,100				2,500		3,600			3,600(2)	0
Ammonia Nitrate	11,848	5,000			2,500	2,500		0				0
Ammonia Sulfate	11,500	11,500				1,000		10,500				10,500
Phosphorus Acid	2,300	2,300				2,300		0				0
Carbon Black	153,105	94,280			74,880	1,400		18,000	18,000			0
Caustic Soda (Dry)	12,750	10,050				1,750		8,300				8,300
Fertilizer	60,589	29,844			560	24,284		5,000	5,000			0
Insecticides	23,276	5,685				5,685		0				0
Paint	12,802	1,350				1,350		0				0
Phosphates	180,335	104,950			12,500	12,950		79,500	7,000	12,500		60,000
Phosphate Rock	140,700	106,000						106,000	46,000	3,000		57,000
Coal-tar Pitch	22,600	21,180				1,180		20,000	20,000			0
Polyethylene	76,600	19,300				4,300		15,000	15,000			0
Caustic Soda (Liquid)	310,322	12,190				581		11,609				11,609
Resin	3,275	3,275				3,275		0				0
Soap & Soap Powders	73,913	73,913				12,900		61,013			8,400(2)	52,613
Soda Ash	114,960	114,960	3,000			2,400		109,560	15,000	30,000		64,560
Solvents	24,552	13,732				1,132		12,600	9,600			3,000
Chemicals, N.E.C.	6,410,105	64,166			3,000	11,391	13,625(7)	36,150	4,000		21,150(2)	11,000
Sub-Total	7,697,082	720,875	3,000		93,440	109,603	13,625	501,207	143,975	45,500	33,150	278,582
Miscellaneous												
Roofing, Composition	3,480	3,480				480		3,000				3,000
Commodities, N.E.C.	91,827	6,500			5,100	650	750(7)	0				0
Sub-Total	95,307	9,980			5,100	1,130	750	3,000				3,000
GRAND TOTAL ALL TRAFFIC, WATERWAY TERMINATING AT FORT WORTH, TEXAS	44,963,863	13,582,783	585,500	137,376	596,700	298,635	1,012,512	10,952,060	1,222,303	474,635	2,333,536	6,921,586

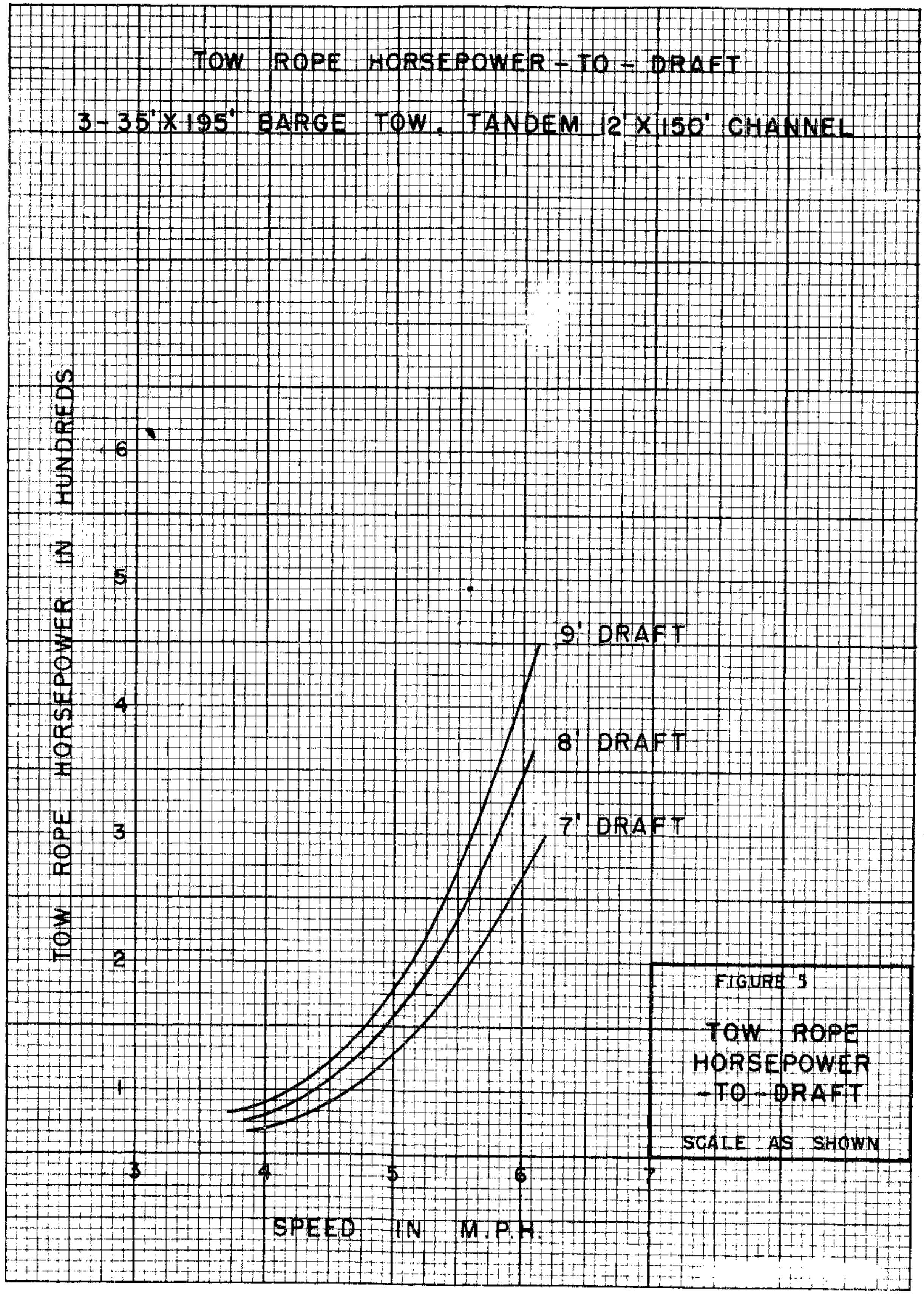
(1) Subject to transit rate.
(2) Frequency of small shipments.
(3) Exports via Corpus Christi not potential.
(4) Insufficient data.
(5) Most tonnage concentrated at interior points under transit rates.
(6) Creditable to Channel to Liberty.
(7) 4-way transfer.

ESTIMATES OF SAVINGS, ACCEPTED WATERBORNE COMMERCE 1958 CONDITIONS

208. GENERAL.- The total accepted traffic was analyzed for channels ranging in width from 125' to 200' and depths of 9 to 12 feet. For convenience, the 12' x 150' - 12' x 125' single-purpose channel to Fort Worth is used as an example in this appendix to illustrate the details of the studies made on each of the channels investigated.

209. The single-purpose navigation project for the Trinity River between the Houston Ship Channel and Fort Worth, Texas, on which the analyses of prospective commerce are based, includes 351 miles of channel. The project includes a 12' x 150' channel with nineteen 84' x 600' locks in the 312-mile reach between the Houston Ship Channel and Dallas, Texas, and a channel 12' x 125' with four 56' x 400' locks for the 39-mile reach between Dallas and Fort Worth, Texas.

210. TOWBOATS.- Towboats used in the single-purpose analysis for the 12' x 150' section of the channel range from 600- to 800- horsepower, depending on the total tonnage of each tow, the loaded draft of the barges, and the number of barges in the individual tows. Towboats for the 12' x 125' section of the channel would be of 400-horsepower. Curves for computing towboat horsepower for several drafts on the 12' x 150' channel are shown in figure 5.


TOW ROPE HORSEPOWER - TO - DRAFT
3 - 35' X 195' BARGE TOW, TANDEM 12' X 150' CHANNEL
TOW ROPE HORSEPOWER IN HUNDREDS
1
2
3
4
5
6
9' DRAFT
8' DRAFT
7' DRAFT
3
4
5
6
7
SPEED IN M.P.H.
FIGURE 5
TOW ROPE HORSEPOWER - TO - DRAFT
SCALE AS SHOWN

211. The towboat should be capable of a speed of 6 m.p.h. to average 4 m.p.h. upbound and 5 m.p.h. downbound on a 12' × 150' channel. An allowance of 25 percent has been added to the towboat horsepower to arrive at the required towboat horsepower capacity. Also, the towboats are bracketed into the next larger 200-horsepower size. Towboats of 800-horsepower were assigned to tows for all commodity groups, except Group No. 9 (sand, gravel, and stone), where towboats of 600-horsepower were used for downbound movements. However, 400-horsepower towboats were assigned for all upbound movements of sand, gravel, and stone because of the smaller locks and channel dimensions above Dallas. On the 12' × 125' section of channel between Dallas and Fort Worth, towboats of 400-horsepower were assigned to all tows.

212. BARGES.- Two sizes of barges were used for the entire project. Barges 26' × 175' were assigned to sand, gravel, and stone traffic, and 35' × 195' barges were assigned to all other commodities. On the 12' × 150' section of the channel below Dallas, all commodities were considered to move in 3-barge tows, in tandem; except sand, gravel, and stone originating below Dallas and terminating at Fort Worth, which would move in 2-barge tows. On the 12' × 125' section of the channel above Dallas, 2-barge tows were considered for all commodities. The loaded drafts of barges varied from 6 to 8 feet depending on the commodity characteristics.

213. TOW SPEEDS AND LOCKAGE TIME.- Speeds of four m.p.h. upbound and five m.p.h. downbound were assumed for all tows on the 12' × 150' section below Dallas. A speed of 3.5 miles per hour both directions was assumed for all tows on the 12' × 125' section above Dallas. Tows of 3 barges in tandem would permit single lockages at each of the 19 locks below Dallas. A uniform lockage time of 60 minutes, including towboat set-over, was allowed for all commodities except sand, gravel, and stone, where a lockage time of 45 minutes was allowed at each lock on the 12' × 150' section. On the 12' × 125' section, 2-barge tows would permit single lockage at each of the four locks on this reach of the channel, and a uniform lockage time of 45 minutes was allowed for all tows. Lockage time is measured from full approach speed to resumption of full speed after lockage.

214. BARGES AND TOWBOATS REQUIRED.- A total of 143 barges would be required to handle all traffic, both directions, on the single-purpose project. Thirty-one 26' × 175' barges would be required for sand, gravel, and stone, and one hundred and twelve 35' × 195' barges would be required for all other commodities. A total of 33 towboats of varying horsepower would be required for the entire fleet. This figure includes a 15 percent reserve for all towboats, except those engaged in the movement of sand and gravel upbound, for which a 25 percent reserve was considered more reasonable.

215. DEVELOPMENT OF BARGE RATE FACTORS.- Methods used to determine the transportation charges vary with the commodities and tonnages to be moved, the origins and destinations, and the types of barges and towboats used are discussed in following paragraphs. Two examples of methods used to develop barge rate factors for the commodities accepted as prospective

commerce are the computations for the 12' x 150' channel to Dallas to develop barge factors for Group 3, Grains and Grain Products, and for Group 4, Iron and Steel Articles. These examples are as follows:

Example 1. GRAINS AND GRAIN PRODUCTS (in bulk) (Group 3):

MOVEMENT: Downbound, Dallas to Houston Ship Channel

TOWBOAT: 800 - H.P.
$27.87 variable operating cost per hour
7.24 variable reserve equipment cost per hour

OPERATIONAL TOWBOAT HOURS PER YEAR: 8,280 (345 days)

SPEED: Upbound 4 m.p.h.
Downbound 5 m.p.h.

BARGES: 195'x35' covered hopper
$9,400 variable cost per year

NUMBER OF BARGES PER TOW: 3

NET TONS CARRIED PER BARGE: 1,200

BARGE UTILIZATION: 1,842 covered barges

BARGE DRAFTS: Loaded 8.0 feet

NET TONS TO BE TRANSPORTED: 2,210,214

LOCKS: 19 locks, 312 miles

LOCKAGE TIME: One hour per lock

ROUND-TRIPS: 403.33

ONE-WAY TRIPS: 210.66

RUNNING TIME, TOWBOAT HOURS:

Downbound, one-way

62.40 hours, downbound @ 5 m.p.h.
19.00 hours, lockage time, 19 locks @ one hour per lock
3.00 hours, shifting barges
84.40 hours, towboat running time

Round-trip

62.40 hours, downbound @ 5 m.p.h.
78.00 hours, upbound @ 4 m.p.h.
38.00 hours, lockage time, 38 locks @ one hour per lock
3.00 hours, shifting barges at Dallas
2.00 hours, shifting barges at destination
183.40 hours, towboat running time

Summary towboat hours
One-way

84.40 hours, towboat running time
x 210.66 trips, number of one-way trips
17,779.70 hours, total towboat running time

Round-trip

183.40 hours, towboat running time
x 403.33 trips, number of round-trips
73,970.72 hours, total towboat running time

Total annual towboat hours, one-way and round-trip

17,779.70 hours, one-way
73,970.72 hours, round-trip
91,750.42 hours, total towboat hours required to move 2,210,214 net tons of grains and grain products

Towboat reserve equipment hours

91,750.42 hours, towboat operating time
15 percent reserve
13,762.56 hours, total towboat reserve equipment hours

TOWBOATS REQUIRED FOR CONSTANT OPERATION:

$$\frac{\text{Towboat operating hours}}{\text{Towboat hours of operation per year}} \quad \frac{91,750}{8,280} = 11.08$$

11.08 towboats required for constant operation

BARGE REQUIREMENTS:

11.08 towboats utilized
x 3 barges per tow
33.24 barges required to haul 2,210,214 tons of grains and grain products
9.76 reserve barges
43.00 total barges required for the fleet

FLEET OPERATING COST:

Towboat variable operating cost

91,750	hours, total operating time
x $ 27.87	variable towboat cost per hour
$2,557,073	total variable towboat cost

Towboat reserve equipment cost

13,763	hours, total towboat reserve time
x $7.24	variable towboat reserve equipment cost per hour
$ 99,644	total variable reserve towboat cost

Barge cost

$ 9,400	variable barge cost per year
x 43	number of barges required
$404,200	total variable barge cost

Summary towboat and barge costs

$2,557,073	variable towboat cost
99,644	variable reserve towboat cost
404,200	variable barge cost
$3,060,917	total towboat and barge cost

TOTAL TON-MILES:

2,210,214 net tons x 312 miles = 689,586,768 commodity ton-miles

MILLS PER TON-MILE:

$$\frac{\text{Total fleet cost}}{\text{Commodity ton-miles}} \quad \frac{\$3,060,917}{689,586,768} = \$0.004438$$

4.44 mills per ton-mile for 2,210,214 net tons of bulk grains and grain products

Example 2. IRON AND STEEL ARTICLES (Group 4):

MOVEMENT: Upbound, Houston Ship Channel to various destinations

TOWBOAT: 800 H.P.
$27.87 variable operating cost per hour
7.24 variable reserve equipment cost per hour

OPERATIONAL TOWBOAT HOURS PER YEAR: 8,280 (345 days)

SPEED: Upbound, 4 m.p.h.
Downbound, 5 m.p.h.

BARGES: 195'x35', covered
$9,400 variable covered barge cost per year
195'x35', open
$8,200 variable open barge cost per year

NUMBER OF BARGES PER TOW: 3

NET TONS CARRIED PER BARGE: 700

BARGE UTILIZATION: 558 covered bargeloads
455 open bargeloads

BARGE DRAFTS: Loaded to 7.0 feet

NET TONS TO BE TRANSPORTED: 709,220 tons of iron and steel articles

2,500	tons to Riverside, round-trip
9,200	tons to Rosser, round-trip
500	tons to Trinidad, round-trip
85,920	tons to Dallas, round-trip
611,100	tons to Dallas, one-way
709,220	total tons

LOCKS: 7 locks to Riverside, 130 miles
11 locks to Rosser, 240 miles
12 locks to Trinidad, 255 miles
19 locks to Dallas, 312 miles

LOCKAGE TIME: 1 hour per lock

ROUND-TRIPS:

1.00	to Riverside
4.33	to Rosser
.33	to Trinidad
41.00	to Dallas
46.66	total round-trips

ONE-WAY TRIPS: 291.00 to Dallas

RUNNING TIME TOWBOAT HOURS:

Round-trip to Riverside

32.50	hours, upbound @ 4 m.p.h.
26.00	hours, downbound @ 5 m.p.h.
14.00	hours, lockage time, 14 locks @ 1 hour per lock
2.00	hours, shifting barges
74.50	hours, say 75 hours, towboat round-trip time

Round-trip to Rosser

60.00	hours, upbound @ 4 m.p.h.
48.00	hours, downbound @ 5 m.p.h.
22.00	hours, lockage time, 22 locks @ 1 hour per lock
2.00	hours, shifting barges
132.00	hours, towboat round-trip time

Round-trip to Trinidad

63.75	hours, upbound @ 4 m.p.h.
51.00	hours, downbound @ 5 m.p.h.
24.00	hours, lockage time, 24 locks @ 1 hour per lock
2.00	hours, shifting barges
140.75	hours, towboat round-trip time

Round-trip to Dallas

78.00	hours, upbound @ 4 m.p.h.
62.40	hours, downbound @ 5 m.p.h.
38.00	hours, lockage time, 38 locks @ 1 hour per lock
3.00	hours, shifting barges
181.40	hours, towboat round-trip time

One-way trip to Dallas

78.00	hours, upbound @ 4 m.p.h.
19.00	hours, lockage time, 19 locks @ 1 hour per lock
1.50	hours, shifting barges
98.50	hours, towboat one-way trip time

SUMMARY TOWBOAT HOURS:

Round-trip to Riverside

75.00	hours - towboat running time
x 1.00	trip - number of round-trips
75.00	hours - total towboat running time

Round-trip to Rosser

132.00	hours - towboat running time
x 4.33	trips - number of round-trips
572.00	hours - total towboat running time

Round-trip to Trinidad

140.75	hours - towboat running time
x .33	trip - number of round-trips
47.00	hours - total towboat running time

Round-trip to Dallas

181.40	hours	- towboat running time
41.00	trips	- number of round-trips
7,437.00	hours	- total towboat running time

One-way trip to Dallas

98.50	hours	- towboat running time
x 291.00	trips	- number of one-way trips
28,664.00	hours	- total towboat running time

Total annual towboat hours, one-way and round-trip

75.00	hours	- round-trip to Riverside
572.00	hours	- round-trip to Rosser
47.00	hours	- round-trip to Trinidad
7,437.00	hours	- round-trip to Dallas
28,664.00	hours	- one-way to Dallas
36,795.00	hours	- total towboat hours required to move 709,220 net tons of iron and steel articles

Towboat reserve equipment hours

36,795.00	hours	- total towboat operating hours
x 15		- percent reserve
5,519.00	hours	- total towboat reserve equipment hours

TOWBOATS REQUIRED FOR CONSTANT OPERATIONS:

$$\frac{\text{Towboat operating hours}}{\text{Towboat hours of operations per year}} \quad \frac{36,795}{8,280} = 4.44 \text{ towboats}$$

4.44 towboats required for constant operation

BARGE REQUIREMENTS:

4.44	towboats utilized
3	number of barges per tow
13.32	barges needed to haul 709,220 net tons of iron and steel articles
13.32	barges required for constant operation
12.00	reserve barges
25.32	say 26 total barges required for the fleet

FLEET OPERATING COSTS:

Towboat variable operating cost

36,795	hours, total operating time
x $27.87	variable towboat operating cost per hour
$1,025,476.65	total variable operating cost

Towboat reserve equipment cost

5,519.00	hours, total towboat reserve time
x $7.24	variable towboat reserve equipment cost per hour
$39,957.56	total variable towboat reserve equipment cost

Barge cost

$9,400	variable covered barge cost per year
x 14	number of covered barges required
$131,600	total variable covered barge cost

$8,200	variable open barge cost per year
x 12	number of open barges required
$98,400	total variable open barge cost

Summary towboat and barge costs

$1,025,477	towboat operating cost
39,958	towboat reserve cost
131,600	covered barge cost
98,400	open barge cost
$1,295,435	total variable towboat and barge cost

TOTAL TON-MILES:

2,500 tons x 130 miles	=	325,000	
9,200 tons x 240 miles	=	2,208,000	
500 tons x 255 miles	=	127,500	
697,020 tons x 312 miles	=	217,470,240	
		220,130,740	commodity ton-miles

MILLS PER TON-MILE:

$$\frac{\text{Total fleet cost}}{\text{Commodity ton-miles}} \quad \frac{\$1,295,435}{220,130,740} = \$0.00588$$

5.88 mills per ton-mile for 709,220 net tons of iron and steel articles

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216. BARGE RATE FACTORS.- The commodities comprising the current prospective traffic for the single-purpose project were allocated to eight commodity groups for developing barge rate factors. Barge rate factors for connecting waterways are assumed to be the same for all channels investigated. The barge rate factors developed for each commodity group, by direction of movement for the single purpose project are shown in Table 28.

TABLE 28

CHANNEL TO FORT WORTH

ESTIMATED BARGE RATE FACTORS FOR CONSTRUCTING BARGE LINE-HAUL RATES 1/

BY COMMODITY GROUPS

Group No.	Item	Variable factors Upbound	Variable factors Downbound	Constant factors Upbound	Constant factors Downbound
		(mills/ton-mile)		(cents/ton)	
1	Petroleum & products (liquid, bulk)	4.97	4.96	34	34
3	Grain & products (bulk)	None	4.50	34	34
4	Iron & steel articles	5.84	4.24	34	34
5	Sulphur, ores & dry chemicals (bulk)	4.53	3.62	34	34
7	Scrap iron & steel	None	4.69	34	34
8	Commodities, N.O.S.	5.99	6.35	34	34
9	Sand, gravel & stone		5.90		18
	Sand & gravel	11.01		.06	
	Stone	8.54		.22	
10	Liquid chemicals & other liquids	6.10	None	34	34

1/ To construct a barge rate per ton, multiply the commodity group factor in mills per ton-mile, according to direction of movement, by the distance traversing the Trinity River, and add the constant factor per ton. The constant factor is to be used only once in constructing a rate from origin to destination; regardless of the number of waterways involved between origin and destination.

217. CURRENT PROSPECTIVE COMMERCE.- As indicated in table 28, if the waterway had been available in 1958, some 6,921,586 tons of barge adaptable traffic could have been transported thereon at a savings in transportation charges estimated at $9,854,000. Upbound traffic amounts to 2,394,000 net tons with $5,371,000 savings and downbound traffic amounts to 4,528,000 net tons with $4,483,000 savings. The most significant traffic included in the total traffic accepted are 2,210,000 tons (32 percent) of downbound grain; 2,934,000 tons (42 percent) of up-and-downbound sand, gravel and stone; 709,000 tons (10 percent) of upbound iron and steel articles and pipe; and 314,000 tons (5 percent) of downbound iron and steel scrap. The total prospective commerce is shown by commodity, annual tonnage, direction of movement, and savings in transportation charges in table 29.

TABLE 29

CHANNEL TO FORT WORTH
ACCEPTED PROSPECTIVE COMMERCE AND SAVINGS IN TRANSPORTATION CHARGES
(1958 commerce)

Commodity	UPBOUND		DOWNBOUND		TOTAL	
	Traffic (Net tons)	Savings (Dollars)	Traffic (Net tons)	Savings (Dollars)	Traffic (Net tons)	Savings (Dollars)
Animal & Animal Products, Inedible						
Fish meal & scrap	30,500	$47,545	-	-	30,500	$47,545
Poultry grits, (shell)	31,200	79,560	-	-	31,200	79,560
Sub-total	61,700	$127,105	-	-	61,700	$127,105
Vegetable Food Products & Beverages						
Wheat	-	-	1,430,801	$1,616,047	1,430,801	1,616,047
Milo (Sorghum)	-	-	779,413	811,743	779,413	811,743
Sub-total	-	-	2,210,214	2,427,790	2,210,214	2,427,790
Vegetable Products, Inedible except Fiber						
Molasses, blackstrap	63,600	$245,977	-	-	63,600	$ 245,977
Feed & meal	15,000	46,290	-	-	15,000	46,290
Soybean meal	36,000	28,080	-	-	36,000	28,080
Rubber, synthetic	6,000	39,960	-	-	6,000	39,960
Sub-total	120,600	$360,307	-	-	120,600	$ 360,307
Textile Fibers & Manufactures						
Burlap bagging, Jute and Sisal	6,450	$23,961	-	-	6,450	$23,961
Rags	-	-	2,000	$6,560	2,000	6,560
Sub-total	6,450	$23,961	2,000	$6,560	8,450	$30,521

TABLE 29 (CONT'D)

CHANNEL TO FORT WORTH
ACCEPTED PROSPECTIVE COMMERCE AND SAVINGS IN TRANSPORTATION CHARGES
(1958 commerce)

Commodity	UPBOUND		DOWNBOUND		TOTAL	
	Traffic (Net tons)	Savings (Dollars)	Traffic (Net tons)	Savings (Dollars)	Traffic (Net tons)	Savings (Dollars)
Wood & Paper						
Waste Paper	15,600	$12,168	-	-	15,600	$12,168
Wrapping paper & bags	16,260	47,992	-	-	16,260	47,992
Pulpboard	82,860	169,580	-	-	82,860	169,580
Newsprint	33,450	77,621	-	-	33,450	77,621
Paper, felt	4,550	4,732	-	-	4,550	4,732
Sub-total	152,720	$312,093	-	-	152,720	$312,093
Non-Metallic Minerals						
Benzene	13,850	$65,902	-	-	13,850	$65,902
Naphtha	14,850	68,013	-	-	14,850	68,013
Lubricating Oil	4,800	24,768	-	-	4,800	24,768
Wax	3,600	16,596	-	-	3,600	16,596
Sand and Gravel	1,134,000	299,200	1,430,900	324,761	2,564,900	623,961
Stone	-	-	369,100	140,259	369,100	140,259
Oil, light grade	-	-	18,000	64,260	18,000	64,260
Roofing, Asphalt	-	-	6,000	8,160	6,000	8,160
Perlite, refined	-	-	14,000	34,020	14,000	34,020
Sub-total	1,171,100	$474,479	1,838,000	$571,460	3,009,100	$1,045,939

TABLE 29 (CONT'D)

CHANNEL TO FORT WORTH
ACCEPTED PROSPECTIVE COMMERCE AND SAVINGS IN TRANSPORTATION CHARGES
(1958 commerce)

Commodity	UPBOUND		DOWNBOUND		TOTAL	
	Traffic (Net tons)	Savings (Dollars)	Traffic (Net tons)	Savings (Dollars)	Traffic (Net tons)	Savings (Dollars)
<u>Metals & Manufactures, except Machinery & Vehicles</u>						
Aluminum, Pig	3,000	$12,210	-	$ -	3,000	$12,210
Pipe, Iron & Steel	215,990	1,122,715	-	-	215,990	1,122,715
Iron & Steel Articles	493,230	2,331,105	4,200	20,366	497,430	2,351,471
Iron & Steel Scrap	-	-	314,100	888,501	314,100	888,501
Ferrous Metals	-	-	15,000	13,650	15,000	13,650
Lead, Pig	-	-	10,700	34,732	10,700	34,732
Non-Ferrous Metals	-	-	7,000	45,010	7,000	45,010
Non-Ferrous Scrap Metal	-	-	14,000	57,820	14,000	57,820
Sub-Total	712,220	$3,466,030	365,000	$1,060,079	1,077,220	$4,526,109
<u>Chemicals & Related Products</u>						
Caustic Soda, liquid	11,609	$ 66,082	-	$ -	11,609	$ 66,082
Caustic Soda, dry	8,300	45,879	-	-	8,300	45,879
Solvents, liquid	3,000	6,900	-	-	3,000	6,900
Soda Ash	64,560	382,757	-	-	64,560	382,757
Ammonia sulphate	10,500	15,625	-	-	10,500	15,625
Phosphate rock	57,000	59,250	-	-	57,000	59,250
Soap, soap powder & compounds	-	-	52,613	96,545	52,613	96,545
Sodium phosphate	-	-	60,000	320,200	60,000	320,200
Chemicals & related products, NEC	11,000	24,020	-	-	11,000	24,020
Sub-Total	165,969	$ 600,513	112,613	$ 416,745	278,582	$1,017,258

TABLE 29 (CONT'D)

CHANNEL TO FORT WORTH
ACCEPTED PROSPECTIVE COMMERCE AND SAVINGS IN TRANSPORTATION CHARGES
(1958 commerce)

Commodity	UPBOUND		DOWNBOUND		TOTAL	
	Traffic (Net tons)	Savings (Dollars)	Traffic (Net tons)	Savings (Dollars)	Traffic (Net tons)	Savings (Dollars)
Miscellaneous						
Roofing Composition	3,000	$ 6,480	-	$ -	3,000	$ 6,480
Sub-total	3,000	$ 6,480	-	$ -	3,000	$ 6,480
GRAND TOTAL - ALL TRAFFIC	2,393,759	$5,370,968	4,527,827	$4,482,634	6,921,586	$9,853,602

218. ANALYSIS OF PROSPECTIVE COMMERCE.- Analysis of the results of the traffic survey indicates that the major portion of the prospective commerce would consist of commodities that would normally move in bulk. About 19 percent of the upbound traffic originates on the Ohio and upper Mississippi Rivers and tributaries, 10 percent originates on the Gulf Coast east of New Orleans, with the remainder shipped from the immediate trade areas of the Texas Gulf coast. Upbound traffic would terminate at Dallas and Fort Worth. Most of the downbound traffic would terminate along the Gulf Coast west of New Orleans either for domestic use or for export through the ports of Houston and Galveston.

219. The ratio over-all commerce is 1 to 1.9 with the downbound commerce being the greater of the two movements. The estimated waterway carrier rates were weighted to reflect the differential movement.

220. As shown in table 27, a total of 114 separate commodities were reported in the field canvass of traffic. Analyses of the reported traffic to develop the estimated prospective commerce for the single-purpose project derived the accepted commerce of 43 commodities consolidated, according to commodity and direction of movement, into 9 major classifications of commodities as shown in table 29.

221. A detailed discussion of the commodities accepted as prospective commerce is presented in the ensuing paragraphs. The detailed discussion is based on the single-purpose waterway terminating at Fort Worth, Texas, for ready comparison and discussion with the traffic claimed by the local interests. Further, accepted traffic on all channels investigated is essentially the same as the accepted traffic to Fort Worth. The primary difference is the quantities of commodities accepted rather than the kinds of commodities concerned. Therefore, the detailed discussion in the following paragraphs is appropriate to all studies except in the tonnages involved.

222. ANIMAL AND ANIMAL PRODUCTS - INEDIBLE.- Items in this classification include fish meal, fish scrap, and seashells. Local interests list 8,000 tons of fish meal and 440,000 tons of seashells as upbound traffic and 2,862 tons of animal products n.e.c. as downbound traffic. It is

assumed that local interests have included seashells now moving over the channel to Liberty in their estimates. The existing traffic on the channel to Liberty is considered as creditable to the existing project. Therefore, none of this traffic is accepted as prospective traffic on the waterway proposed for the Trinity River.

223. About 34,000 tons of fish meal and fish scrap reported in the traffic canvass were developed for rate analysis. These commodities originate at the two Menhaden processing plants at Port Arthur and Sabine Pass, Texas, and from imports of fish meal at Houston, Texas. Analysis of this traffic disclosed that about 3,000 tons of fish meal move in small lots to widely dispersed points in Texas and would not realize a saving from waterway movement. The remaining 31,000 tons move from these points to large fertilizer plants in Fort Worth, Texas, and would realize an annual saving of about $48,000, or an average unit saving of about $1.56 per ton.

224. Seashells reported amounted to about 1,526,000 tons, of which 209,000 tons were developed for further analysis. Excluding the seashells moving over the existing channel to Liberty, most of the seashell movement was through the port of Houston to scattered inland points. These movements could not move via the Trinity River at a saving. The movement of 31,000 tons of seashells from Houston to feed mills in Dallas, Texas, for processing into poultry grit was accepted as prospective traffic and would realize a saving of about $80,000, or an average saving of about $2.55 per ton.

225. VEGETABLE FOOD PRODUCTS AND BEVERAGES.- There is a total of 1,144,000 tons of these commodities reported by the local interests. They include Molasses and Syrups, Coarse Grain, Sugar, Canned Fruit, Canned Goods, Beer, and Food Products. The total tonnage on 17 products reported on the traffic canvass, including the products reported by local interests, amounts to about 7,000,000 tons. Primary analysis developed about 4,928,000 tons of accepted traffic on these commodities for further rate analysis. As discussed in paragraph 196, about 1,431,000 tons of wheat and 779,000 tons of milo downbound for export are accepted as prospective traffic at an annual saving of $2,428,000, or an average unit saving of about $1.10 per ton. It was determined that the remainder of these commodities, based on individual commodity rate analysis, would not move over the proposed waterway because of rail transit privileges, requirement for frequent shipment of small amounts, or the commodities moved to inland points that do not permit reduction in transportation costs over the present mode of shipment.

226. VEGETABLE PRODUCTS, INEDIBLE.- The local interests reported about 12,000 tons of these commodities which include cottonseed products, scrap rubber, crude rubber, tires and tubes, and other rubber products. Reported on the traffic survey were about 1,378,000 tons on the ten different commodities that include those commodities reported by the local interests. Screening of the reported traffic developed about 396,000 tons of traffic that were subjected to a detailed rate analysis.

227. The rate analysis indicates that about 121,000 tons of blackstrap molasses, feed and meal, soybean meal, and synthetic rubber would move upbound from Houston, Corpus Christi, and Baytown, Texas, and Memphis, Tennessee, to Fort Worth, Dallas, Sherman, and Wichita Falls, Texas, for animal feed supplement, animal feed and, in the case of synthetic rubber, for use in the rubber products plants in Dallas. This movement would represent an annual saving to transportation of about $360,000, or an average unit saving of about $2.99 per ton. The remainder of the traffic developed would not move over the waterway because of small shipments involved and the frequency that these products are needed by the consumers.

228. TEXTILE FIBERS AND MANUFACTURES.- The 206,000 tons of these commodities reported by the local interests include burlap, cotton piece goods, baled cotton, rags, floor covering, and other commodities not classified. Reported on the traffic survey are about 518,000 tons on 5 commodities. This tonnage was screened, and about 351,000 tons were developed for detailed rate analysis. The rate analysis indicates that about 6,000 tons of burlap bagging, jute and sisal would move upbound from Houston to Fort Worth and Dallas, Texas, and about 2,000 tons of rags in bales would move downbound from Dallas to Houston for export. This movement represents a total annual saving to transportation of about $31,000, or an average unit saving of about $3.61 per ton. The requirement of frequent small shipments eliminates the remaining tonnage except cotton.

229. Cotton could not be accepted as prospective traffic at this time for a variety of reasons. A special study similar to the study made on grain was made of the cotton movement in the study area. Leading brokers in cotton stated that (1) loss of interest on their investment because of excessive time required to assemble barge load quantities and excessive transit time over present transportation methods; (2) additional warehouse and other extra handling expense for sampling before shipment is authorized; (3) small quantity involved in typical export shipment; and (4) pooling of shipments to secure minimum barge loads involved excessive time to locate interested shippers that may result in loss of ship would prevent cotton from moving by barge. Therefore, cotton was eliminated from the estimated prospective traffic.

230. WOOD AND PAPER.- There were 449,000 tons of these commodities reported by the local interests as prospective waterway traffic. They state that 348,000 tons of paperboard, lumber, newsprint, paper and paper articles, logs, celotex siding, and lumber products would move upbound at an annual saving of $930,000, or an average unit saving of $2.67 per ton. They also include 151,000 tons of pulpwood, folding cartons, waste paper, lumber, and lumber products moving downbound at an annual saving of about $200,000, or an average unit saving of $1.32 per ton.

231. There was a total of 14 commodities with an aggregate annual tonnage of 1,453,000 tons reported on the traffic survey. The reported traffic includes commodities listed by the local interests, as well as wood manufactures, insulating board, and mahogany disclosed by the canvass

of traffic in the area. The total reported traffic was subjected to a preliminary analysis and subsequently reduced to a total of 765,000 tons which was accepted for a detailed rate analysis.

232. The detailed rate analysis indicated that about 153,000 tons of waste paper, wrapping paper, bags, pulpboard, newsprint, and felt paper would move upbound from points in Florida, Georgia, Alabama, Illinois, and Louisiana to Fort Worth and Dallas, Texas. This movement would represent an average saving of $312,000 annually, or a unit saving of about $2.04 per ton.

233. The predominant reason that paperboard for boxes, lumber, paper and paper articles, and lumber products were eliminated from the accepted traffic is the requirement of frequent small shipments. Consumers of these commodities do not have the storage facilities for barge load quantities, and producers indicate that volumes of business in these commodities at present would not sustain a major distribution point at the head of navigation. Pulpwood would not represent a saving over existing routes because of excessive handling costs.

234. NONMETALLIC MINERALS.- The commodities in this group reported by the local interests include 3,357,000 tons of sand, gravel, petroleum products, brick, tile, asphalt, asbestos, carbon black, charcoal, coal tar and pitch moving upbound at an annual saving of about $2,709,000, or a unit saving of $.81 per ton. They also list 2,197,000 tons of sand, gravel, sulfur, petroleum products, brick, tile, roofing material, perlite, and asbestos siding moving downbound at an annual saving of about $2,184,000, or a unit saving of $.99 per ton.

235. The traffic study disclosed a total reported tonnage of 16,282,000 tons on 19 commodities which includes those commodities reported by the local interests. A total of 4,236,000 tons of the reported traffic was accepted for further analysis by a detailed rate study. The results of the rate analysis of the special study made on sand, gravel, and stone are given in paragraph 195 of this section of the appendix. The study indicates that about 1,134,000 tons of these commodities would annually move upbound from the middle river at an annual average saving of about $299,000, or a unit saving of about $.26 per ton, and about 1,800,000 tons annually would move out of the river to Houston and Gulf coast points at an annual saving of about $465,000, or a unit saving of about $.25 per ton.

236. The remaining traffic accepted as prospective commerce includes 37,000 tons annually of benzene, naphtha, lubricating oil, and wax moving upbound from Beaumont, Port Arthur, Houston, Texas, and Vanport, Pennsylvania, to Fort Worth and Dallas, Texas, at an average annual saving of about $175,000, or a unit saving of $4.72 per ton. Also included is about 38,000 tons annually of light oil, perlite, and roofing asphalt moving downbound from Trinity, Dallas, and Fort Worth, Texas, to Whiting, Indiana, and Houston, Texas, at an annual saving of about $106,000, or an average unit saving of about $2.80 per ton.

237. Commodities reported by local interests that were eliminated include sulfur which moves to Liberty, Texas, and is creditable to the channel to Liberty only, and asbestos, carbon black, charcoal, brick, tile, coal tar and pitch, which at present are required in small amounts at frequent intervals.

238. METALS AND MANUFACTURES.- The 898,000 tons of these commodities reported by the local interests include 622,000 tons of iron and steel articles, pipe and fittings, tin plate, brass, copper, aluminum, sash and doors, cast iron pipe, home appliances and welding equipment, and supplies moving upbound at an annual saving of about $4,565,000, or an average unit saving of $7.34 per ton. The downbound movement they reported includes 276,000 tons of scrap iron, iron and steel articles, and scrap copper at an annual saving of $997,000, or an average unit saving of $3.61 per ton.

239. There was a total of 8,869,000 tons of 21 commodities reported on the field survey of traffic. This tonnage was reduced by the initial screening to 1,893,000 tons of traffic to be subjected to the more detailed rate analysis study. The detailed rate analysis indicated that about 712,000 tons annually of aluminum pig, iron and steel pipe, articles, and scrap, pig lead, and nonferrous metals and scrap would move upbound from points in Illinois, Ohio, Pennsylvania, Indiana, Alabama and the Texas coast to Fort Worth and Dallas, Texas, at an annual saving of about $3,466,000, or an average unit saving of about $4.87 per ton. In addition, about 365,000 tons of iron and steel articles and scrap, ferrous metals, and nonferrous scrap would move downbound from Fort Worth, Dallas, McKinney, and Grand Prairie, Texas, to Houston, Texas; Chicago, Illinois; Milwaukee, Wisconsin; and Saint Louis, Missouri, for export and domestic consumption. The downbound movement of these materials would realize an annual saving of about $1,060,000, or an average unit saving of about $2.90 per ton.

240. About 13 of the 21 commodities reported were eliminated from the accepted prospective traffic. These commodities either moved in insufficient volume or did not represent a sufficient saving over existing means of transportation to be accepted as prospective traffic.

241. MACHINERY AND VEHICLES.- According to the local interests there would be about 267,000 tons of automobile parts, power plant equipment, tractor parts, battery separators, and unclassified machinery that would move upbound at an annual saving of $2,324,000, and about 5,000 tons of unclassified machinery that would move downbound at an annual saving of about $24,000. The traffic canvass reported 62,000 tons of oil well machinery, tractors and farm equipment, and other vehicles. About 38,000 tons of these commodities were developed for further analysis by rates. The detailed rate study indicated that either it is not practical to ship these commodities by barge (i.e. not adaptable, excessive circuity of routing, or insufficient volume) or there was insufficient or no saving to transportation from barge movement. Therefore, none of this traffic is included in the accepted prospective traffic for the waterway.

242. CHEMICALS AND RELATED PRODUCTS.- The local interests report 194,000 tons of phosphate rock, soda ash, fertilizer, dicalcium phosphate, and liquid phosphate soda that would move upbound at a saving of $714,000 annually. They also include 14,000 tons of liquid silicate of soda, paints, varnishes, soap and soap powders moving downbound at a saving of $59,000 annually.

243. There was a total of 7,697,000 tons of 20 separate commodities reported on the traffic canvass. Preliminary screening reduced this to about 721,000 tons that were developed for rate analysis. According to the rate analysis, there would be about 166,000 tons of phosphate rock, ammonia sulfate, soda ash, liquid solvents, and liquid and dry caustic soda that would move upbound from Florida, Louisiana, and points on the Texas Gulf coast to Fort Worth and Dallas at an annual saving of about $601,000, or an average unit saving of about $3.62 per ton. There would also be about 113,000 tons of soap, soap powders and compounds, sodium phosphate, chemicals and related products not classified that would move downbound at an annual saving of $417,000, or an average unit saving of about $3.70 per ton.

244. The commodities eliminated from the traffic accepted for this classification were excluded primarily because of insufficient volume to constitute a minimum barge shipment or they did not constitute a saving over the existing transportation media now utilized.

245. MISCELLANEOUS.- Proponents of the waterway indicate a minor tonnage in this classification would use the waterway. They do not identify specific commodities but state that 32,000 tons of miscellaneous commodities would move upbound at an annual saving of $124,000, and about 12,000 tons would move downbound at an annual saving of about $57,000.

246. The traffic study reported a total of 95,000 tons of these commodities from which initial analysis developed 10,000 tons for rate analysis. The rate analysis indicates that most of these commodities would not move because of insufficient tonnage for barge movement or excessive handling costs would be incurred in water movement. Accepted for prospective traffic are 3,000 tons of composition roofing that would move from New Orleans, Louisiana, to Dallas, Texas, at an annual saving of about $6,000, or an average unit saving of about $2.16 per ton.

PROJECTION OF WATERBORNE COMMERCE

247. INTRODUCTION.- In order to estimate the average annual commerce that would use the proposed waterway over the 100-year amortization period it was necessary to estimate conditions of economic development, within the traffic area, that can reasonably be expected to occur during this period. Basic economic factors may be utilized to estimate future economic activity in the traffic area and these factors may then be related to prospective waterway commerce in commodities that are responsive to these factors.

248. The basic factors selected for purposes of estimating future economic conditions in the traffic area are trends in population, value of farm products sold, value added by manufacture, new construction, and wheat exports. The historic trends of these basic economic factors, as developed in detail in the economic base study in appendix VII are then used as a basis for projection of future growth and to establish indices which may be applied to appropriate groups of commodities in the accepted 1958 prospective commerce from which estimates of the prospective average annual commerce may be developed.

249. ALLOCATION OF PROSPECTIVE 1958 COMMERCE TO MAJOR INDICES.- The allocation of individual commodities within the accepted 1958 prospective commerce to major indicators is made on the basis of the indicator that is most nearly representative of the sector of economy that controls the movement of the specific commodity. The accepted 1958 prospective commerce as given in table 29 is allocated by commodity, tonnage, and savings for the channel to Fort Worth in table 30.

TABLE 30

CHANNEL TO FORT WORTH

ALLOCATION OF PROSPECTIVE COMMERCE TO MAJOR INDICES

POPULATION			VALUE OF FARM PRODUCTS SOLD			VALUE ADDED BY MFG			NEW CONSTRUCTION			EXPORT WHEAT		
COMMODITY	TONS	SAVINGS	COMMODITY	TONS	SAVINGS	COMMODITY	TONS	SAVINGS	COMMODITY	TONS	SAVINGS	COMMODITY	TONS	SAVINGS
Waste Paper	15,600	$ 12,168	Fish Meal & Scrap	30,500	$ 47,545	Rubber, Synthetic	6,000	$ 39,960	Paper, Felt	4,550	$ 4,732	Wheat	1,430,801	$1,616,047
Wrapping Paper & Bags	16,260	47,992	Poultry Grits, Shell	31,200	79,560	Rags	2,000	6,560	Sand & Gravel	2,564,900	623,961	Milo	779,413	811,743
Pulpboard	82,860	169,580	Molasses, Blackstrap	63,600	245,977	Aluminum Pig	3,000	12,210	Stone	369,100	140,259			
Newsprint	33,450	77,621	Feed & Meal	15,000	46,290	Iron & Steel Scrap	314,100	888,501	Roofing, Asphalt	6,000	8,160			
Benzene	13,850	65,902	Soybean Meal	36,000	28,080	Ferrous Metals	15,000	13,650	Perlite, Refined	14,000	34,020			
Naptha	14,850	68,013	Burlap Bagging, Jute & Sisal	6,450	23,961	Lead, Pig	10,700	34,732	Pipe, Iron & Steel	215,990	1,122,715			
Lubricating Oil	4,800	24,768	Ammonia Sulfate	10,500	15,625	Non-Ferrous Metals	7,000	45,010	Iron & Steel Articles	497,430	2,351,471			
Wax	3,600	16,596	Phosphate Rock	57,000	59,250	Non-Ferrous Scrap Metal	14,000	57,820	Roofing Composition	3,000	6,480			
Oil, Light Grade	18,000	64,260	Sodium Phosphate	60,000	320,200	Caustic Soda, Liquid	11,609	66,082						
Solvents, Liquid	3,000	6,900	Chemicals & Related Products, NEC	11,000	24,020	Caustic Soda, Dry	8,300	45,879						
Soap, Soap Powder & Compounds	52,613	96,545				Soda Ash	64,560	382,757						
TOTAL	258,883	$650,345		321,250	$890,508		456,269	$1,593,161		3,674,970	$4,291,798		2,210,214	$2,427,790

250. PROJECTION FACTORS.- The estimates of growth trends for the five basic economic factors were projected over the 100-year life of the project. These projections, shown as growth curves in the economic base study, were then used to develop numerical measure of growth by which the estimates of base-year creditable commerce are to be multiplied to derive corresponding estimates of average annual commerce over the same period.

251. The estimates of accepted prospective commerce are based on economic conditions in 1958 since this was the latest year for which complete traffic information was available. The year 1958 is used as the base-year to develop projection factors or multipliers. Using the 1958 values on each of the economic indicators as the base of 1.00, factors were developed for the years 1970, the initial year, 1995 the quarter year, 2020 the midyear, and 2070 the terminal year of the life of the project. The projection factors or multipliers developed for all channels investigated are given by major indicator and by year in table 31.

TABLE 31

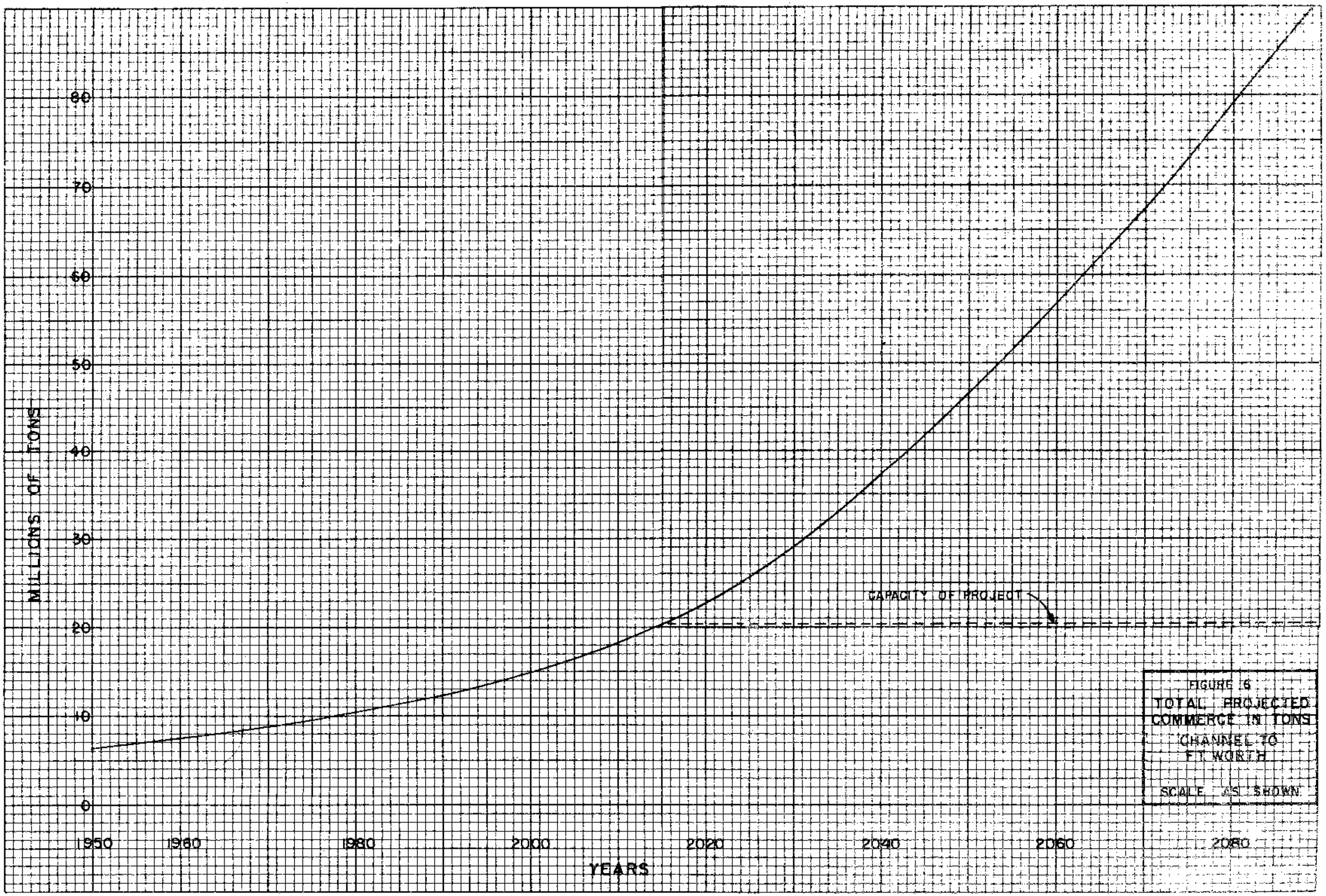
PROJECTION FACTORS

(All channels investigated)

Economic indicator	1958	1970	1995	2020	2070
Population	1	1.25	1.90	2.90	5.50
Value added by manufacture	1	1.80	4.50	11.63	45.77
Value of farm products sold	1	1.20	1.79	2.63	5.63
New construction	1	1.37	2.67	5.23	17.31
Wheat exports	1	1.04	1.26	1.76	2.29

252. PROJECTION OF PROSPECTIVE COMMERCE.- The projection factors shown for each major index in table 31 are used to project the corresponding commodity tonnages and savings of the 1958 prospective commerce accepted for the project, as allocated in table 30. The projected tonnages and savings for the years listed for each economic indicator are given in table 32.

253. COMPOSITE PROJECTIONS.- Composite projections of estimates of growth of prospective commerce and savings to navigation are required to derive estimates of equivalent average annual values of tonnage and savings that would accrue to the project over the 100-year life. Accordingly, total values for each of the selected years, as given in table 32 were plotted to establish the composite projection of total tonnage and total savings. These curves are shown on figures 6 and 7, respectively.


MILLIONS OF TONS
0
10
20
30
40
50
60
70
80
1950
1960
1980
2000
2020
2040
2060
2080
YEARS
CAPACITY OF PROJECT
FIGURE 6
TOTAL PROJECTED COMMERCE IN TONS
CHANNEL TO FT WORTH
SCALE AS SHOWN

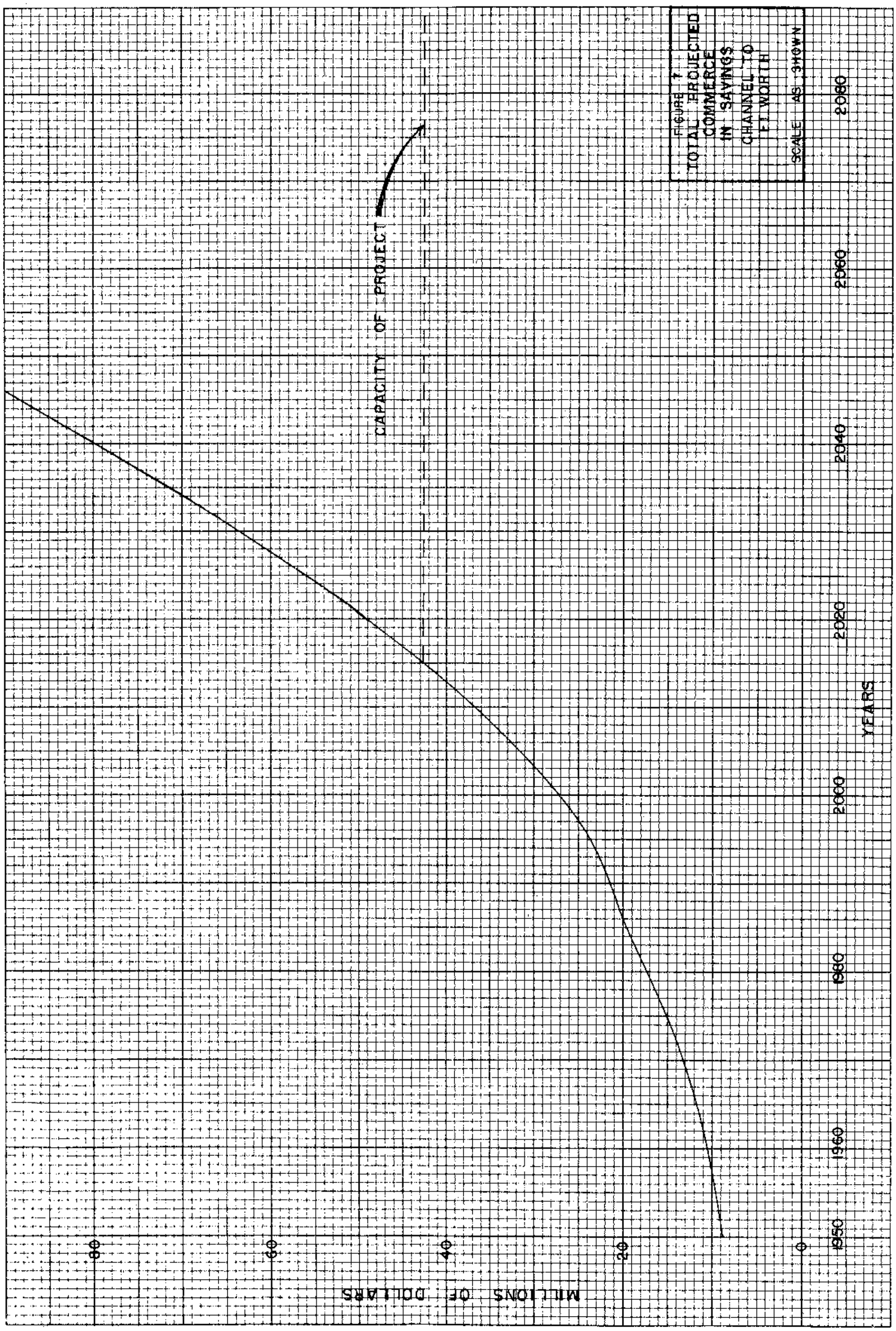


FIGURE 7
TOTAL PROJECTED
COMMERCE
IN SAVINGS
CHANNEL TO
FT WORTH
SCALE AS SHOWN
CAPACITY OF PROJECT
YEARS
1950
1960
1980
2000
2020
2040
2060
2080
MILLIONS OF DOLLARS
0
20
40
60
80

TABLE 32

CHANNEL TO FORT WORTH

PROJECTIONS OF COMMERCE - TRINITY RIVER, TEXAS

Index	1958	1970	1995	2020	2070
TONNAGE (thousands)					
Population	259	324	492	751	1,425
Value added by Mfg.	457	824	2,060	5,303	20,871
Value of farm products sold	321	384	576	844	1,807
New construction (1)	3,675	4,997	5,962	11,694	38,709
Export wheat	2,210	2,299	2,777	3,892	5,053
Total	6,922	8,828	11,867	22,484	67,865
SAVINGS (thousands)					
Population	$ 650	$ 797	$ 1,213	$ 1,849	$ 3,511
Value added by Mfg.	1,593	2,880	7,200	18,527	72,912
Value of farm products sold	891	1,064	1,596	2,338	5,007
New construction (1)	4,292	5,836	10,542	20,675	68,441
Export wheat	2,428	2,526	3,051	4,277	5,552
Total	9,854	13,103	23,602	47,666	155,423

(1) Projection allows for depletion of sand and gravel in lower river in 1988.

ESTIMATES OF TRANSPORTATION BENEFITS

254. GENERAL.- The navigation benefits that would accrue to the proposed waterway in the Trinity River from the Houston Ship Channel to Fort Worth, Texas, are considered to be the savings to transportation afforded by barge transportation as compared to the lowest cost alternate method of movement, less the increased vehicular operating costs resulting from raising the vehicular bridges across the waterway.

255. All channels investigated were analyzed on the basis of 1958 traffic and savings, using the procedures illustrated by the single-purpose channel examples given herein to determine the most efficient and economic waterway capable of transporting the estimated prospective commerce. Investigation reveals that the mulitple-purpose channel is the most feasible for improvement of the Trinity River for all purposes, including navigation. This section of the appendix presents the estimated navigation benefits creditable to the single-purpose and multiple-purpose channels to Fort Worth and the incremental navigation benefits creditable to the section of these channels extending the proposed waterway for Dallas to a terminal at Fort Worth. The multiple-purpose channel adheres closer to the natural stream channel of the Trinity River than the single-purpose project and is about 9 miles longer than the single-purpose project. However, studies of barge operating costs on the multiple-purpose channel indicate that the more favorable cross-section ratios of barge-to-channel in the multiple-purpose channel permits an increase in the operating efficiency of barge traffic and results in an additional saving to navigation from a reduction of operating costs. The increased cost because of the additional length of channel is more than offset by reduced cost because of the additional operating efficiency of the tows, resulting in a net gain in saving to navigation on the multiple-purpose channel over the saving for the single-purpose project.

256. CAPACITY OF WATERWAY.- Studies of lock requirements in paragraphs 153 through 158 of this appendix indicate that the maximum capacity of the waterway, as limited by locks No. 13 through 17, would be reached when commerce on the entire channel has increased to about 20 million tons annually. Figure 6 shows that the estimated prospective commerce for the channel to Fort Worth will reach 20 million tons about 2015, five years before the midpoint of the project life period. Therefore, prospective commerce for the purpose of computing savings to navigation from the improvements recommended in this report, is considered to continue at the 20 million ton level over the last 55 years of the life of the project. Similarly, a waterway terminating at Dallas would develop commerce that would reach to a capacity of the central locks in 2019 and continue at that level for the remaining 51 years of the project life.

257. NAVIGATION BENEFITS.- In a comparison of estimated benefits with estimated annual costs, both benefits and costs should be on an equivalent average annual time basis. The benefits from saving to navigation increase

over a portion of the life of the project as the waterway tonnage increases, while the annual costs are computed as a uniform annual amount. Therefore, it is necessary to compute the benefits as a uniform annual amount throughout the life of the improvement.

258. EQUIVALENT AVERAGE ANNUAL GROSS NAVIGATION BENEFITS.- Depletion of sand and gravel reserves in the lower river in 1988 results in a non-uniform rate of projected growth of prospective commerce, and the limited capacity of the locks results in an equal annual benefit over a large portion of the life of the project. To determine the equivalent average annual gross navigation benefits, in accordance with procedures given in EM 1120-2-118, the present worth of each of the varying estimated annual benefits during the life of the project were computed, using a compound interest rate of 2.875 percent. The sum of the present-worth values of the benefits amortized over the 100-year project life at 2.875 percent interest rate with annual interest at the same ratio gives an equivalent average annual gross navigation benefit of $26,832,000.

259. BENEFITS FROM EXTENSION OF LIFE OF EXISTING BRIDGES ACROSS THE TRINITY RIVER.- Benefits from the extended useful life of existing bridges crossing the Trinity River that would be obtained by alteration or reconstruction of the bridges under the multiple-purpose channel project were computed in accordance with the paragraph titled, "Extension of Useful Life," on page 31 et seq. of, "Proposed Practices for Economic Analysis of River Basin Projects," prepared by the subcommittee on Evaluation Standards in the Report to the Inter-Agency Committee on Water Resources (May 1958).

260. These benefits were computed on the basis of an assumed average life of 50 years for highway bridges and assumed average lives for segments of railway bridges as follows: 37 years for timber trestles, 50 years for steel superstructure, and 100 years for substructure.

261. The year 1970, used as the year of initial use of the multiple-purpose channel project in computing estimates of project benefits, was also used as the base year for computing benefits from extended useful life of existing bridges. Estimates of replacement costs were based on 1962 price levels. Since the estimated benefits would maintain a constant ratio to increases or decreases in price levels, a constant level of estimated replacement costs was used in computations.

262. The benefits that would be derived from the extended useful life of existing bridges were computed separately for each of two reaches and for the entire river for both highway and railway bridges using an amortization factor based upon an interest rate of 2.875 percent compounded annually. The lower reach extends from channel mile 0.00 to channel mile 312.84 inclusive, and the upper reach from above channel mile 312.84 to Fort Worth.

263. The average annual charges necessary to amortize the replacement cost of the affected portion of each bridge over its assumed total life period were computed by applying the capital recovery factor for that number of years. The extended life of the affected portion of each bridge would be equal to the expired life of the existing structure with respect to the initial project year, 1970. This extended life was determined by obtaining the difference between the assumed total life of the structure and the estimated remaining life as of 1970. The annual charges over the number of years of extended life were assumed to be a uniform annual annuity series, and the lump sum worth at the beginning year of the series was determined by applying the present worth factor for the number of years of extended life at an interest rate of 2.875 percent compounded annually. Where the beginning year of the series was subsequent to the initial project year 1970, the beginning year worth was further discounted for the number of intervening years to determine the 1970 worth of the total extended life benefit. This was done by applying the single payment present-worth factor at 2.875 percent interest compounded annually. The average annual value over the 100-year assumed economic life of the proposed Trinity River navigation project was then computed as the uniform annual annuity value over a 100-year period at 2.875 percent compounded annually for a single payment of the 1970 worth of the benefit. The annuity, thus determined, is the estimated annual benefit from extended useful life of a given bridge.

264. For the affected portions of railway bridges, the different estimated total service lives of 37 years for wooden trestles, 50 years for steel superstructures, and 100 years for substructures were taken into account and computed separately. The estimated annual benefits for each portion of a given bridge were added together to obtain the total annual benefit for that bridge.

265. The estimated annual benefits for each reach of the river described above were obtained by adding the benefits from each modified bridge in that reach. The total benefits were estimated as follows:

	Benefits	
Highway bridges (upper reach)	$135,827	
Railway bridges (lower reach)	28,284	
Total upper reach	164,111	$164,111
Highway bridges (lower reach)	25,792	
Railway bridges (lower reach)	12,180	
Total lower reach	37,972	37,972
Total upper and lower reaches		$202,083

266. VEHICLE OPERATING COSTS (BRIDGES).- The proposed canalization of the Trinity River would require the raising of 37 Federal, State, County and municipal highway bridges to provide navigation clearances for the waterway traffic. The cost of operating vehicles over the existing bridges would be increased when the bridges are raised. The increased vehicular costs represent a negative benefit of the proposed project. Unit values developed by the U. S. Department of Commerce in their report entitled "Navigational Clearance Requirements for Highway and Railroad Bridges" dated February 1955, and statistical data on present and projected number of vehicles a day furnished by the Texas Highway Department and county and municipal engineers were used to derive the estimates of increased annual cost of operation of vehicles over the higher bridges.

267. Unit values per foot of lift of $0.000236 per truck and $0.0000303 per passenger car, were applied to the estimated present and future traffic load over each bridge and the proposed increased height of each bridge in feet of lift to derive the estimated increase in annual operating cost to vehicles for each bridge. These costs are then consolidated according to type of vehicle and to kind of roadway for the several segments of the channel.

268. Procedures contained in Engineering Manual 1120-2-118 were used to derive the equivalent average annual costs to vehicular traffic. These costs are estimated to amount to $323,000 annually for the channel terminating at Fort Worth, and $71,000 annually for the channel terminating at Dallas.

269. A summary of the estimates of equivalent average annual costs to vehicular traffic is given in table 33.

TABLE 33

SUMMARY OF EQUIVALENT AVERAGE ANNUAL COSTS OF VEHICLE TRAFFIC FOR ALL BRIDGES - 100-YEAR LIFE (1970-2070)

Item	Freight vehicles	Passenger vehicles	Total
Toll roads, interstate U. S. highways	$ 37,000	$ 42,000	$ 79,000
State highways	18,000	22,000	40,000
Farm-to-market and county roads	17,000	19,000	36,000
Municipal streets	78,000	90,000	168,000
Totals	150,000	173,000	323,000

270. The increased cost to vehicular traffic operating over the modified bridges across the waterway is taken as a negative benefit to the waterway and is deducted from the gross equivalent average annual benefits to transportation.

271. SUMMARY OF ESTIMATED BENEFITS.- The total net equivalent average annual benefits creditable to the proposed canalization of the Trinity River to Fort Worth, Texas, are the savings in transportation costs that are realized over the lowest cost alternate method of movement, less the additional costs to vehicular traffic from raising of highway bridges. The total net equivalent average annual benefits creditable to the section of the waterway between Dallas and Fort Worth is the difference in the net equivalent average annual benefits creditable to the channel that would terminate at Dallas, Texas, and to a similar channel that would terminate at Fort Worth, Texas. A summary of the benefits creditable to the single-purpose and multiple-purpose channels from the Houston Ship Channel to Fort Worth and to Dallas and the incremental benefits to the section of the channels between Dallas and Fort Worth is given in table 34.

TABLE 34

SUMMARY OF EQUIVALENT AVERAGE ANNUAL NET BENEFITS CREDITABLE TO THE PROPOSED NAVIGATION PROJECT, TRINITY RIVER, TEXAS

(in thousands of dollars)

Item	Gross savings to navigation	Extended life of bridges	Less vehicular costs	Net benefits
		SINGLE-PURPOSE CHANNEL		
HSC to Ft.Worth	26,832	202	323	26,711
HSC to Dallas	23,519	38	71	23,486
Dallas-Ft.Worth	3,313	164	252	3,225
		MULTIPLE-PURPOSE CHANNEL		
HSC to Ft.Worth	27,074	202	323	26,953
HSC to Dallas	23,730	38	71	23,697
Dallas-Ft.Worth	3,344	164	252	3,256

272. Comparative benefits of net transportation savings were developed for all channels investigated. These benefits are estimated on the same basis as the detailed study of the 12- x 150-foot single-purpose channel for the traffic that would have used each of the channels investigated. The equivalent average annual net transportation benefits are estimated as a proportion of the net 1958 transportation benefits creditable to each channel. Detailed projections of traffic and savings creditable to the 12- x 150-foot channel presented in this appendix were used to develop the ratio of 1958 savings to navigation to equivalent average annual net savings to transportation for each of the channels. The calculated 1958 benefits and the estimated equivalent average annual benefits for all channels are given in table 35.

TABLE 35

SUMMARY OF EQUIVALENT AVERAGE ANNUAL NET BENEFITS CREDITABLE TO ALL CHANNELS TO DALLAS TRINITY RIVER, TEXAS

Channel size	1958 savings to navigation (thousands of dollars)	Equivalent average annual net benefits (thousands of dollars)
9' x 150'	6,931	20,682
12' x 150'	7,869	23,486
9' x 200'	7,408	22,108
12' x 200'	8,264	24,666

COMPREHENSIVE SURVEY REPORT

ON

TRINITY RIVER AND TRIBUTARIES, TEXAS

APPENDIX IV

FLOOD CONTROL ECONOMICS

U. S. ARMY ENGINEER DISTRICTS
FORT WORTH AND GALVESTON
CORPS OF ENGINEERS
FORT WORTH AND GALVESTON, TEXAS

JUNE 1962

COMPREHENSIVE SURVEY REPORT
ON
TRINITY RIVER AND TRIBUTARIES, TEXAS

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FLOOD CONTROL ECONOMICS

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FLOOD CONTROL ECONOMICS

1. SCOPE AND RELATIONSHIP TO OTHER PARTS OF REPORT.- The comprehensive survey of the Trinity River and tributaries made necessary a complete study of each of the project purposes resulting from the investigated improvements. These purposes include navigation, flood control, water supply, recreation, fish and wildlife, and allied uses. A definite relationship exists between most of these purposes in each segment of the recommended plan. For example, the multiple-purpose channel would produce benefits for navigation, flood control, recreation, and fish and wildlife. Likewise, Tennessee Colony Reservoir would produce all of these benefits and the additional benefit of water supply. The local protection projects on the main stem of the Trinity River, such as the Dallas Floodway Extension and the West Fork Floodway, have a direct relationship with navigation benefits since these two purposes would utilize the same channel through these areas. This in turn introduces other purposes since the increase in the elevation of the water surface required for navigation results in benefits for recreation and fish and wildlife. The only elements of the proposed plan which would produce only flood-control benefits are the Elm Fork, Liberty, and Duck Creek local protection projects.

2. Other appendices of this report contain information and data concerning studies and investigations relating to the proposed flood control facilities evaluated in this appendix. Appendix I - Project Formulation, presents information on different amounts of flood control storage in the proposed reservoir projects and on various channel capacities and levee heights in connection with other recommended improvements. Appendix II - Hydrology, Hydraulic Design, and Water Resources, contains data on discharge frequencies on which flood damage evaluations were based and also on water supply storage in the multiple-purpose reservoir projects. Appendix VI-Cost Estimates, Geology, and Design Information, contain data on the structural design and first cost of the various flood-control improvements recommended in the report. Appendix VII - Economic Base Study, contains information on the estimated projection of various economic indicators in the area affected by the recommended flood-control projects. The entire base study area and the portion of this area studied specifically for projection of future development in connection with flood damages are shown in figure 1.

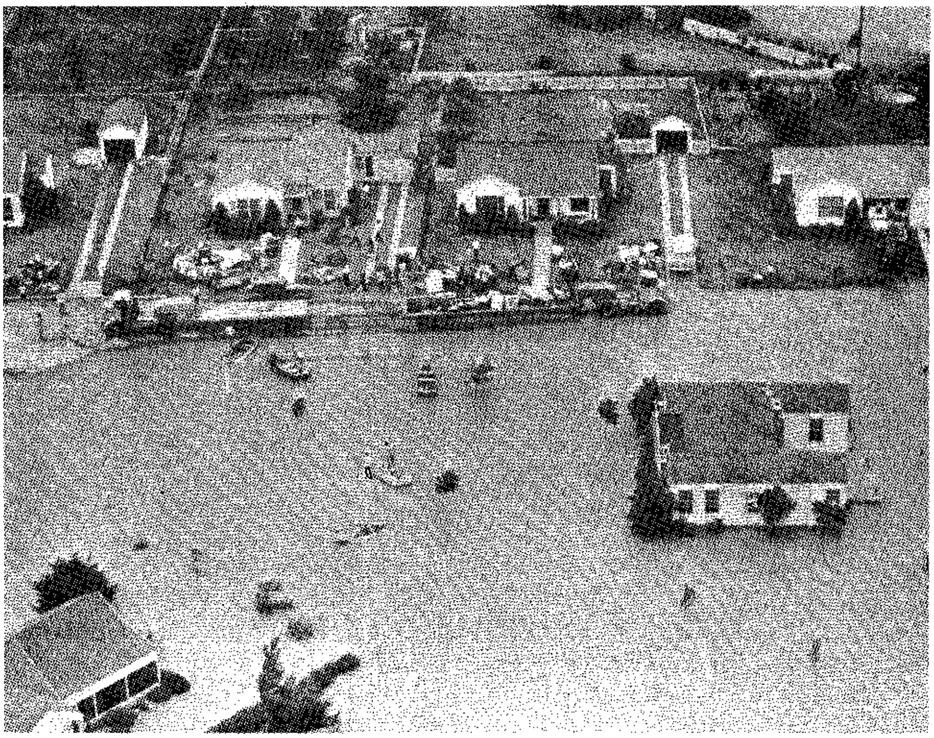
THE CROSSHATCHED PORTION SHOWN ABOVE IS THE AREA PRINCIPALLY AFFECTED BY FLOOD DAMAGES.

FIGURE I. PORTION OF BASE STUDY AREA PERTINENT TO FLOOD CONTROL

3. This appendix discusses the evaluation of flood control benefits which would accrue through operation of the proposed additions to the existing, authorized, and previously recommended Trinity River Basin projects. It describes the methods of determining the property valuations and annual flood damages, the damage reductions that would be realized through the addition of the recommended projects to the program, and the benefits that would result from these damage reductions. Although the estimated benefits found creditable to the various alternate or incremental units tested in the comprehensive plan through the process of project formulation are not contained in this appendix, the method of deriving those benefits is identical to that described herein. This appendix describes the area subject to flooding; presents tables of values, damages, and flood control benefits; and includes examples of typical curves used in determining average annual damages.

4. FLOOD PROBLEMS.- The Trinity River Basin, like all others, experiences various degrees of flooding at irregular intervals. The effort to alleviate this flood problem dates back many years to the time when the early settlers built small levees to protect their land. This was followed by the formation of locally organized levee districts who joined together to construct larger levees, and finally by the major public works activities of the Federal Government in regard to flood control operations. Although much improvement in regard to flood protection has taken place in the Trinity River Basin, a serious problem still remains. This problem is principally due to the attractiveness of the bottom lands for residential, industrial, and agricultural development, and the fact that partial protection of the flood plain encourages increased use and development. Major floods have occurred in the Trinity River Basin in 1899, 1908, 1913, 1915, 1922, 1929, 1936, 1940, 1942, 1944, 1945, 1949, and 1957. Photographs showing typical flood damages from two of these floods are shown in figure 2. The flood of May 16-17, 1949, was centered on the upper portion of the Trinity River watershed, principally on the Fort Worth area, and caused damages estimated at more than $16,000,000. The flood of April-June 1957 was general over the entire Trinity River Basin. This flood caused damages estimated at about $19,500,000, but it is estimated that the flood-control projects in operation on the basin at the time this flood occurred prevented an additional $85,000,000 in damages. Based on these damage-prevention figures, these projects more than repaid their total first cost for all purposes by preventing the damages from this one flood.

5. Agricultural damages account for approximately 69 percent of the total damages in the flood plain studied in this report, these damages being most heavily concentrated along the main stem of the Trinity River between Dallas and Liberty and along Elm Fork and Denton Creek. Urban damages occur principally at Fort Worth, Dallas,



WEST FORK TRINITY RIVER – MAY 1949

BIG FOSSIL CREEK—APRIL–JUNE 1957

FIGURE 2. URBAN FLOOD SCENES
VICINITY OF FORT WORTH, TEXAS

and Liberty and account for about 22 percent of the total damages. The remaining 9 percent of the total damages are due to losses sustained by oil field and gravel pit operations, highways, railroads, and utilities in the flood plain. The above percentages indicate that agricultural losses account for most of the damages experienced in the Trinity River Basin under present conditions of economic development. The principal crops grown in the flood plain consist of cotton, corn, grain sorghums, hay, and forage crops for improved pasture use. The following tabulation shows the estimated annual value of all crops grown in the flood plain assuming no damage from floods:

Reach		Improved agricultural acreage	Annual value per acre	Total annual value
Trinity River	1	7,934	$46.25	$366,900
	2	19,406	93.00	1,804,800
	3	73,834	93.71	6,919,000
	4	19,022	61.40	1,168,000
	5	49,473	70.82	3,503,700
	6	31,716	77.73	2,465,300
	7	6,655	45.00	299,500
Elm Fork and Denton Creek	1	13,358	54.00	721,300
Mountain Creek	1	0	0	0
Duck Creek	1	0	0	0
Total		221,398	77.91(1)	17,248,500

(1) Average amount per acre.

6. AREAS SUBJECT TO FLOODING.- The areas subject to flooding along the Trinity River and its tributaries considered in this report are predominantly agricultural; however, substantial urban, rural nonagricultural, transportation, and utility property lies within these areas. The urban property is on the Clear and West Forks of the Trinity River at Fort Worth, on the Elm Fork of the Trinity River in the vicinity of Dallas, on Duck Creek at Garland, and on the Trinity River at Dallas and Liberty. The rural nonagricultural

property is located principally along the main stem of the Trinity River, Elm Fork, Denton Creek, and Mountain Creek. Numerous railroads, state highways, county roads, electric powerlines, oil and gas pipe lines, and telephone and telegraph lines cross the areas subject to flooding throughout the length of the Trinity River and its tributaries.

7. Plates 2 through 12 of this appendix show the limits of the area subject to flooding on the Trinity River, the West Fork of the Trinity River below Bridgeport Dam, the Clear Fork of the Trinity River below Benbrook Dam, Elm Fork and Denton Creek below Lewisville and Grapevine Dams, Mountain Creek below river mile 7.2, and Duck Creek in the vicinity of Garland, Texas. For convenience in analyzing the property values and damages and for estimating the benefits creditable to the various improvements considered in this report, the areas subject to flooding were divided into ten reaches as shown on plates 1 through 12 of this appendix. These plates show the limits of flooding resulting from a combination of the maximum floods of record. The area studied in detail for this report and the area on which tables of property values, flood damages, and benefits have been prepared is the same as that described above and shown on the referenced plates except that the West Fork of the Trinity River above Lake Worth Dam has not been included. The evaluation of the area subject to flooding as studied in this report is based on the consideration that Livingston and Wallisville Reservoirs are existing projects, and the area inundated by these reservoirs has not been included in any of the tables pertaining to the area subject to flooding. The areas of the flood plain situated behind substandard levees have been included as a portion of the area subject to flooding.

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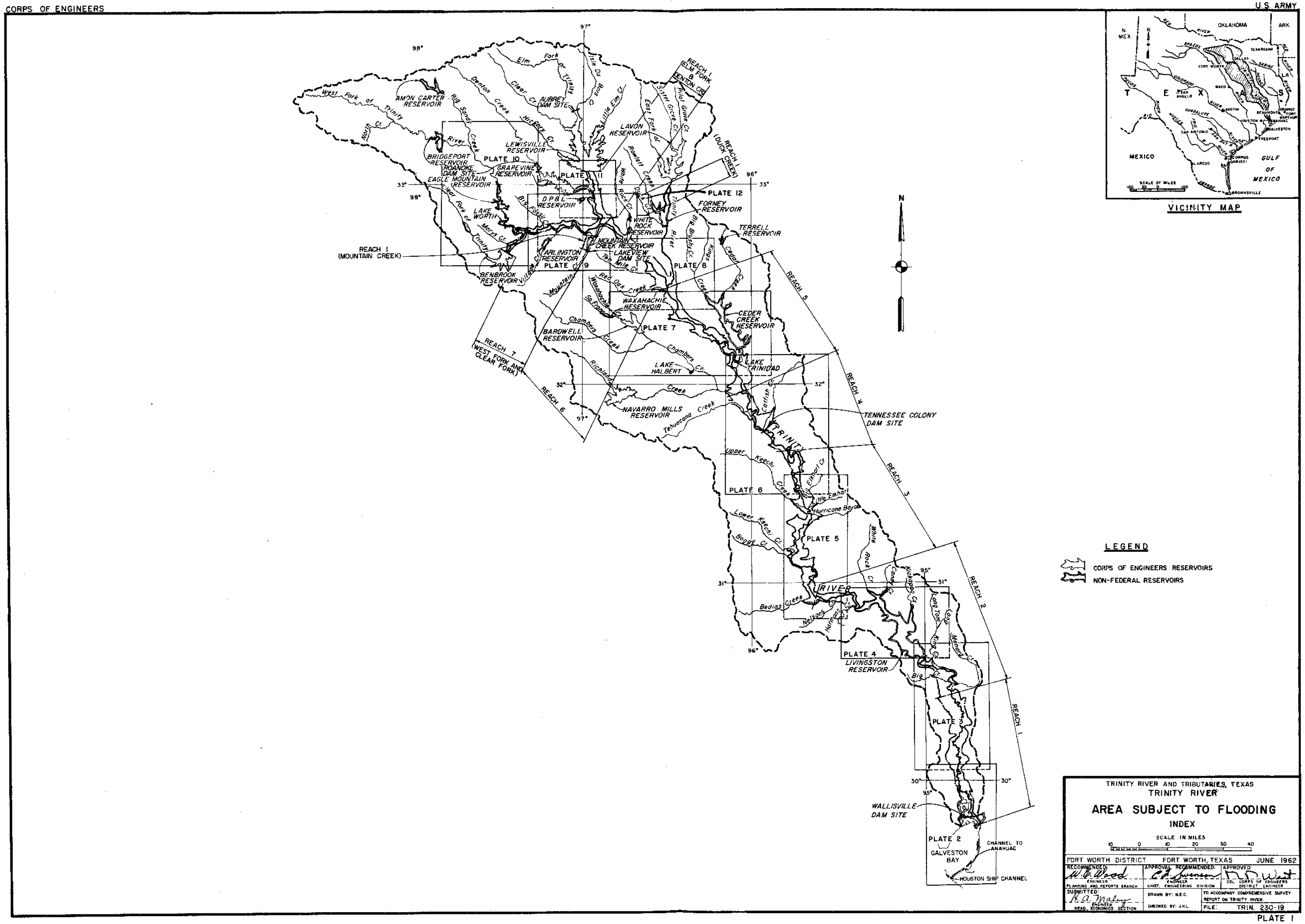
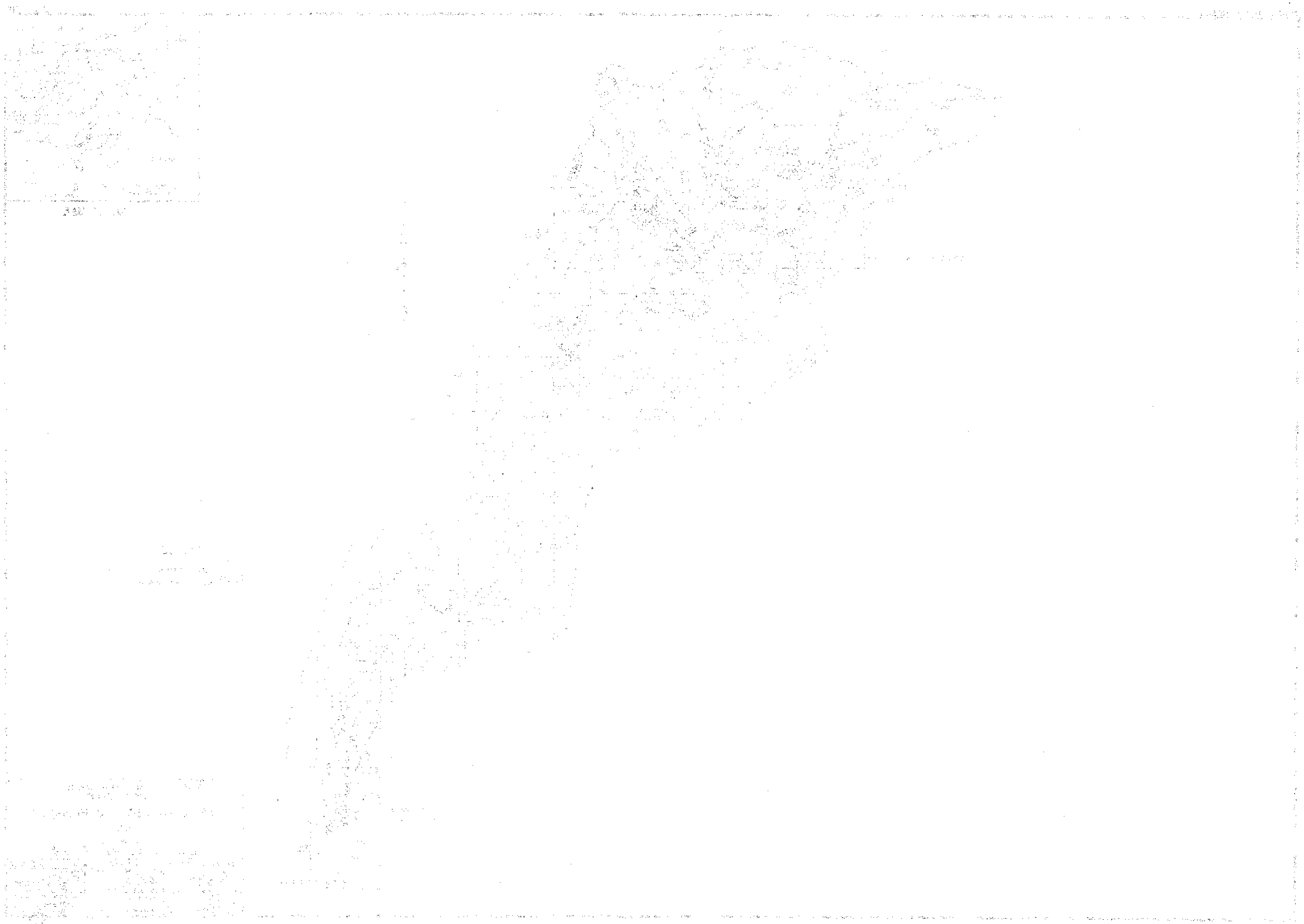


PLATE 1

52-704 O-65 Vol. II (Face p. 250) No. 1



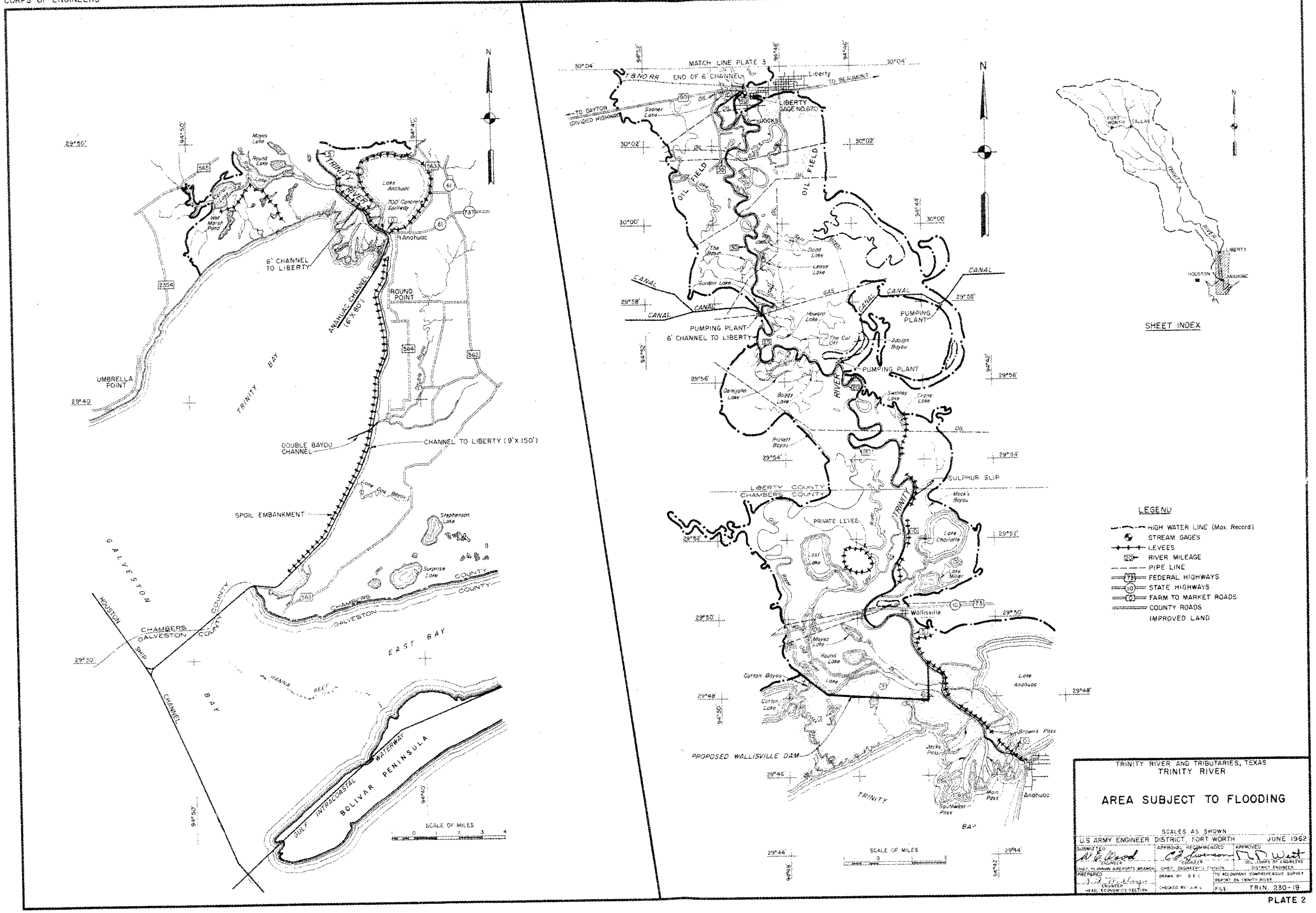


PLATE 2

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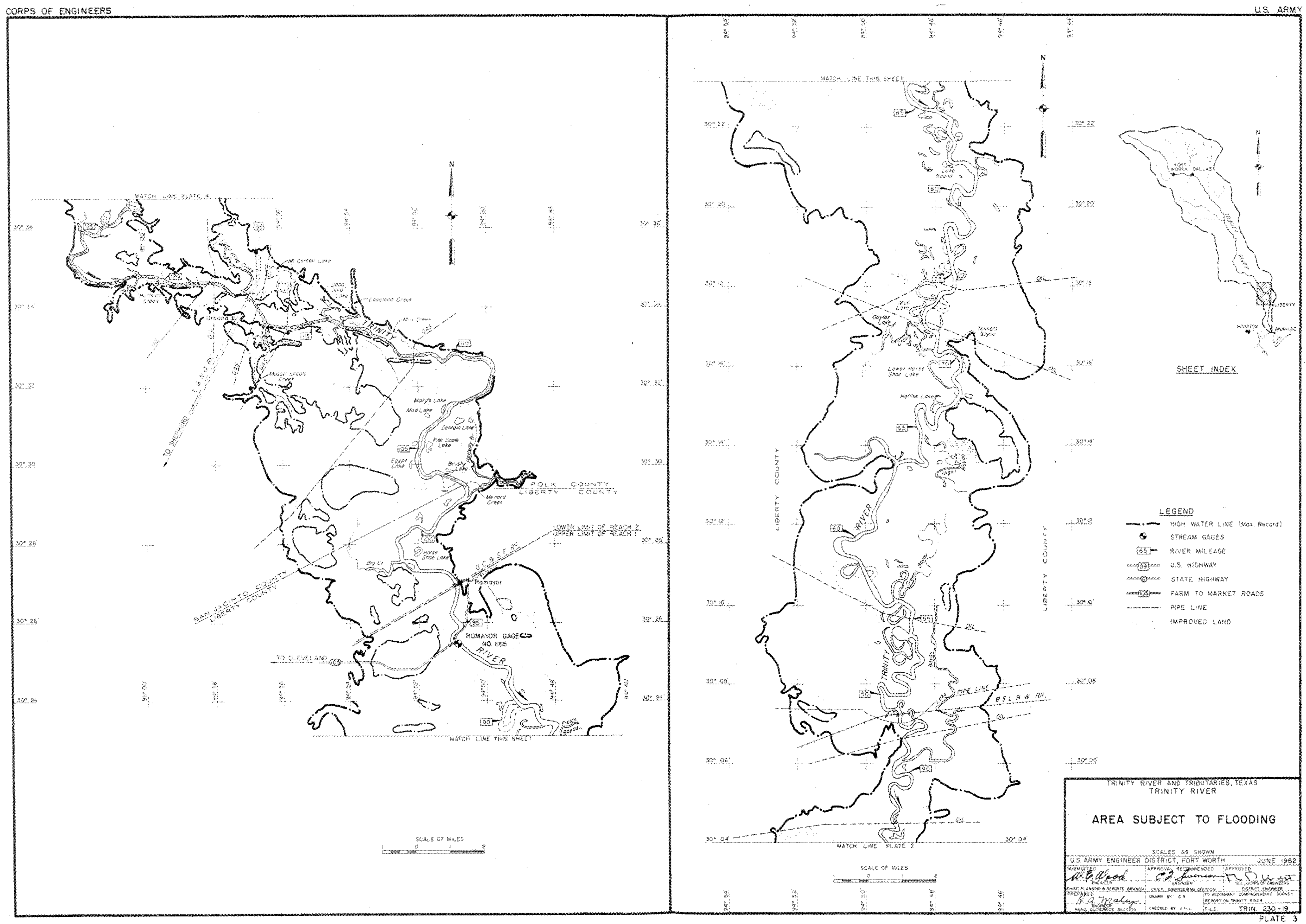

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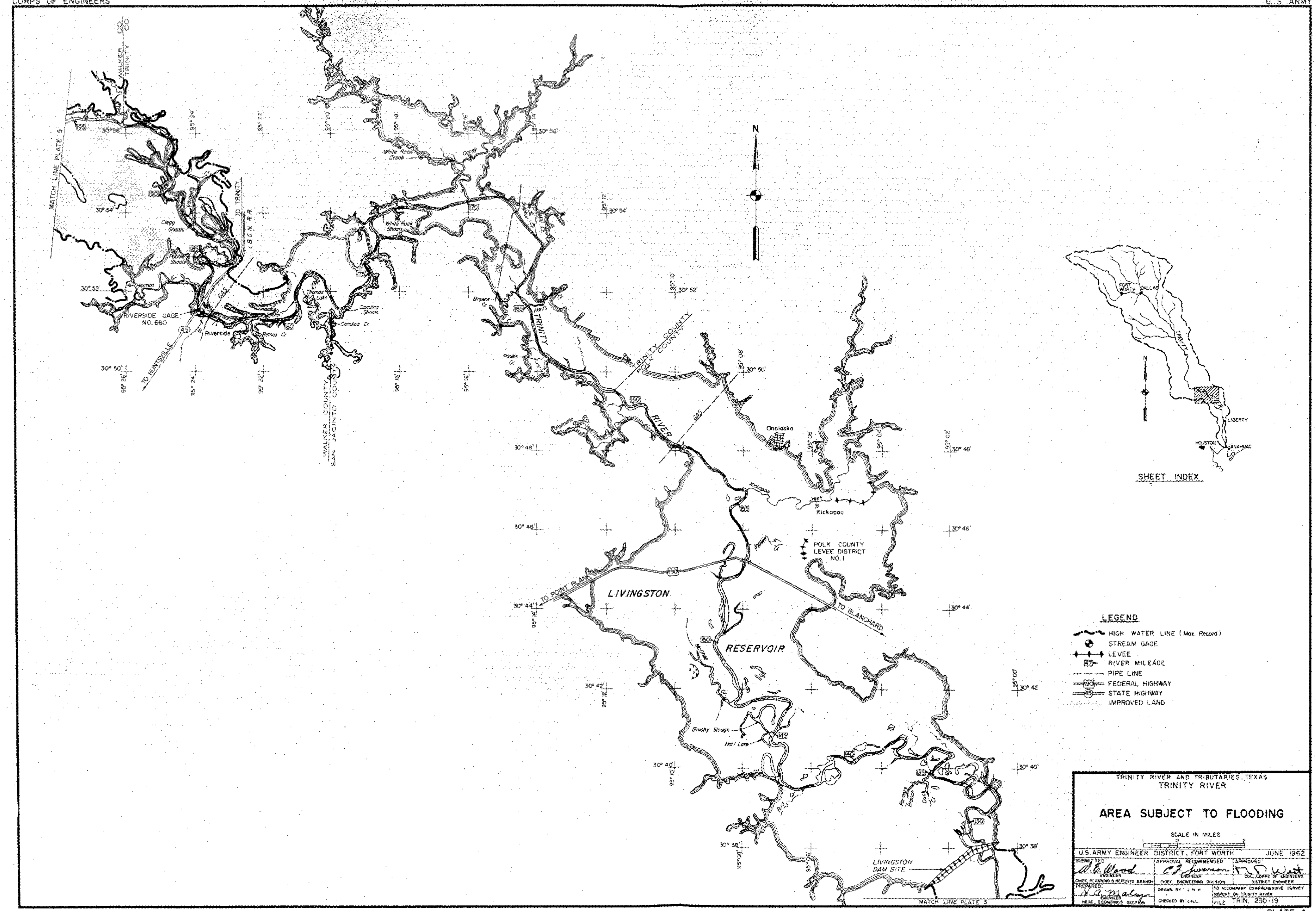

PLATE 4

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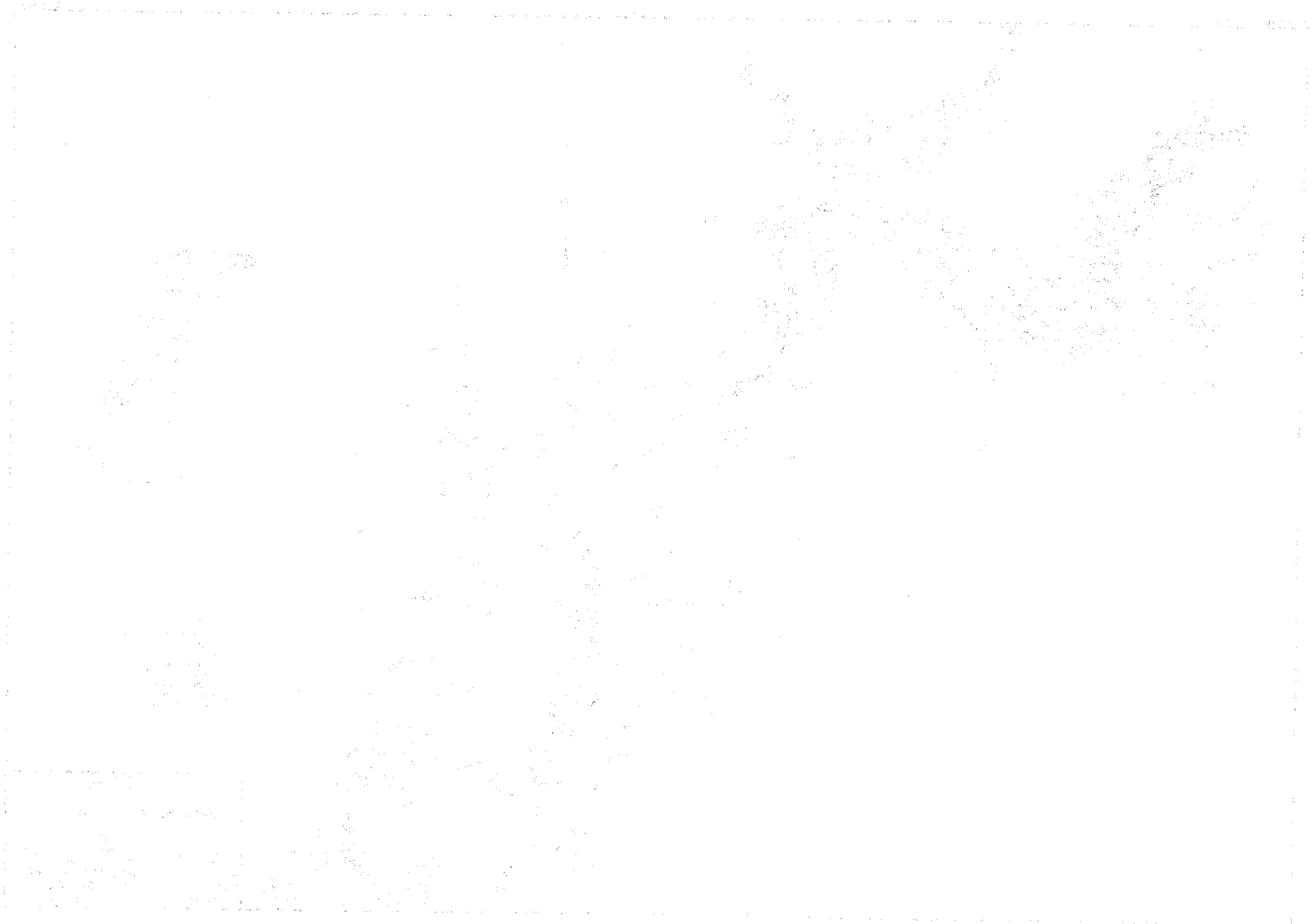

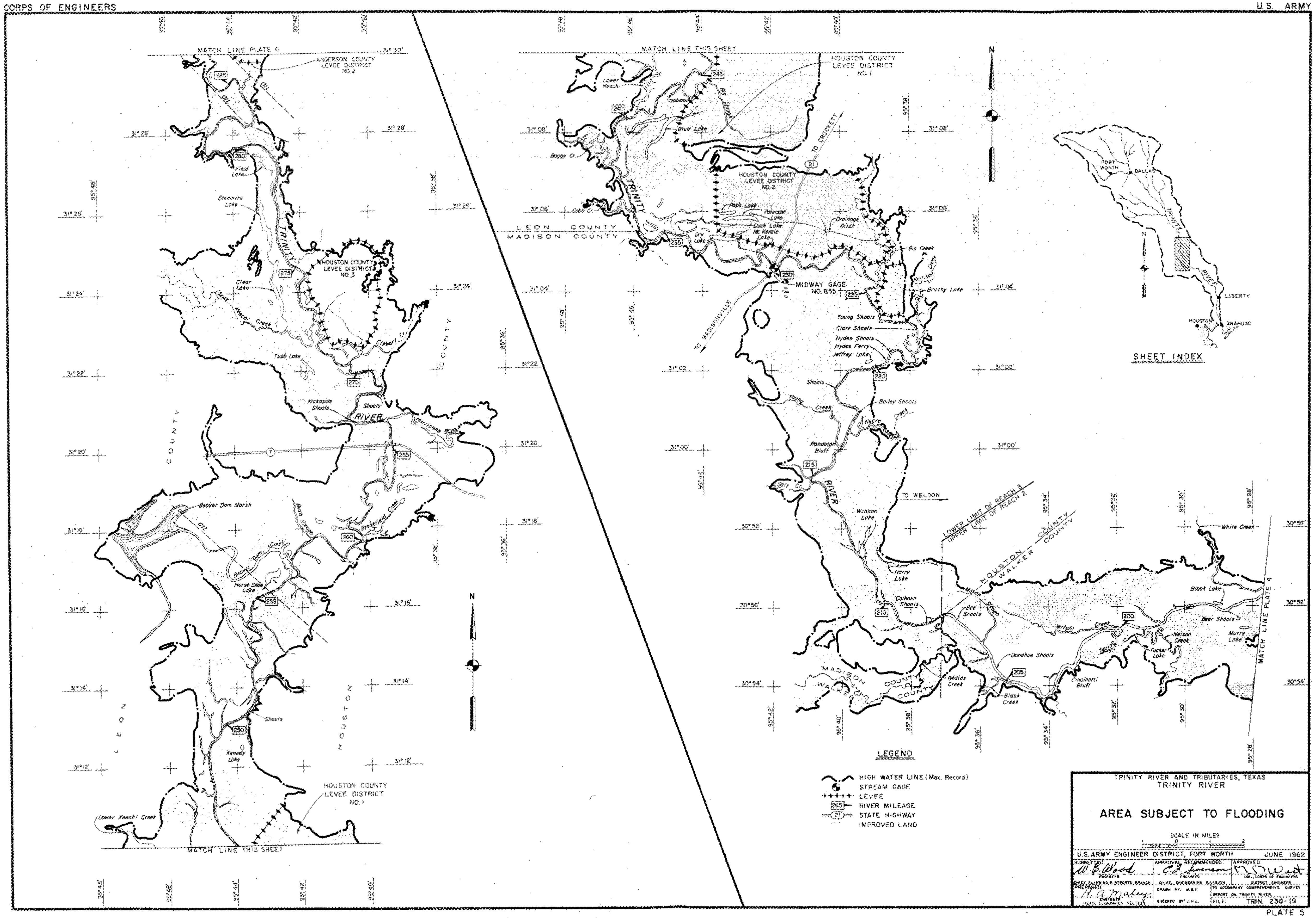

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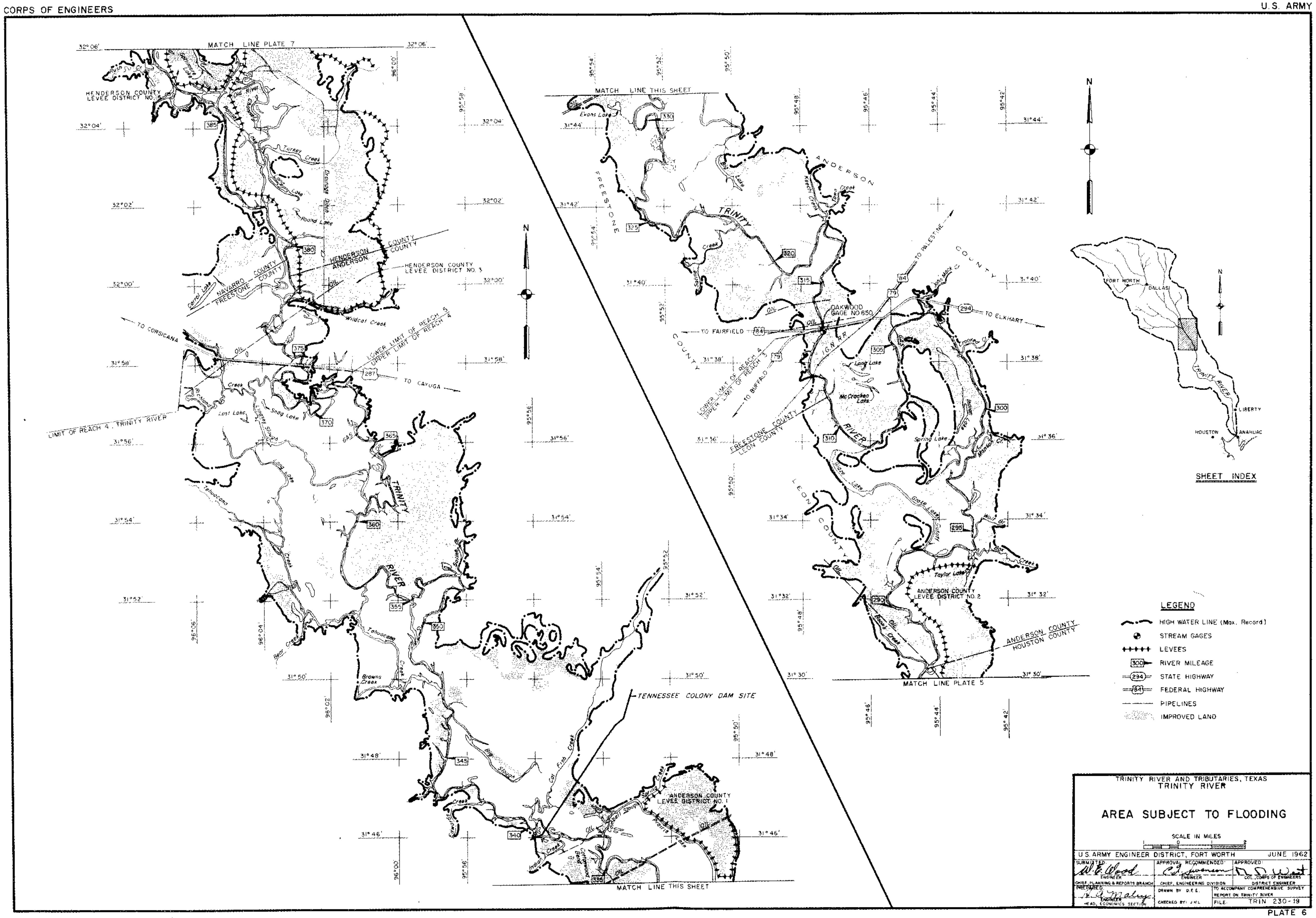

PLATE 6

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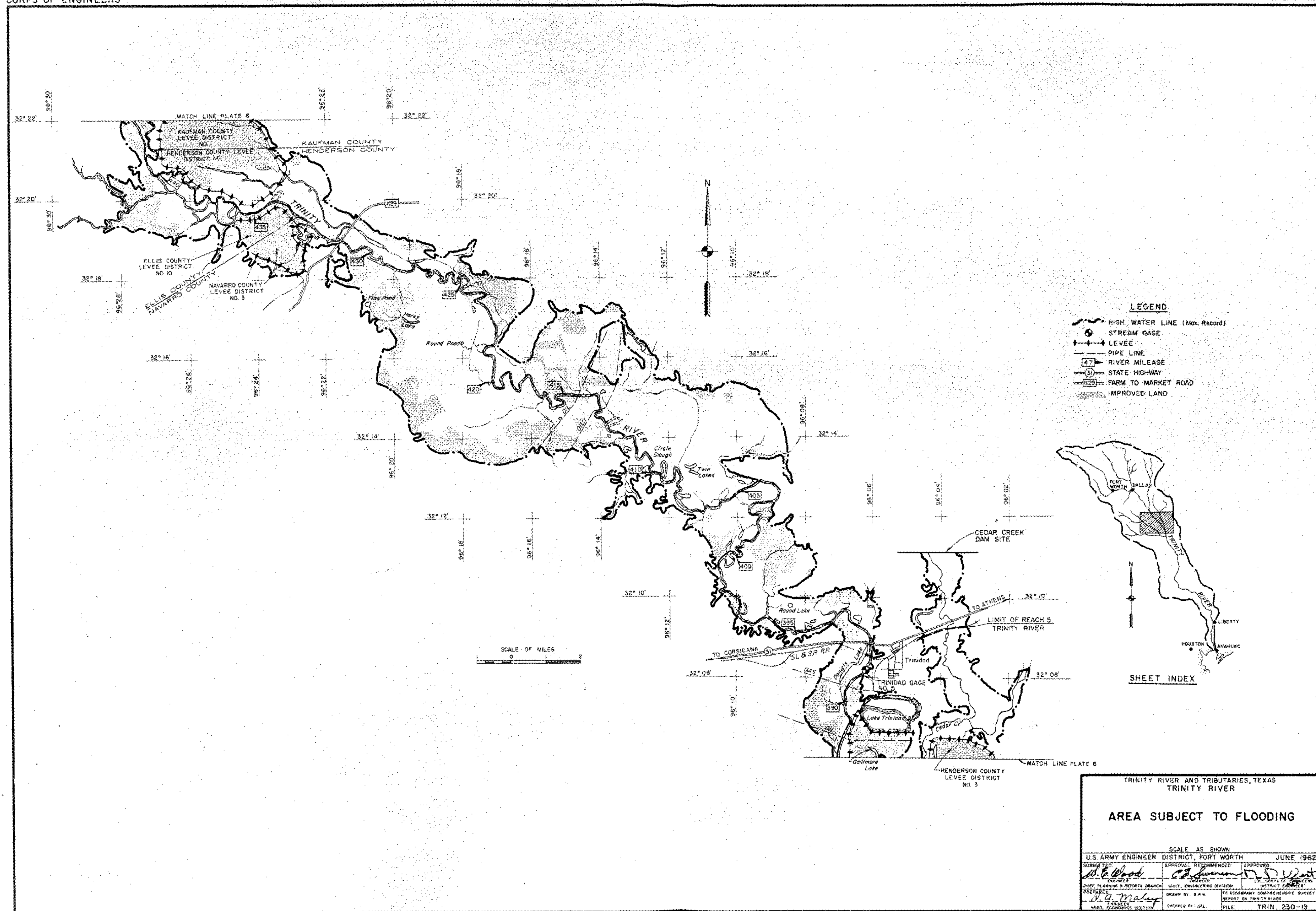


TRINITY RIVER AND TRIBUTARIES, TEXAS
TRINITY RIVER

AREA SUBJECT TO FLOODING

SCALE AS SHOWN

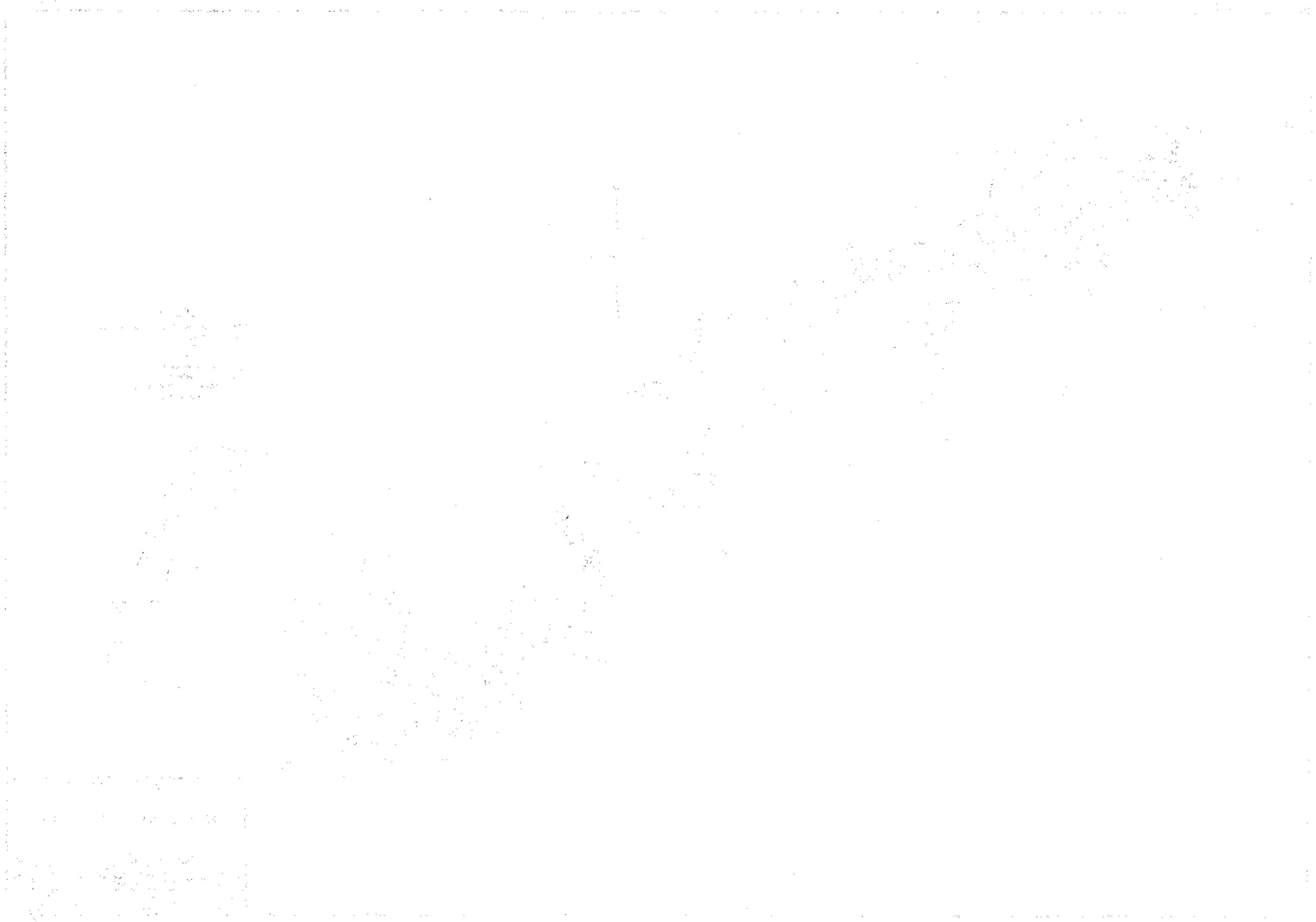
U.S. ARMY ENGINEER DISTRICT, FORT WORTH — JUNE 1962

SUBMITTED: ENGINEER, CHIEF, PLANNING & REPORTS BRANCH — APPROVAL RECOMMENDED: ENGINEER, CHIEF, ENGINEERING DIVISION — APPROVED: COL. CORPS OF ENGINEERS, DISTRICT ENGINEER

PREPARED: ENGINEER, HEAD, ECONOMICS SECTION — TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER

FILE TRIN. 230-19

PLATE 7



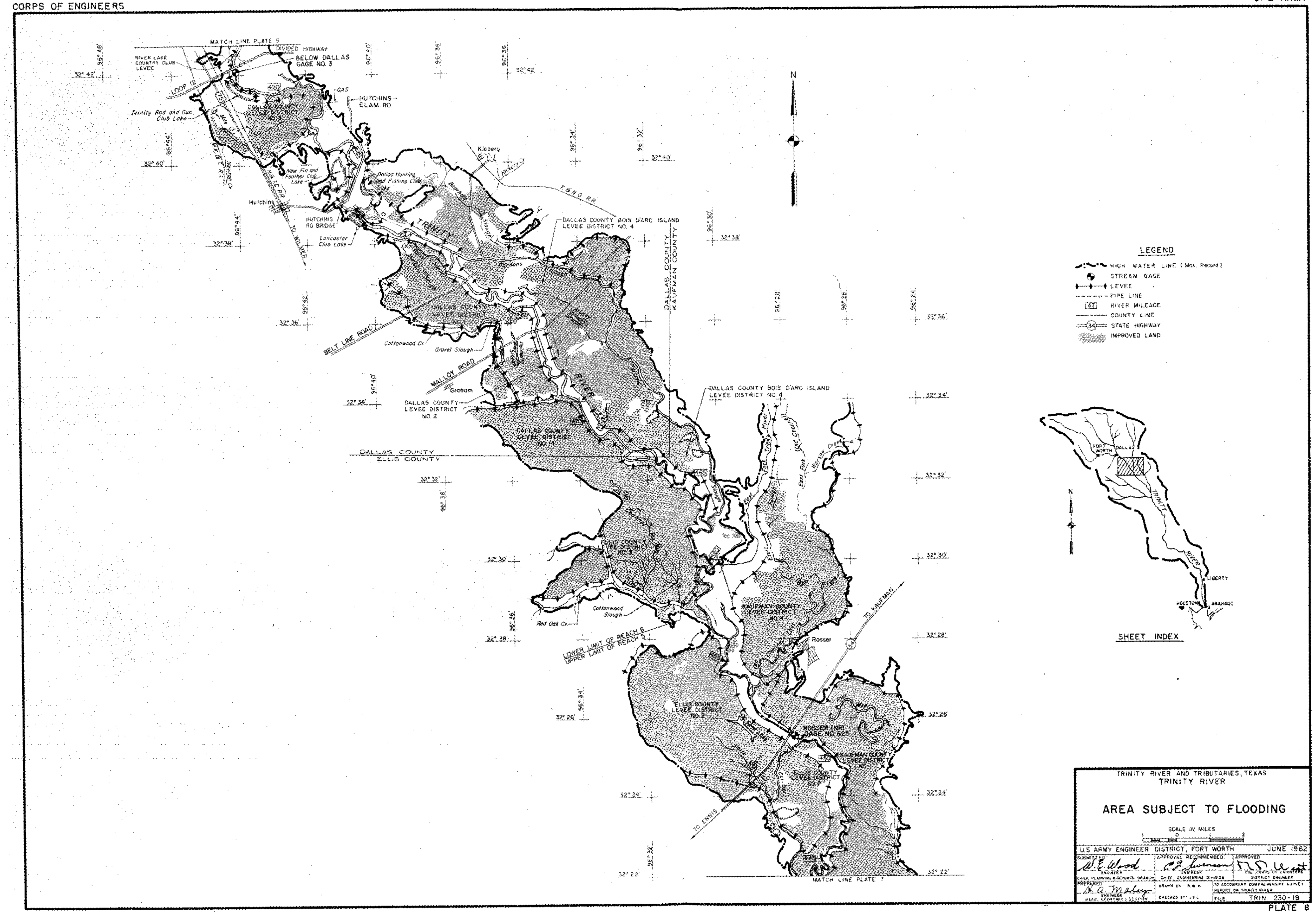


PLATE 8

52-704 O-63 Vol. II (Face p. 250) No. 8

CORPS OF ENGINEERS U.S. ARMY

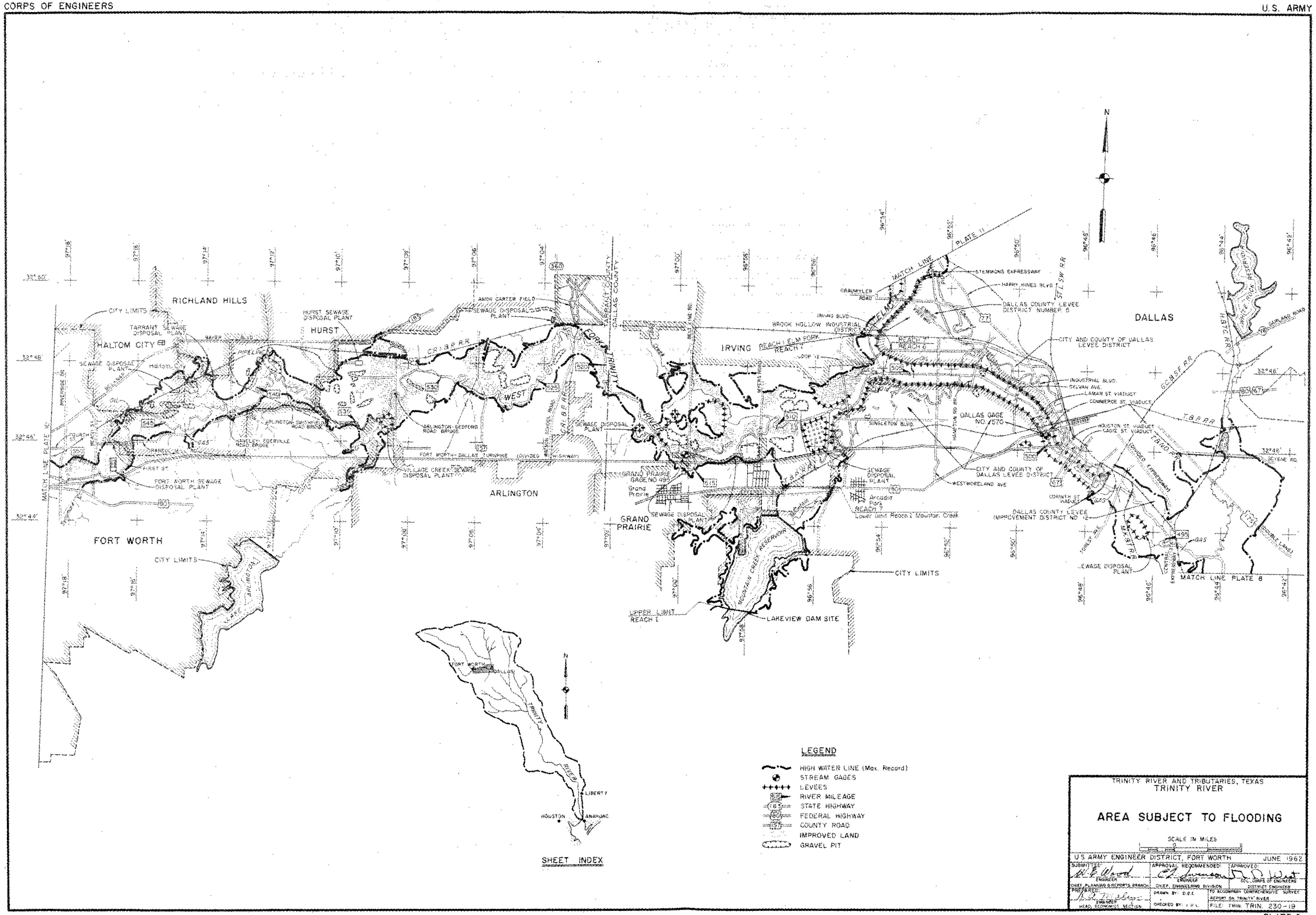
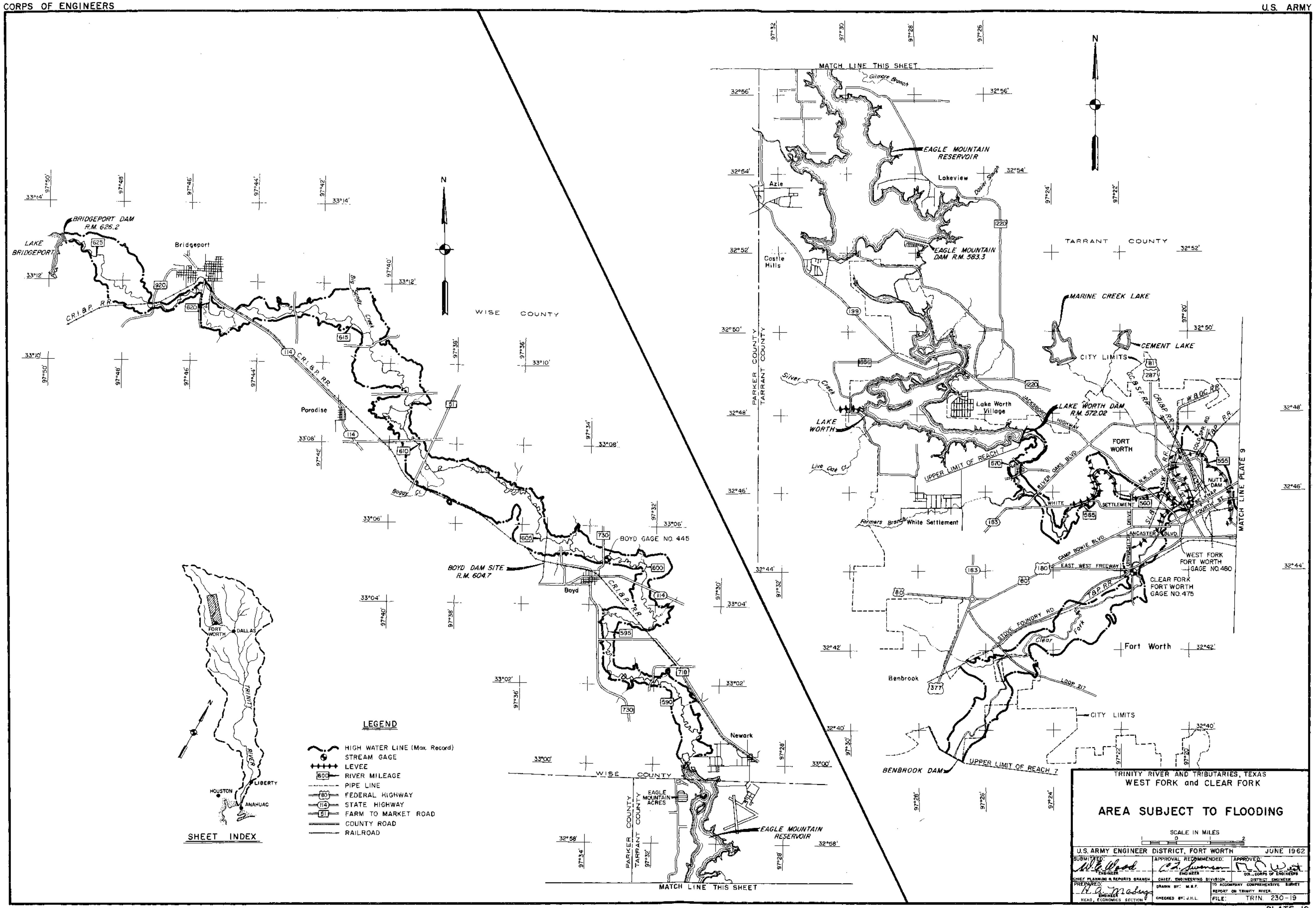


PLATE 9

52-704 O-65 Vol. II (Face p. 250) No. 9



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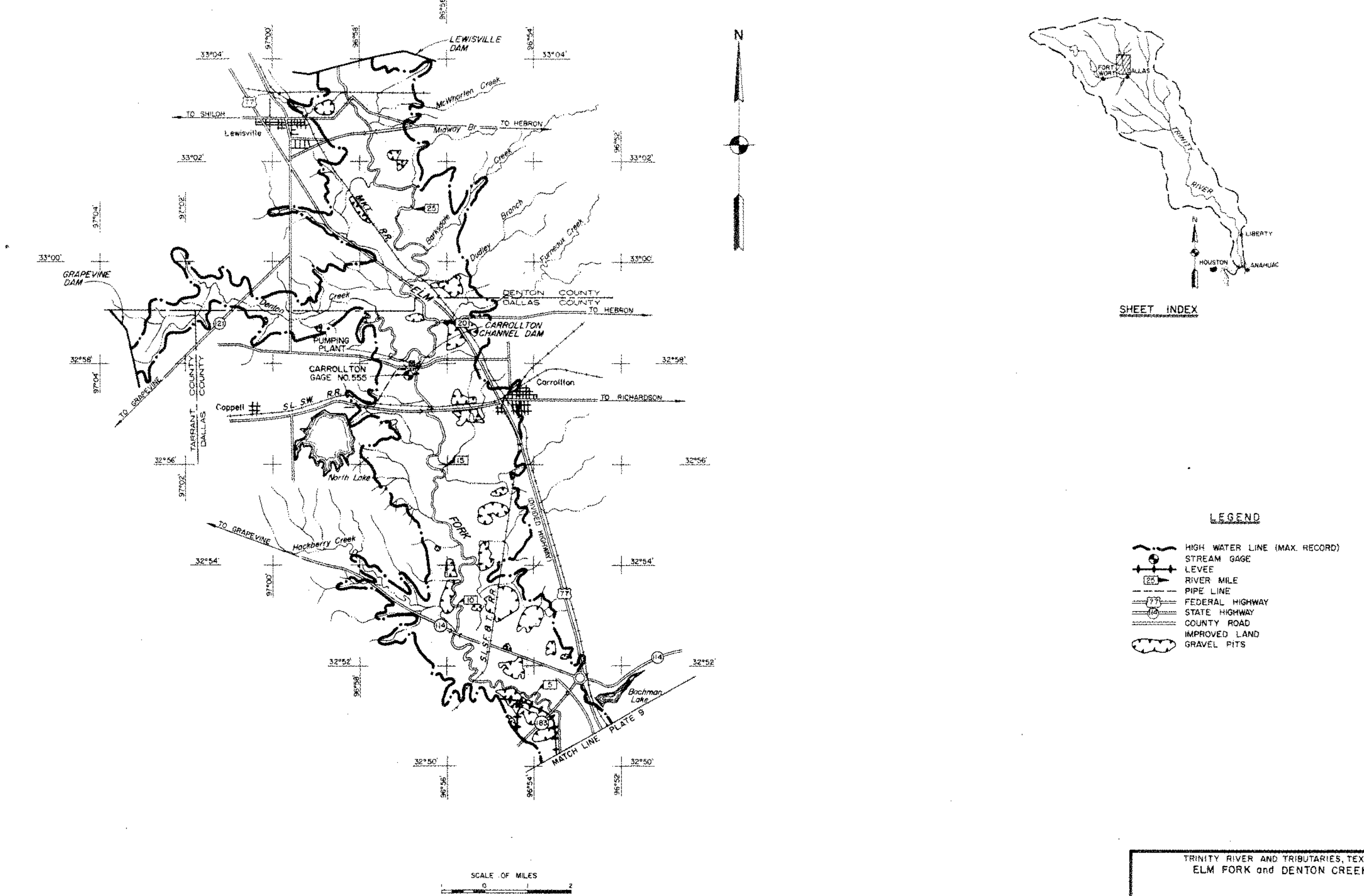


TRINITY RIVER AND TRIBUTARIES, TEXAS
ELM FORK and DENTON CREEK

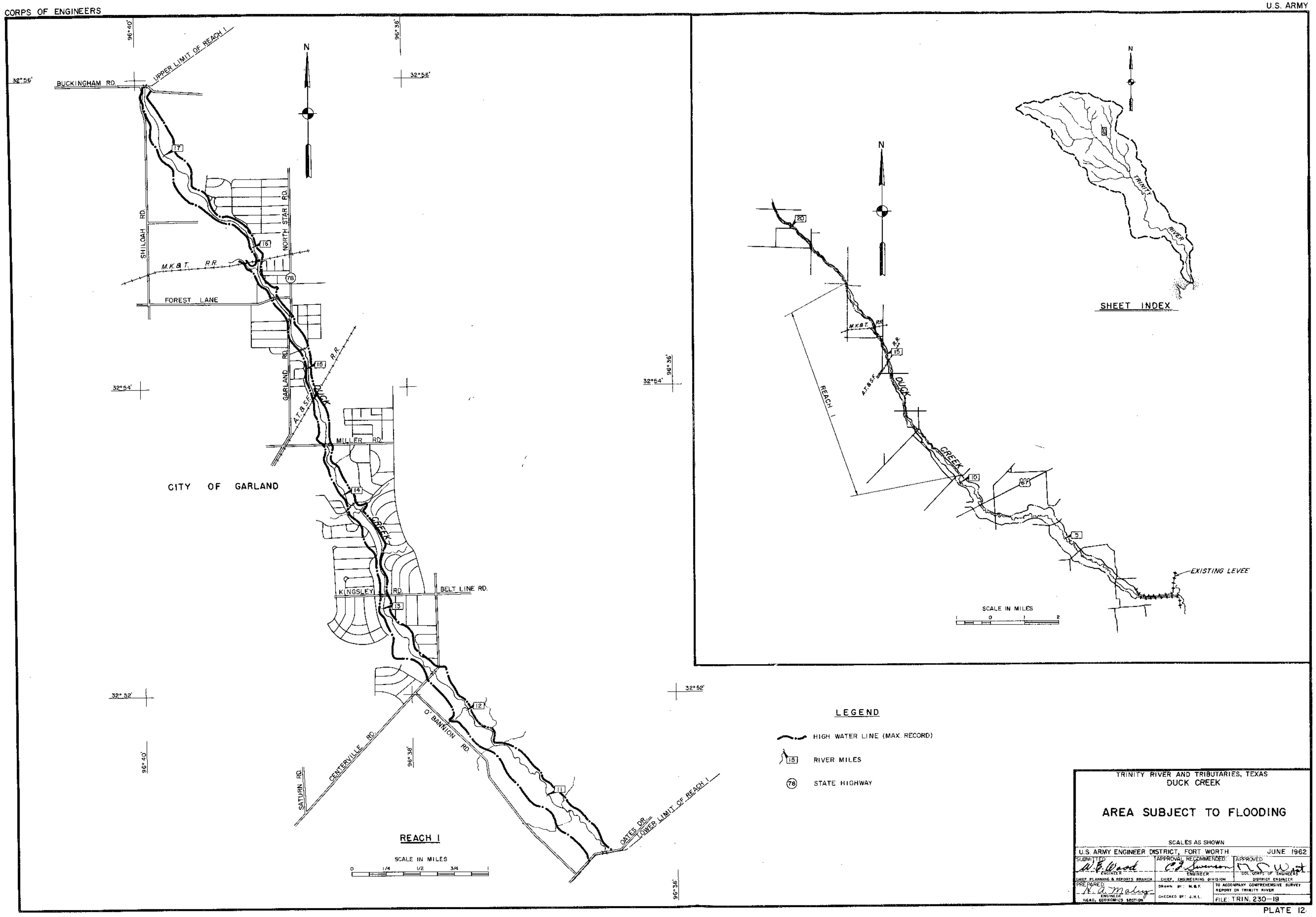
AREA SUBJECT TO FLOODING

SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH JUNE 1962

SUBMITTED: W. E. Wood, ENGINEER, CHIEF, PLANNING & REPORTS BRANCH
APPROVAL RECOMMENDED: ENGINEER, CHIEF, ENGINEERING DIVISION
APPROVED: COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ENGINEER, HEAD, ECONOMICS SECTION
DRAWN BY: O.E.C. CHECKED BY: J.H.L.
TO ACCOMPANY COMPREHENSIVE SURVEY REPORT ON TRINITY RIVER
FILE: TRIN. 230-19

52-704 O-65 Vol. II (Face p. 250) No. 11



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8. CHARACTER OF FLOOD PLAIN AREAS.- The flood plain areas total 605,103 acres, of which 18,603 acres are urban or suburban. The land acreage and classification for each reach are shown in table 1.

9. DETERMINATION OF VALUES AND DAMAGES.- In 1960 a field investigation was made, using 1959 aerial photography to study the development and improvements in the flood plain. County agricultural agents and farmers were interviewed in order to obtain crop schedules and estimates of yield. Also, local governmental officials; state highway officials; officials of railroads, businesses, and industries; and other local residents were interviewed to obtain information on property values and experienced or potential flood damages.

10. VALUE OF PHYSICAL PROPERTY IN THE FLOOD PLAINS.- The total value of physical property in the flood plain reaches as considered herein is estimated at about $326,875,000. These valuations are shown in detail in table 2 and are summarized in table 3.

11. CLASSIFICATION OF DAMAGES.- The tangible damages considered in the monetary evaluation in connection with this study consist of physical property losses directly due to floods, cost of flood fighting, rescue work and other emergency measures, business losses, and increased cost of normal operations and living. In addition, there are other damages of an intangible nature such as loss of life, health, security, and other factors which cannot be readily expressed in monetary terms. Damages of this nature have not been monetarily evaluated in this report.

12. TANGIBLE DAMAGES.- The tangible damages described above were considered under several principal classifications when the economic surveys were made, these classifications being further described as follows:

a. Agricultural damages.- These include damages to growing crops, soil erosion and deposition of undesirable material, weed infestation, loss of livestock and poultry, damages to buildings, fences, and equipment, and damages to irrigation facilities.

b. Rural nonagricultural damages.- These include damages to physical property and loss of production of rural industrial properties such as oil fields, sand and gravel plants, and other property of this type.

c. Damages to transportation facilities.- These consist of damages to railroads, highways, and county roads.

d. Damages to utilities.- These consist of damages to electric power lines, telephone and telegraph lines, and pipe lines.

TABLE 1

LAND AREAS IN THE FLOOD PLAIN

Stream	Reach	Stream mile From	Stream mile To	Agricultural Improved (acres)	Agricultural Unimproved grazing (acres)	Urban & suburban (acres)	Total (acres)
Trinity River	1	0.0	96.4	7,934	131,166	10	139,110
	2	96.4	207.9	19,406	21,966	-	41,372
	3	207.9	313.4	73,834	49,226	-	123,060
	4	313.4	374.5	19,022	51,506	-	70,528
	5	374.5	459.8	49,473	66,437	-	115,910
	6	459.8	505.7	31,716	17,817	9,647	59,180
Total Trinity River				201,385	338,118	9,657	549,160
West Fork and Clear Fork	7	505.7	(1)	6,655	16,289	2,389	25,333
Elm Fork and Denton Creek	1	1.3	(2)	13,358	10,695	5,337	29,390
Mountain Creek	1	2.4	7.2	-	-	857	857
Duck Creek	1	10.4	17.5	-	-	363	363
Total				221,398	365,102	18,603	605,103

(1) Reach extends to Lake Worth Dam, mile 572.0, on West Fork to Benbrook Dam, mile 15.0 on Clear Fork.

(2) Reach extends to Lewisville Dam, mile 30.0 on Elm Fork and to Grapevine Dam, mile 11.7 on Denton Creek.

TABLE 2

DETAILED PROPERTY VALUATION IN THE FLOOD PLAIN

(1962 price levels - 1960 conditions of development)

Item	Trinity River							Elm Fork & Denton Cr.	Mountain Cr.	Duck Creek
	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7	Reach 1	Reach 1	Garland
1. Agricultural property										
a. Improved land	$991,800	$2,910,900	$14,766,800	$3,804,400	$9,894,600	$7,929,000	$2,884,000	$3,339,500	0	0
b. Unimproved grazing land	6,558,300	1,098,300	3,692,000	3,863,000	4,982,800	1,781,700	2,715,000	1,069,500	0	0
c. Levees, irrigation facilities, etc.	804,300	0	1,842,300	85,800	4,445,500	3,697,000	0	446,000	0	0
Total agricultural property	8,354,400	4,009,200	20,301,100	7,753,200	19,322,900	13,407,700	5,599,000	4,855,000	0	0
2. Rural nonagricultural property	2,369,600	30,043,000	393,000	281,000	33,730,000	850,000	8,717,000	2,633,000	0	0
3. Transportation facilities										
a. Railroads	3,088,800	2,767,900	431,500	0	322,400	0	1,096,000	3,518,000	0	0
b. State highways	1,356,400	1,641,200	1,107,700	1,010,500	1,489,000	1,915,000	3,472,000	4,890,000	0	0
c. County roads	50,700	79,200	45,300	60,100	38,400	253,000	318,800	1,899,000	0	0
Total transportation facilities	4,495,900	4,488,300	1,584,500	1,070,600	1,849,800	2,168,000	4,886,800	10,307,000	0	0
4. Utilities										
a. Electric power lines	107,300	79,800	381,300	26,000	333,000	194,000	150,000	804,000	0	0
b. Telephone and telegraph lines	59,600	48,000	8,700	0	15,000	172,000	31,000	275,000	0	0
c. Pipe lines	4,198,500	1,763,600	436,700	692,300	912,300	25,000	194,000	77,000	0	0
Total utilities	4,365,400	1,891,400	826,700	718,300	1,260,300	391,000	375,000	1,156,000	0	0
5. Urban and suburban property	5,017,000	0	0	0	0	32,348,000	56,641,200	13,569,000	$7,509,000	$7,336,400
Total	24,602,300	40,431,900	23,105,300	9,823,100	56,163,000	49,164,700	76,219,000	32,520,000	7,509,000	7,336,400

TABLE 3

SUMMARY OF
VALUE OF PHYSICAL PROPERTY IN THE FLOOD PLAIN

(1962 price levels - 1960 conditions of development)

Stream	Reach	Value of physical property in the flood plain: Agricultural property	Rural non-agricultural property	Trans-portation facilities	Utilities	Urban and suburban property	Total
Trinity River	1	$8,354,400	$2,369,600	$4,495,900	$4,365,400	$5,017,000	$24,602,300
	2	4,009,200	30,043,000	4,488,300	1,891,400	-	40,431,900
	3	20,301,100	393,000	1,584,500	826,700	-	23,105,300
	4	7,753,200	281,000	1,070,600	718,300	-	9,823,100
	5	19,322,900	33,730,000	1,849,800	1,260,300	-	56,163,000
	6	13,407,700	850,000	2,168,000	391,000	32,348,000	49,164,700
Total Trinity River - - - - -		73,148,500	67,666,600	15,657,100	9,453,100	37,365,000	203,290,300
West Fork and Clear Fork	7	5,599,000	8,717,000	4,886,800	375,000	56,641,200	76,219,000
Elm Fork and Denton Creek	1	4,855,000	2,633,000	10,307,000	1,156,000	13,569,000	32,520,000
Mountain Creek	1	-	-	-	-	7,509,000	7,509,000
Duck Creek	1	-	-	-	-	7,336,400	7,336,400
Total - - - - - - - - - - - - -		83,602,500	79,016,600	30,850,900	10,984,100	122,420,600	326,874,700

e. Urban damages.- These consist of damages to residences, business and industrial establishments, churches, schools, automobiles, house trailers, local utilities, railroads, streets, highways, and city and Federal property, when these damages occur within or adjacent to a city or town.

f. Interruption to traffic and communications.- These losses consist of costs of detouring railroad and truck traffic, loss of gross income of railroad and trucking companies, cost of towing vehicles over flooded highways, additional expenses to motorists while detouring or waiting for floodwaters to subside, and cost of repairs to vehicles driven through the floodwaters. Also included are losses of business and production to commercial establishments and industries that are dependent on the transportation of raw materials and manufactured products.

g. Cost of rescue work and policing.- These losses consist of the actual cost of rescue operations conducted during the flood period, and include damages to vehicles assigned to this operation. Also included are costs of military personnel, local law enforcement officers, and others responsible for maintaining law and order.

h. Cost of combating insects and disease.- This includes the cost of innoculations against typhoid, the cost of spraying of places likely to be infested with flies and mosquitoes, and the extra cost of analyzing and treating all sources of drinking water which might have become contaminated.

13. DAMAGES FROM MAXIMUM FLOODS OF RECORD.- The total damages that would be caused by a recurrence of the maximum flood in each of the various reaches considered in this report have been estimated at $23,887,000, based on January 1962 price levels and 1960 conditions of development. Table 4 shows these damages by reaches and by principal property classifications and shows the year of occurrence of each maximum flood. The flood of April-June 1957 was general over the entire Trinity River Basin and approached the magnitude of the flood of record in most of the reaches. It is estimated that the recurrence of this flood under the same conditions of modification and development as used for the maximum flood damages shown on table 4 would cause damages as shown in the following tabulation. This tabulation also shows estimated damages for two future conditions of economic development:

Year	Estimated damages
1960	$15,200,000
2020	163,600,000
2070	251,100,000

TABLE 4

ESTIMATED DAMAGES FROM MAXIMUM FLOOD (1)

(1962 price levels - 1960 conditions of development)

Stream	Reach	Year of flood	Agricultural damages: Crops	Agricultural damages: Other agricultural	Agricultural damages: Total	Nonagricultural damages: Urban and suburban	Nonagricultural damages: Other non-agricultural	Nonagricultural damages: Total	Total damages
Trinity River	1	1957	$452,000	$146,000	$598,000	$770,000	$494,000	$1,264,000	$1,862,000
	2	1945	1,056,000	181,000	1,237,000	0	65,000	65,000	1,302,000
	3	1945	4,305,000	865,000	5,170,000	0	108,000	108,000	5,278,000
	4	1908	760,000	174,000	934,000	0	45,000	45,000	979,000
	5	1957	758,000	252,000	1,010,000	0	189,000	189,000	1,199,000
	6	1908	1,040,000	271,000	1,311,000	1,120,000	231,000	1,351,000	2,662,000
Total Trinity River			8,371,000	1,889,000	10,260,000	1,890,000	1,132,000	3,022,000	13,282,000
West Fork and Clear Fork	7	1949 & 1957(2)	166,000	58,000	224,000	6,985,000	365,000	7,350,000	7,574,000
Elm Fork and Denton Creek	1	1923	998,000	144,000	1,142,000	767,000	128,000	895,000	2,037,000
Mountain Creek	1	1928	0	0	0	156,000	0	156,000	156,000
Duck Creek	1	1949	0	0	0	838,000	0	838,000	838,000
Total damages			9,535,000	2,091,000	11,626,000	10,636,000	1,625,000	12,261,000	23,887,000

(1)Experienced flood in each reach which would produce maximum peak discharges when modified by the flood control improvements in operation in 1960 plus Navarro Mills and Bardwell Reservoirs.
(2)Combination of 1949 and 1957 floods but no duplication of damages reflected.

14. DETERMINATION OF AVERAGE ANNUAL DAMAGES.- For each flood plain reach, discharge-damage curves and discharge-frequency curves were developed. These curves were then employed to construct damage-frequency curves. Figures 3, 4, and 5 of this appendix show discharge-frequency, discharge-damage, and damage-frequency curves, respectively, for reach 3, a typical reach of the Trinity River. These curves and the following discussion are furnished as being representative of the methods used to determine the average annual damages for the investigated reaches of the Trinity River Basin. By use of rainfall records, stream gage records, synthetic unit hydrographs, and historical flood information in the form of high water marks and other data furnished by local interests and observed by personnel of the Fort Worth District, relationships between discharge and frequency were developed as shown by the discharge-frequency curve, figure 3. The flood damage data obtained through an economic survey in the field during 1960 formed the basis for constructing the discharge-damage curves. Relationships between discharge and acres of land flooded were established for the flood plain areas. Unit-crop damages were then applied to the acreage of improved land inundated by each flood of record, the amount of damages depending upon the crop value and the probability of floods occurring in the various seasons of the year. Damages to agricultural property other than crops were computed in a similar manner, except that it was not necessary to give consideration to the season of the year. For transportation facilities, utilities, and urban damages, discharge versus damage relationships were employed for estimating damages from the various flood magnitudes. All of these data were then utilized to construct discharge-damage curves as shown by figure 4. By use of the discharge-frequency and discharge-damage curves, a damage-frequency curve was constructed as shown by figure 5. The area under this damage-frequency curve represents the damages which can be expected to accrue over a period of 100 years. These damages were then divided by 100 to give the anticipated average annual damages. The procedures outlined above were repeated on each given reach for each condition of modification being studied in order to determine the damages that would be prevented by each improvement having a potential effect on that reach.

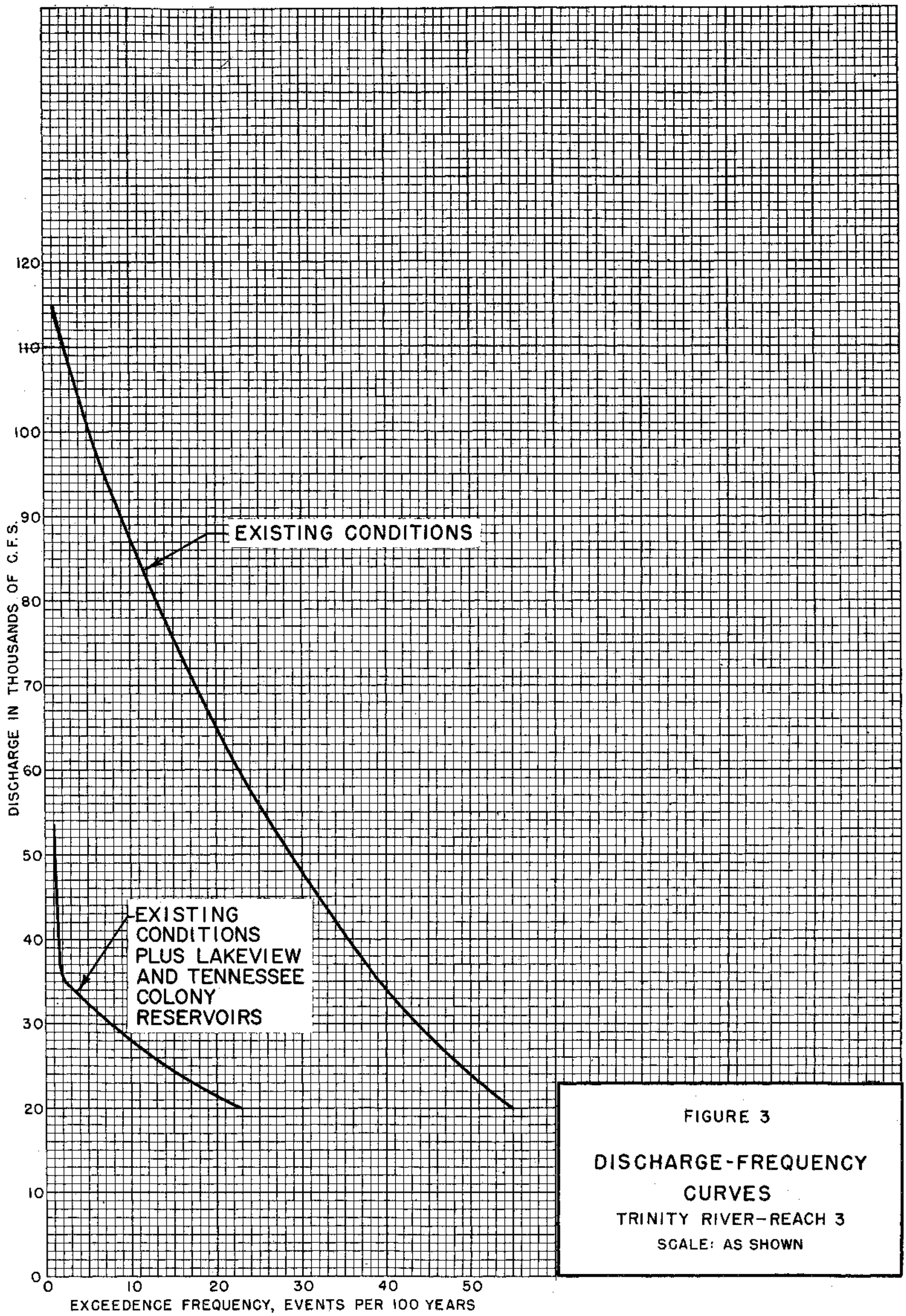


FIGURE 3

DISCHARGE-FREQUENCY CURVES

TRINITY RIVER-REACH 3

SCALE: AS SHOWN

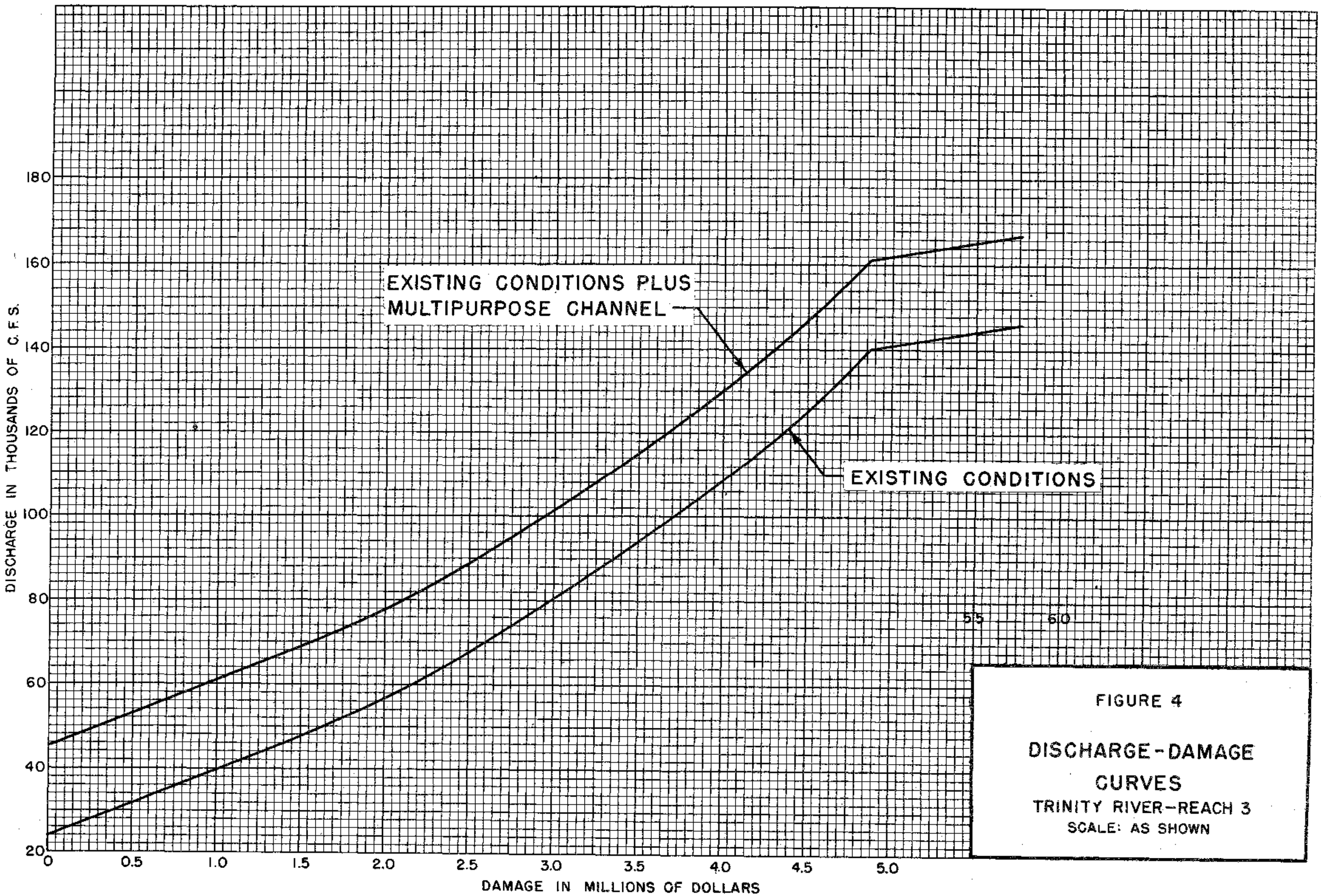
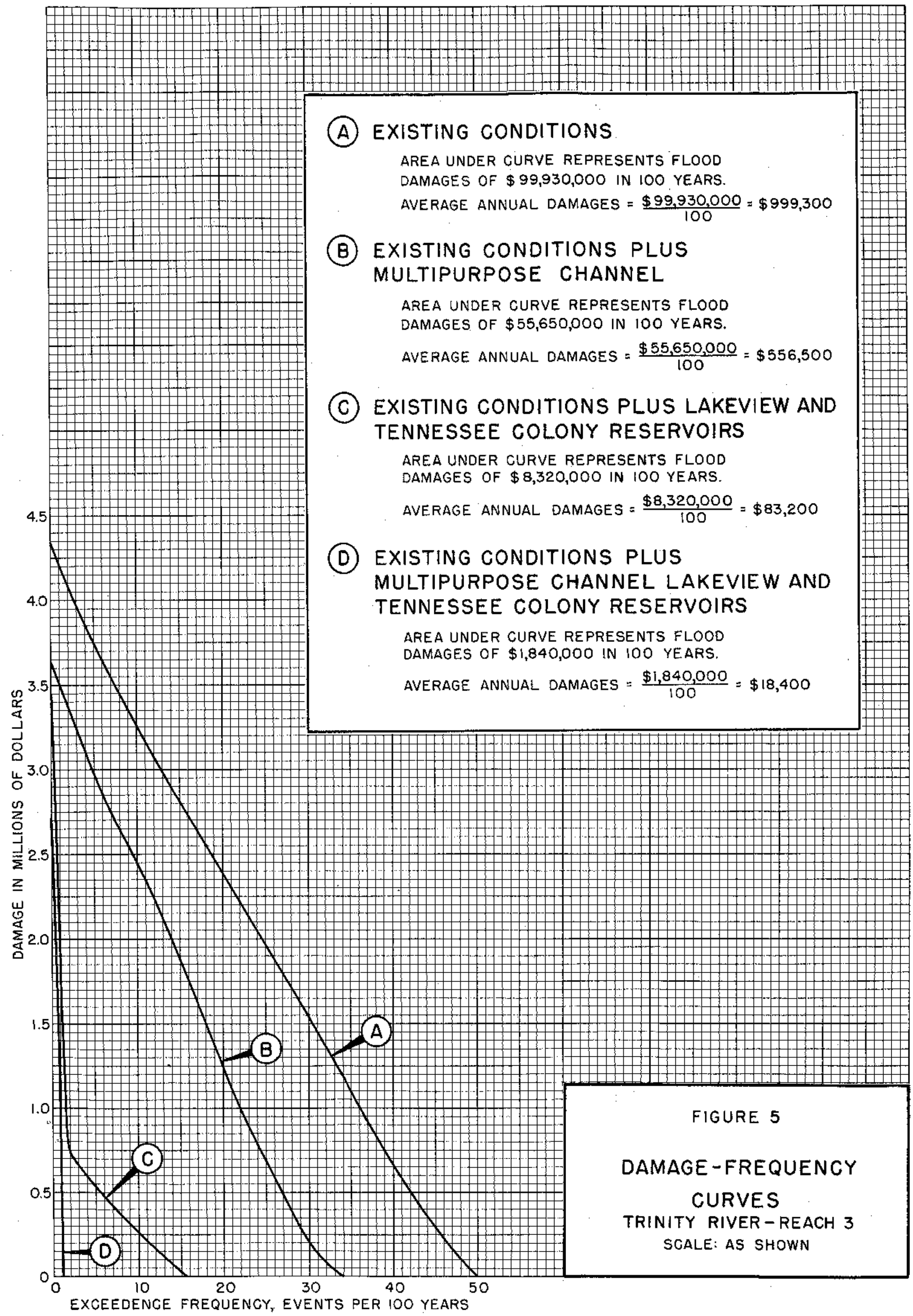


FIGURE 4

DISCHARGE-DAMAGE CURVES

TRINITY RIVER—REACH 3

SCALE: AS SHOWN


(A) EXISTING CONDITIONS
AREA UNDER CURVE REPRESENTS FLOOD DAMAGES OF $99,930,000 IN 100 YEARS.
AVERAGE ANNUAL DAMAGES = $99,930,000 / 100 = $999,300
(B) EXISTING CONDITIONS PLUS MULTIPURPOSE CHANNEL
AREA UNDER CURVE REPRESENTS FLOOD DAMAGES OF $55,650,000 IN 100 YEARS.
AVERAGE ANNUAL DAMAGES = $55,650,000 / 100 = $556,500
(C) EXISTING CONDITIONS PLUS LAKEVIEW AND TENNESSEE COLONY RESERVOIRS
AREA UNDER CURVE REPRESENTS FLOOD DAMAGES OF $8,320,000 IN 100 YEARS.
AVERAGE ANNUAL DAMAGES = $8,320,000 / 100 = $83,200
(D) EXISTING CONDITIONS PLUS MULTIPURPOSE CHANNEL LAKEVIEW AND TENNESSEE COLONY RESERVOIRS
AREA UNDER CURVE REPRESENTS FLOOD DAMAGES OF $1,840,000 IN 100 YEARS.
AVERAGE ANNUAL DAMAGES = $1,840,000 / 100 = $18,400
DAMAGE IN MILLIONS OF DOLLARS
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
A
B
C
D
0
10
20
30
40
50
EXCEEDENCE FREQUENCY, EVENTS PER 100 YEARS
FIGURE 5
DAMAGE-FREQUENCY CURVES
TRINITY RIVER-REACH 3
SCALE: AS SHOWN

15. TRENDS OF DEVELOPMENT.- Appendix VII, "Economic Base Study," is the presentation of the economic indicators considered applicable to the various project purposes under consideration in this report. The indicators considered applicable to flood control and their overall projection factors for the entire base study area are as follows:

Indicator	2020/1960	2070/1960	Avg. Annual percent increase 1960 to 2070
Population	2.72	5.20	1.5
New construction	5.08	16.75	2.6
Value added by manufacture	11.11	48.71	3.6
Mineral production	6.28	28.55	3.1
Retail sales	6.69	27.48	3.1
Value of farm products sold	2.56	5.50	1.6
Personal income	7.80	35.99	3.3
Bank deposits	7.27	31.56	3.5

In order to apply these indicators to flood control, it was necessary to determine the relationship between the effect each indicator would have on the entire base study area and the effect it would have on the specific reach being considered. This involved a study of the development in the flood plain and adjacent areas of each reach. It was determined to be feasible to modify the above base study area indicators to fit the conditions of flood plain reaches 2, 3, 4, and 5 of the Trinity River. These reaches reflect a comparatively stable agricultural economy with a potential for future development which can probably be predicted with reasonable accuracy based on the present conditions of economic development within the flood plain. This assumption is predicated on the condition that the present state of water resource development within the area will prevail. Provision of the improvements recommended in this report will probably result in growth patterns in these reaches even more spectacular than those that would be expected in the presently urbanized reaches of the basin. A study of reaches 1 and 6 of the Trinity River, reach 7 of the West Fork and Clear Fork, Elm Fork, Denton Creek, Mountain Creek, and Duck Creek was made which indicated that a different type of development allowance would be required at these locations. This is due to the fact that these areas are geographically located in such a manner that they are expected to experience a greatly accelerated growth pattern that has no direct relationship to their present state of development. For these reaches an estimate was made of the probable future change in land use in order to reflect the influence of the highly urbanized adjacent areas and the anticipated developments within the flood plain.

16. MODIFICATION OF ECONOMIC INDICATORS.- In the modification of the development factors to the purpose of flood control, consideration was given to historical economic data for the flood plain and adjacent areas, to the projections contained in data prepared by the United States Study Commission, Texas, and to anticipated development and improvement in and near the flood plain areas. The following tabulation gives the flood control development factors for Trinity River reaches 2, 3, 4, and 5. These development factors reflect estimated future development expected even though additional flood control improvements are not installed.

DEVELOPMENT FACTORS
FLOOD CONTROL

Indicator	Factors 1960	1970	2020	2070	Avg. Annual percent increase 1960 to 2070
	Trinity River - Reach 2				
Nonagricultural					
Population	1.00	1.23	4.59	6.02	1.6
Mineral production	1.00	1.13	2.13	2.13	0.7
Retail sales	1.00	1.34	8.29	23.68	2.9
Bank deposits	1.00	1.24	4.69	8.28	1.9
Personal income	1.00	1.55	18.44	75.23	4.0
Geometric mean	1.00	1.29	5.88	11.36	2.2
Agricultural					
Population	1.00	1.18	2.72	5.20	1.5
Value farm products sold	1.00	1.16	3.10	5.50	1.6
Geometric mean	1.00	1.17	2.90	5.35	1.5
	Trinity River Reaches 3, 4, and 5				
Nonagricultural					
Population	1.00	1.14	2.91	4.02	1.3
Mineral production	1.00	1.32	8.11	19.19	2.7
Retail sales	1.00	1.23	4.77	10.10	2.1
Bank deposits	1.00	1.20	4.00	7.00	1.8
Personal income	1.00	1.36	12.59	28.62	3.1
Geometric mean	1.00	1.25	5.63	10.93	2.2
Agricultural					
Population	1.00	1.18	2.72	5.20	1.5
Value farm products sold	1.00	1.16	3.10	5.50	1.6
Geometric mean	1.00	1.17	2.90	5.35	1.5

17. CHANGING PATTERN OF LAND USE.- Studies of the flood plain and the adjacent area in Trinity River reaches 1, 6, and 7, and of the Elm Fork of the Trinity River, Denton Creek, Mountain Creek, and Duck Creek disclosed that proximate urbanized areas, planned improvements, existing and proposed transportation facilities, and availability of area for expansion are influencing and will continue to influence growth patterns in these areas to such an extent that development factors obtained by modification of the economic indicators prepared in the economic base study would be incompatible with the probable future growth. Therefore, future development of the flood plain in each of these reaches was computed by estimating the probable change in land use. This future development is expected to take place even though additional flood control improvements are not installed.

18. FUTURE DEVELOPMENT.- Based on the above considerations, the future development in various reaches of the Trinity River and tributaries are estimated as follows:

a. Trinity River, reach 1.- Reach 1 of the Trinity River lies within the zone of influence of three rapidly growing metropolitan areas: the Beaumont-Port Arthur area to the east, and the Houston area and Galveston-Texas City area to the west. These three areas increased in population between 1910 and 1960 at the average rate of 4 percent per year. Economic base studies indicate that the 1960 population of 1,629,200 will increase to about 8,500,000 by year 2070. Main arteries of transportation cross reach 1 of the Trinity River from east to west and guide the pattern of expansion. These factors, plus the availability of additional water for industry and irrigation from Livingston Reservoir, which is now under construction, will exert increasing influence on the reach under discussion. The development within the flood plain of reach 1 increased 50 percent in the years 1952 to 1960. Guided by these factors, it is estimated that the value of property within the flood plain in reach 1 will increase from about $24,602,000 in 1960 to $524,600,000 in 2070. (2.8 percent average annual increase).

b. Trinity River, reach 6.- Reach 6 of the Trinity River includes the highly developed portion of Dallas along the Trinity River. All of the reach is partially protected by upstream reservoirs and part of the reach is further protected by levees and a rectified channel. Most of the reach is within Dallas County and is affected by the continued expansion of the city of Dallas and its satellite cities. The urban population of Dallas County increased from 92,100 in 1910 to 927,600 in 1960, an average annual rate of about 4-3/4 percent. It has been estimated that the population will continue to increase to nearly 5,400,000 by year 2070. Development within the flood plain nearly doubled from 1949 to 1960. Guided by these factors, it is estimated that the property within reach 6 will increase in value from $49,165,000 in 1960 to $1,378,800,000 in 2070 (3.1 percent average annual increase).

c. West Fork of the Trinity River.- Reach 7 of the Trinity River includes the West Fork of the Trinity River from Dallas through the city of Fort Worth. The area in which it lies is subject to the urbanizing influence of both Dallas and Fort Worth and is becoming a continuous urban development. Two smaller cities, Arlington and Grand Prairie, in the area between Dallas and Fort Worth and contained within the metropolitan areas, increased in population from 5,835 in 1940 to 75,161 in 1960. Transportation facilities have been enlarged and many industries have entered the area. Invasion of the flood plain has been increasing. It is estimated that value of property within the flood plain will increase from $76,219,000 in 1960 to $1,436,400,000 in 2070 (2.7 percent average annual increase).

d. Mountain Creek.- Mountain Creek, reach 1, is tributary to the West Fork of the Trinity River at the upper limits of the city of Dallas and lies wholly within the metropolitan areas of Dallas and Fort Worth. It is estimated that the value of property within the flood plain of Mountain Creek will increase from $7,509,000 in 1960 to $47,500,000 in 2070 (1.7 percent average annual increase).

e. Elm Fork and Denton Creek, reach 1.- Reach 1 of Elm Fork of the Trinity River includes the flood plain of Denton Creek below the Grapevine Dam. This area is protected from most major floods by the Grapevine Reservoir on Denton Creek and the Garza-Little Elm Reservoir on the Elm Fork. Consistent encroachment on the flood plain due to the rapid urbanization of the Dallas metropolitan area has been encouraged by the protection afforded by the upstream reservoirs. Damage due to flooding from the uncontrolled drainage area will increase. It is estimated that the value of property in the flood plain will increase from $32,520,000 in 1960 to $837,600,000 in 2070 (3.0 percent average annual increase).

f. Duck Creek, reach 1.- Reach 1 of Duck Creek is principally within the environs of the city of Garland, Texas. This city of 38,500 people is one of the satellite cities of Dallas. Its population increased from 804 in 1910 to 10,571 in 1950 and 38,501 in 1960. This rapid increase has been accompanied by progressively greater encroachment on the flood plain of Duck Creek. The possibility of future development of the flood plain in this reach is limited by its narrowness. It is estimated that development will increase the value of property in the flood plain from $7,336,000 in 1960 to $29,300,000 in 2070 (1.3 percent average annual increase).

19. SUMMARY OF ESTIMATED FUTURE DEVELOPMENT.- The average annual percent of increase in development in the flood plain is estimated at 2.6 percent for the period 1960 to 2070. As pointed out earlier in this appendix, somewhat faster development is expected to occur in Trinity River reaches 1 and 6; West Fork, Clear Fork, and Elm Fork of the Trinity River; and Denton Creek than in the average rate for the total flood plain. In the remaining reaches, the development is not expected to increase as rapidly as that of the total flood plain. Table 5 shows the estimated value of physical property in the flood plain for 1960, 1970, 2020, and 2070. Also, the average annual percent of increase from 1960 to 2070 is shown for each reach.

20. BENEFITS DUE TO PREVENTION OF FLOOD DAMAGES.- The average annual damages due to flooding were computed using the procedures outlined in paragraph 14 of this appendix. The computations were first based on "existing" conditions, reflecting the protection afforded by the flood control storage in Benbrook, Grapevine, Garza-Little Elm, Lavon, Navarro Mills, and Bardwell reservoirs and all existing, authorized, and previously recommended local protection projects under 1960 conditions of flood plain development. The results represent the residual average annual damages under conditions of modification by the existing flood control improvements. Similar computations were made based on the modified conditions which will exist after completion of the proposed plan of improvement. The difference between the two answers gives the average annual benefits. Table 6 gives the average annual damages under existing and modified conditions and the resulting benefits based on 1960 conditions of flood plain development.

TABLE 5

ESTIMATED FUTURE DEVELOPMENT

Stream	Reach	Value of physical property in the flood plain (in millions of 1960 constant dollars) 1960	1970	2020	2070	Average annual percent of increase 1960-2070
Trinity River	1	$24.6	$80.6	$304.6	$524.6	2.8
	2	40.4	51.7	225.8	435.3	2.2
	3	23.1	27.3	74.7	139.3	1.6
	4	9.8	11.6	34.1	64.1	1.7
	5	56.2	68.7	263.4	506.0	2.0
	6	49.2	266.0	886.8	1,378.8	3.1
Total Trinity River		203.3	505.9	1,789.4	3,048.1	2.5
West Fork and Clear Fork	7	76.2	298.2	1,001.1	1,436.4	2.7
Elm Fork and Denton Creek	1	32.5	210.6	668.6	837.6	3.0
Mountain Creek	1	7.5	16.4	39.1	47.5	1.7
Duck Creek	1	7.3	9.4	19.5	29.3	1.3
Total Trinity Basin		326.8	1,040.5	3,517.7	5,398.9	2.6

TABLE 6

FLOOD DAMAGE PREVENTION BENEFITS

1960 ECONOMIC DEVELOPMENT

Stream	Reach	Average annual damage		Benefits due to prevention of damages
		Existing(1)	Modified(2)	
Trinity River	1	$322,400	$600	$321,800
	2	130,500	5,400	125,100
	3	999,300	18,400	980,900
	4	193,200	105,800	87,400
	5	120,000	47,800	72,200
	6	207,200	35,400	171,800
West Fork and Clear Fork	7	88,200	13,900	74,300
Elm Fork-Denton Creek	1	114,800	7,500	107,300
Mountain Creek	1	39,500	1,900	37,600
Duck Creek	1	118,100	0	118,100
Total		2,333,200	236,700	2,096,500

(1) Flood control existing in 1960 plus Navarro Mills Reservoir, Bardwell Reservoir, and previously recommended improvements.

(2) Existing plus proposed plan of improvement.

21. The benefits thus computed for the Trinity River reaches 2, 3, 4, and 5 were converted to the average annual benefits for the 100-year period from 1970 to 2070 by applying the development factors for the reaches and the appropriate annual equivalent factors at 2 7/8 percent interest. For the other reaches considered, where the flood plain has a high potential for development even though the present development is not extensive, a thorough study of the flood plain was made to determine the areas that were likely to be developed by the year 2070 even though additional water resource improvements were not provided. A field reconnaissance of these areas was made to determine the type of improvement most likely to be constructed in the flood plain. These improvements were then assumed to be in place, and hypothetical discharge-damage curves were constructed based on estimated 2070 development. The discharge-damage curve thus obtained was then applied to the pertinent discharge-frequency curve and a damage-frequency curve was constructed. From this curve the average annual damages, based on 2070 conditions of development, were determined. Using the average annual damages under 1960 conditions as the base, and the average annual damages under 2070 conditions as the ultimate, the equivalent average annual damages for the period 1970-2070 were determined.

22. **BENEFITS FOR INCREASED UTILIZATION OF DOWNSTREAM LANDS.- It is believed that about 82,700 acres of land in the flood plain below the proposed Tennessee Colony Dam site will be improved and converted to higher order of use as the result of prevention of flooding by the multiple purpose channel under consideration. Studies have disclosed that the increase in value of these lands, attributable to the prevention of flooding, will average about $100** per acre. This increase in value when capitalized at 4 percent, therefore, amounts to $330,800 in annual benefits for increased utilization of lands. The benefits from increased land utilization were assigned to areas exclusive of those on which prevention of damages was estimated, and also exclusive of any land necessary for rights-of-way for the proposed improvements.

23. **FLOOD CONTROL BENEFITS.-** In the benefit evaluation used in project formulation in connection with this report, only those flood-control benefits were estimated which resulted from reducing the remaining residual damages with all the existing, authorized, and previously recommended projects in the Trinity River Basin in operation, plus the benefits assigned for increased net return from increased utilization of downstream lands. On this basis, each of the recommended projects shows benefits in excess of costs, and will share equitably in the total system benefits that will be produced along the Trinity River and tributaries by the recommended plan of development. The fair share benefits for each project in the recommended plan are set forth below:

a. Reservoirs.- The average annual flood-control benefits assignable on a fair share basis to each of the two reservoir projects included in the recommended plan of improvement are shown in the following tabulation. These benefits are based only on prevention of flood damages:

Project	Flood-control benefits
Lakeview Reservoir	$1,391,000
Tennessee Colony Reservoir	3,238,000

b. Local protection units.- The average annual flood-control benefits assignable on a fair share basis to the local protection units included in the recommended plan of improvement are shown in the following tabulation. The benefits shown for the Dallas Floodway Extension and the West Fork Floodway do not include an allowance for damages prevented by the multiple-purpose channel through those floodways since these damages prevented have been included with those for the multiple-purpose channel as shown in the following subparagraph. The benefits are based only on prevention of flood damages:

Project	Flood-control benefits
Dallas Floodway Extension	$685,000
West Fork Floodway	2,359,400
Elm Fork Floodway	1,866,700
Duck Creek Channel	224,400
Liberty Levee	240,900

c. Multiple-purpose channel.- The average annual flood control benefits assignable on a fair share basis to the multiple-purpose channel, as included in the recommended plan of improvement, are estimated at $4,695,800 This estimate includes benefits of $233,500 for the channel through the Dallas Floodway Extension and $944,200 for the channel through the West Fork Floodway. These benefits are based on prevention of flood damages only, except on the portion below Tennessee Colony Reservoir which includes an estimate for increased utilization of downstream lands in the amount of $330,800.

24. SUMMARY.- The total flood-control benefits which would accrue to the various improvements recommended in this report have been summarized in table 7. This table shows the average annual damages under existing and modified conditions based on projected 1970-2070 conditions of flood plain development and the resulting benefits that accrue to the various projects in the plan of improvement. These benefits are based on January 1962 prices. The benefits are based on each project functioning as an integral unit of the plan of improvement in the Trinity River Basin, and each project has been credited with an equitable share of the benefits it will produce along the Trinity River in conjunction with other units of the plan.

25. The data contained in table 7 and shown graphically in figure 6 indicate that the recommended improvements will prevent 93 percent of the flood problem under existing and projected conditions of development. Most of the residual damages are along the main stem of the Trinity River between the Dallas Floodway Extension and Tennessee Colony Reservoir and are based almost entirely on anticipated future development. The prevention of these residual damages is not economically feasible at the present time, but it is possible that the future development in this area may be such that additional control will be justified at a later date.

TABLE 7

FLOOD CONTROL BENEFITS

Stream	Reach	Average annual damages 1970-2070			Increased land utilization	Total	1970-2070 flood-control benefits by projects				
		Existing	Modified	Prevented			Tennessee Colony Res	Lakeview Reservoir	Multi-purpose channel	Local protection units	
Trinity River	1	$2,122,800	$5,600	$2,117,200	$230,900	$2,348,100	$983,800	$24,200	$1,099,200	$240,900	(Liberty Levee)
	2	324,900	13,400	311,500	0	311,500	304,000	7,500	0	0	
	3	2,768,100	51,000	2,717,100	70,900	2,788,000	1,787,300	44,000	956,700	0	
	4	270,300	4,600	265,700	29,000	294,700	162,900	4,000	127,800	0	
	5	226,300	41,500	184,800	0	184,800	0	42,300	142,500	0	
	6	3,491,400	569,800	2,921,600	0	2,921,600	0	811,200	1,425,400	685,000(1)	(Dallas Fldwy. Ext.)
West Fork and Clear Fork	7	3,624,400	320,800	3,303,600	0	3,303,600	0	0	944,200	2,359,400(2)	(West Fork Fldwy.)
Elm Fork and Denton Creek	1	1,895,200	28,500	1,866,700	0	1,866,700	0	0	0	1,866,700	(Elm Fork Fldwy.)
Mountain Creek	1	481,800	24,000	457,800	0	457,800	0	457,800	0	0	
Duck Creek	1	224,400	0	224,400	0	224,400	0	0	0	224,400	(Duck Creek Channel)
Total		15,429,600	1,059,200	14,370,400	330,800	14,701,200	3,238,000	1,391,000	4,695,800	5,376,400	

(1) Excludes $233,500 benefits included in multiple-purpose channel.

(2) Excludes $944,200 benefits included in multiple-purpose channel.

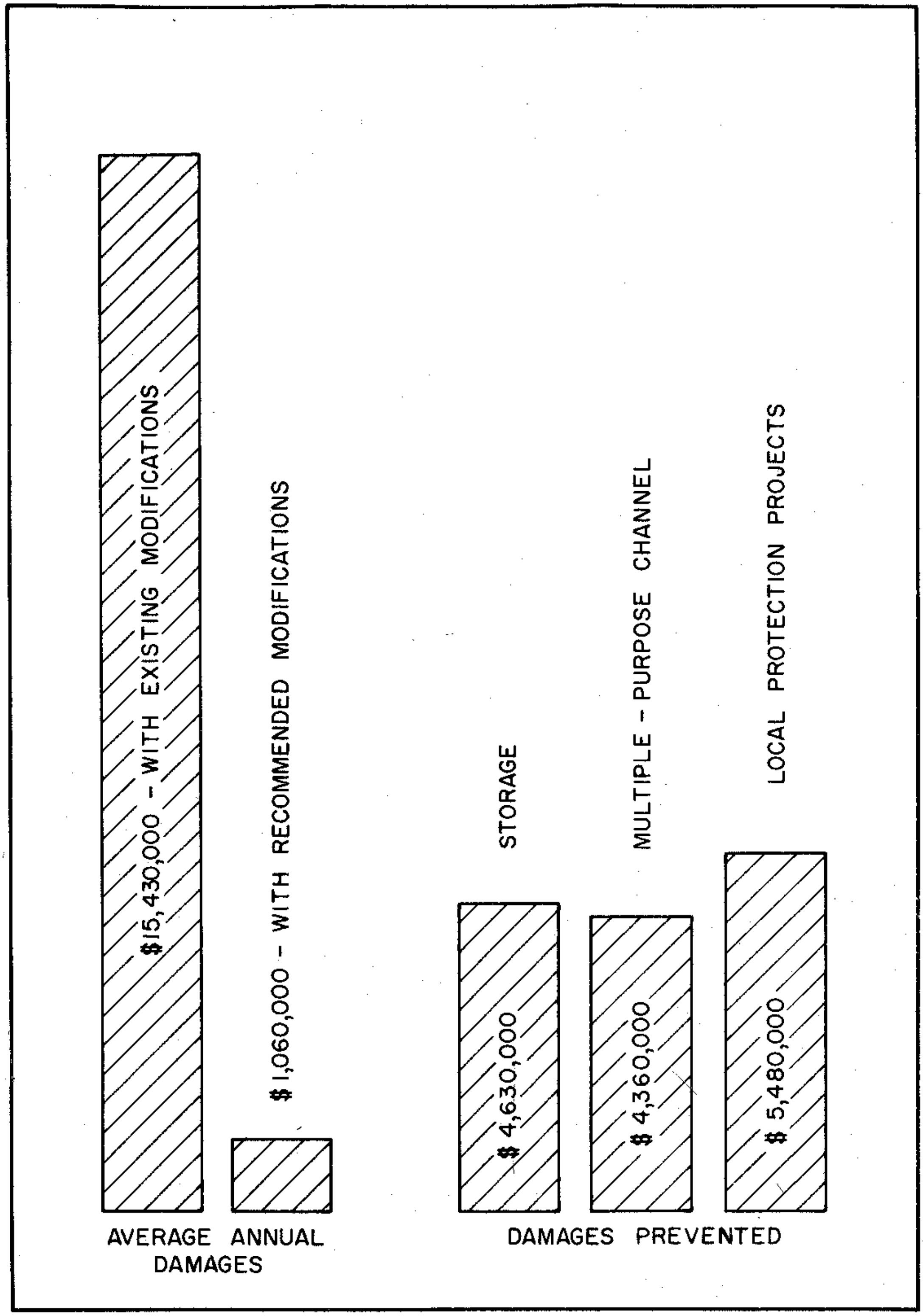


FIGURE 6. AVERAGE ANNUAL DAMAGES AND DAMAGES PREVENTED