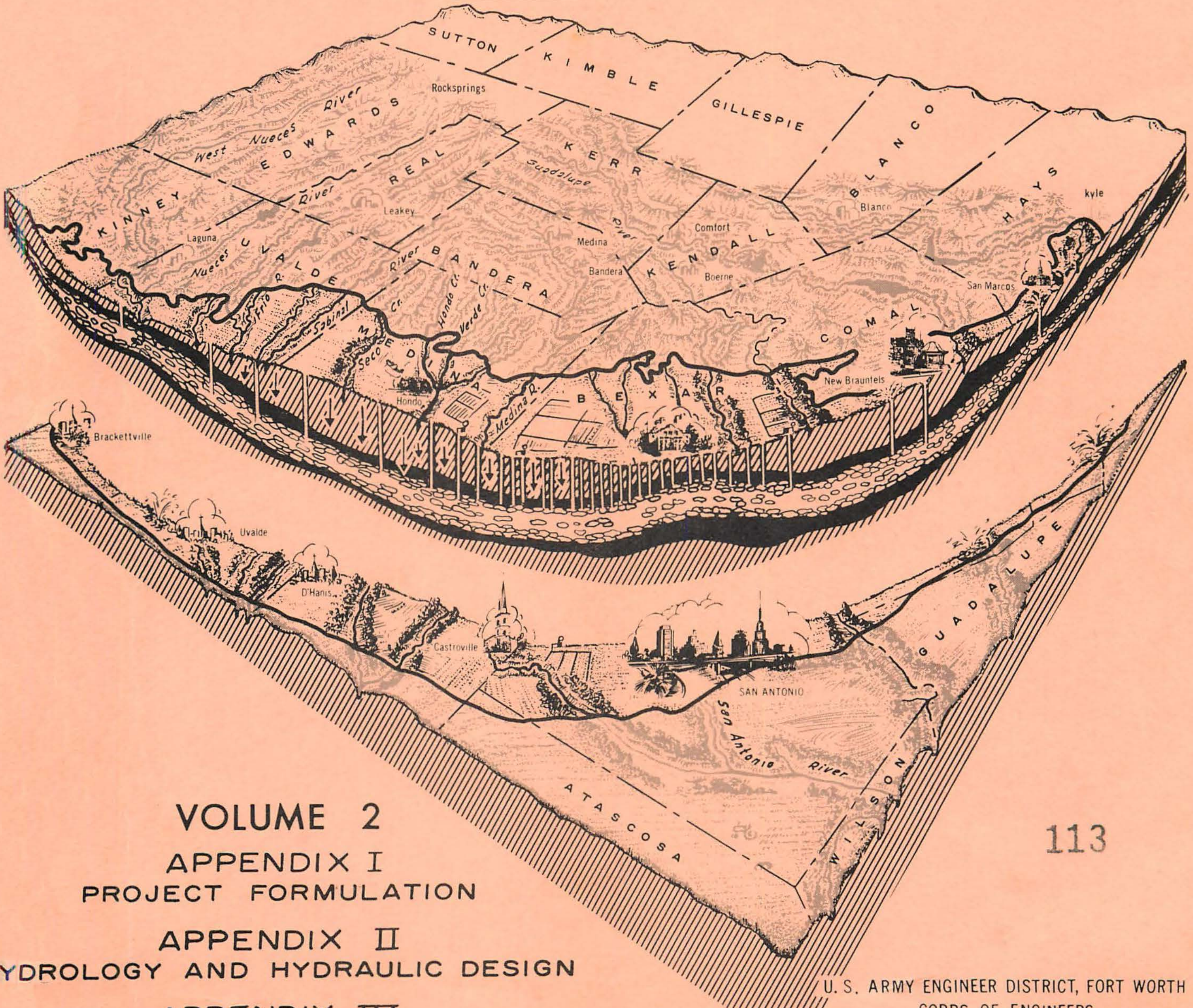
MATTHEWS, NOWLIN, MACFARLANE & BARRETT

SURVEY REPORT
ON
EDWARDS UNDERGROUND RESERVOIR

GUADALUPE, SAN ANTONIO AND NUECES RIVERS AND TRIBUTARIES, TEXAS.

AS SENT TO CHIEF OF ENGINEERS



VOLUME 2

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CORPS OF ENGINEERS
FORT WORTH, TEXAS

AND

EDWARDS UNDERGROUND WATER DISTRICT
SAN ANTONIO, TEXAS

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APPENDIX I

PROJECT FORMULATION

INTRODUCTION

1. PURPOSE.- The plan of improvement was formulated with a view to the following objectives: to provide flood protection, where economically feasible, to portions of the rural and urban areas of the Guadalupe, San Antonio, and Nueces River Basins by construction of reservoirs upstream from the Balcones fault zone in the Edwards Plateau; to provide, as part of the plan, an effective means of additional recharge of the Edwards Underground Reservoir; to develop, to the extent feasible, the water resources of the area in an attempt to meet the projected future water supply requirements; and to provide for the future development of the fish and wildlife and general recreation potentials which would be afforded by proposed reservoirs.

2. SCOPE.- This appendix presents the methods used in formulating the plan of improvement to meet the above objectives. It presents a summary of the preliminary investigations, the selection of the plan of improvement, economic evaluation of the proposed plan, allocation of costs to project purposes and apportionment of costs to Federal and non-Federal interests.

3. RELATIONSHIP TO OTHER APPENDIXES.- Most of the physical information and data presented in this appendix consists of summations and integration of data and information taken from other appendixes of this report. The information contained herein concerning the supplies of water available, the frequency and magnitude of floods in the area, hydrologic objectives relative to reservoir storages, operation requirements for various reservoir project purposes, and the basic design data of tentative plans considered in these studies is based on detailed hydrologic and hydraulic data presented in appendix II. Future water requirements and benefits used herein are based on information contained in a report prepared by the Public Health Service of the Department of Health, Education and Welfare, which is included as an attachment to this appendix. Geologic conditions in the Edwards Underground Reservoir area and reservoir geology discussed in connection with investigated projects is presented in detail in Appendix III, Geology. Information used herein on the extent of flooding, flood damages and flood control benefits accruing to the investigated projects was obtained from data

contained in Appendix IV, Flood Control Economics. Economic projections and analysis utilized to develop future needs and benefits for flood control and water conservation are described in detail in Appendix V, Economic Base Study. The demand for recreation and fish and wildlife opportunities and the benefits therefor were summarized from information presented in Appendix VI, Recreation and Fish and Wildlife.

4. EXISTING PROJECTS.- At present, Canyon Reservoir is the only Corps of Engineers reservoir in operation in the study area and it is located at river mile 303.0 on the Guadalupe River, about 12 miles northwest of New Braunfels. It was constructed for flood control, water supply, and recreational purposes. Construction of Canyon Reservoir began in April 1958 and deliberate impoundment began on June 16, 1964. Blieders Creek Reservoir, a flood control only project to be located at river mile 5.8 on Blieders Creek, 1.5 miles north of New Braunfels, is in the advance planning stage. Blieders Creek Reservoir, when constructed, will control the runoff from a 14.8 square mile area and provide flood protection to the city of New Braunfels. The Corps of Engineers also has under construction a channel improvement project in the city of San Antonio which includes the clearing, widening, deepening, and straightening of approximately 31 miles of river and creek channels and construction of certain related structures. This project was begun in November 1957 and, when completed, will control the runoff from approximately 114 square miles of drainage area in and adjacent to the city of San Antonio. Pertinent data for the Canyon and Blieders Creek Reservoir projects and the San Antonio Channel Improvement project are presented in tables 1 and 2. In addition to the above projects, Gonzales Reservoir, on the San Marcos River near Gonzales, was authorized for construction as a flood-control and water supply project by the Corps of Engineers under the Flood Control Act of 1954; however, due to lack of assurances of local cooperation, no funds have been appropriated to initiate advance planning and the project was not considered in studies for this report.

5. The Soil Conservation Service of the U. S. Department of Agriculture has formulated "work plans" for the Martinez, York, and Salado Creeks watersheds within the Edwards Reservoir area. The plans provide for construction of 38 watershed protection and floodwater retarding structures to provide control over a drainage area of about 218 square miles. The structures will contain a total of about 63,767 acre-feet of detention storage.

6. On July 1, 1964, the Soil Conservation Service had in operation 18 structures in two of the watersheds in the study area. Of these structures, 5 are located in the watershed of Martinez Creek, a tributary of Cibolo Creek in Bexar County, and 13 are in the watershed of York Creek, a tributary of the San Marcos River. Pertinent data on the projects which have been constructed and on those

TABLE 1

PERTINENT DATA - EXISTING AND AUTHORIZED
CORPS OF ENGINEERS RESERVOIRS

	RESERVOIR	
	Canyon	Blieders Creek
Stream	Guadalupe	Blieders Creek
River mile	303.0	5.8
Contributing Drainage Area (square miles)	1,425	14.8
Net Storage - acre feet		
Sediment Reserve		
Conservation Pool	19,800	-
Flood Control Pool	8,300	400
Conservation	366,400	-
Flood Control	346,400	7,312
Total Controlled Storage (acre-feet)	740,900	7,712
Yield (acre-feet per year)	96,400	-
Pertinent Elevations - ft. msl		
Top Conservation Pool	909.0	-
Top Flood Control Pool	943.0	750.5
Design Water Surface	969.1	763.1
Top of Dam	974.0	768.0
Dam		
Type	Earth Fill	Earth Fill
Length	4,410 ft. (Main Emb.)	3,730 ft.
Maximum height	224 ft.	84 ft.
Top width	20 ft.	20 ft.

TABLE 2
PERTINENT DATA - EXISTING LOCAL IMPROVEMENT (FLOODWAY)
PROJECTS BY CORPS OF ENGINEERS

Project	Local Agency	Stream	Drainage area at head of project - sq. mi. Controlled	Uncontrolled	Total	Drainage area at lower limit of project (sq.mi.)	River mile limits of project	Improved channel length (ft)
San Antonio Channel Improvement	San Antonio River Authority	San Antonio River	32.0	1.6	33.6	113.7	221.8 to 237.3	60,600
		San Pedro Creek	0.0	1.0	1.0	44.5	0.0 to 4.9	26,100
		Apache Creek	0.0	17.6	17.6	22.6	0.0 to 3.4	18,115
		Martinez Creek	0.0	2.6	2.6	7.1	0.0 to 4.5	23,830
		Alazan Creek	0.0	3.9	3.9	17.7	0.0 to 4.3	22,770
		East Fork Martinez Creek	0.0	0.5	0.5	1.7	0.0 to 1.6	8,300
		North Fork Martinez Creek	0.0	0.9	0.9	1.2	0.0 to 0.7	3,910

additional projects which are planned for the area are presented in table 3.

7. Development of surface water resources by local interests in the study area has been minimal due largely to the availability of ground-water resources. In the Guadalupe River Basin, Comal County has constructed one floodwater retarding structure, with a detention capacity of 350 acre-feet, on the Comal Creek watershed to increase ground-water recharge and to provide flood protection.

8. Local interests developments on the San Antonio River and tributaries consist of Lake Medina and Medina Diversion Reservoir on the Medina River, and Olmos Reservoir on Olmos Creek in San Antonio. Lake Medina, with a capacity of 254,000 acre-feet, and Medina Diversion Reservoir, with a capacity of 5,750 acre-feet, were completed in 1913. These projects are owned and operated by the Bexar-Medina-Atascosa Counties Water Improvement District No. 1 to provide a water supply and gravity diversion for irrigation of lands in the District. In 1926, the city of San Antonio constructed Olmos Reservoir on Olmos Creek to provide flood protection for certain urban areas of the city. Olmos Reservoir has a storage capacity of about 15,500 acre-feet and controls the runoff from about 32 square miles of drainage area. Upon completion of the San Antonio Channel Improvement project, discussed previously, Olmos Reservoir will become an integral part of the plan for flood protection of the San Antonio area. Pertinent data for the existing reservoir projects in the San Antonio River Basin are presented in table 4.

9. Except for stock ponds and several small recreation lakes, there has been no development by local interests in the Nueces River Basin upstream of the Balcones fault zone for surface water supply or flood control; however, several structures have been built in Uvalde County near Uvalde to improve the natural facilities for ground-water recharge. The first such project, a grating over a cave in the Leona River bed two miles north of Uvalde, was constructed by the city of Uvalde in 1940. The injection system of artificial recharge, whereby waters are introduced into an aquifer by means of wells, caves, crevices, and other openings, has been used in Uvalde County since the early 1950's. Several structures have also been constructed to divert flood waters and runoff into natural openings or drilled wells in dry stream beds. These structures generally consist of low concrete dams or dikes located a short distance downstream from protected openings into the bedrock. Recharge structures of this type have been constructed on Indian Creek, Leona River, Dry Frio River, and the Sabinal River north and northeast of Uvalde. Sink holes west and southeast of Uvalde have been developed for recharge by inserting perforated concrete pipes 20 to 25 feet into the sinks and covering the

openings with trash racks. Most of these structures are still in existence and provide some recharge to the underground reservoir by reducing the velocity of water across the land surface and enabling the water to be introduced to the underground strata at higher rates.

TABLE 3

SUMMARY OF PERTINENT DATA FOR EXISTING AND PROPOSED SOIL CONSERVATION SERVICE RESERVOIRS

Watershed	Number of structures completed (1)	Total Proposed Structures (2)			
		Number	Drainage area controlled (sq.mi.)	Sediment storage (ac.ft.)	Detention storage (ac.ft.)
Martinez Creek	5	6	29	2,478	6,511
Salado Creek	0	16	118	5,263	42,005
York Creek	13	16	71	4,950	15,251

(1) Completed as of July 1, 1964.

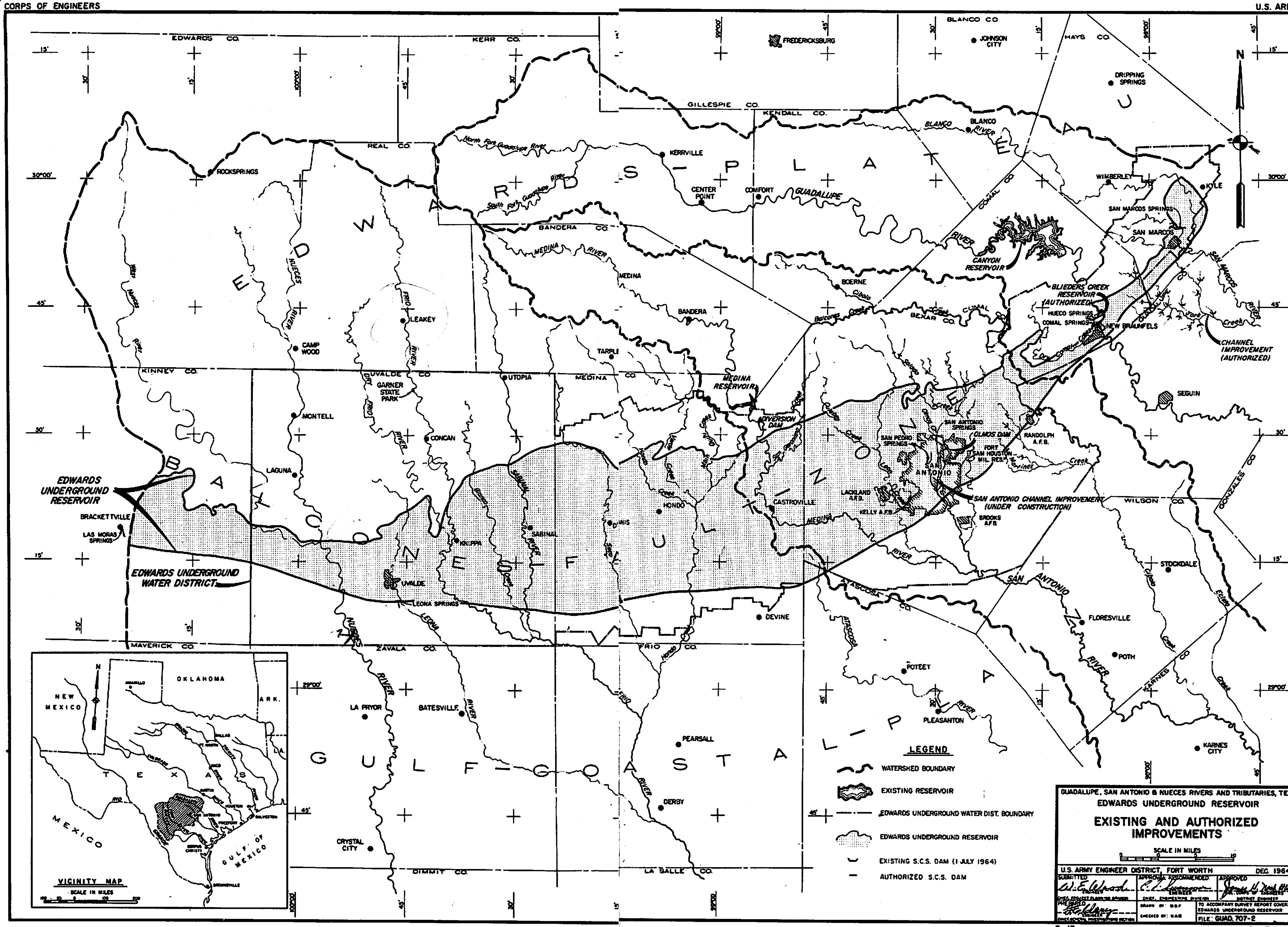
(2) Includes completed structures.

TABLE 4

PERTINENT DATA - EXISTING NON-FEDERAL RESERVOIRS
WITH CAPACITIES GREATER THAN 5,000 ACRE-FEET

Project	Ownership	Location: Stream	Location: River mile	Contributing drainage area (sq.mi.)	Total storage (ac.ft.)	Elevation at maximum controlled storage (ft. msl)	Year constructed	Dependable yield (cfs)
Medina Lake	Bexar-Medina-Atascosa Counties W.I.D. No. 1	Medina River	70.4	633	254,000	1064.5	1913	0
Medina Lake Diversion Reservoir	Bexar-Medina-Atascosa Counties W.I.D. No. 1	Medina River	66.4	-	5,750	919.0	1913	0
Olmos Dam	City of San Antonio	Olmos Creek	0.8	32	15,500	728.0	1926	(1)

(1) Olmos Dam constructed for flood control only.


GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
EXISTING AND AUTHORIZED IMPROVEMENTS
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC. 1964
TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
FILE: GUAD. 707-2
LEGEND
WATERSHED BOUNDARY
EXISTING RESERVOIR
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
EXISTING S.C.S. DAM (1 JULY 1964)
AUTHORIZED S.C.S. DAM
EDWARDS PLATEAU
BALCONES FAULT ZONE
GULF-COASTAL PLAIN
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
CANYON RESERVOIR
BLIEDERS CREEK RESERVOIR (AUTHORIZED)
CHANNEL IMPROVEMENT (AUTHORIZED)
SAN ANTONIO CHANNEL IMPROVEMENT (UNDER CONSTRUCTION)
MEDINA RESERVOIR
DIVERSION DAM
OLMOS DAM
EDWARDS CO.
KERR CO.
BLANCO CO.
HAYS CO.
GILLESPIE CO.
KENDALL CO.
REAL CO.
BANDERA CO.
COMAL CO.
BEXAR CO.
KINNEY CO.
UVALDE CO.
MEDINA CO.
GUADALUPE CO.
WILSON CO.
GONZALES CO.
MAVERICK CO.
ZAVALA CO.
FRIO CO.
ATASCOSA CO.
KARNES CO.
DIMMIT CO.
LA SALLE CO.
FREDERICKSBURG
JOHNSON CITY
DRIPPING SPRINGS
BLANCO
KERRVILLE
CENTER POINT
COMFORT
WIMBERLEY
KYLE
SAN MARCOS SPRINGS
SAN MARCOS
ROCKSPRINGS
BOERNE
MEDINA
BANDERA
HUECO SPRINGS
COMAL SPRINGS
NEW BRAUNFELS
LEAKEY
CAMP WOOD
TARPLE
UTOPIA
GARNER STATE PARK
MONTELL
CONCAN
SEGUIN
SAN ANTONIO SPRINGS
SAN PEDRO SPRINGS
FORT SAM HOUSTON MIL. RES.
RANDOLPH A.F.B.
SAN ANTONIO
LACKLAND A.F.B.
KELLY A.F.B.
BROOKS A.F.B.
CASTROVILLE
HONDO
D'HANIS
SABINAL
KNIPPA
UVALDE
LEONA SPRINGS
LAGUNA
BRACKETTVILLE
LAS MORAS SPRINGS
DEVINE
STOCKDALE
FLORESVILLE
POTH
POTEET
PLEASANTON
KARNES CITY
LA PRYOR
BATESVILLE
PEARSALL
DERBY
CRYSTAL CITY
North Fork Guadalupe River
South Fork Guadalupe River
GUADALUPE
BLANCO RIVER
MEDINA RIVER
Cibolo Creek
NUECES RIVER
FRIO RIVER
SABINAL RIVER
LEONA
SAN ANTONIO RIVER
ATASCOSA RIVER
SAN MARCOS RIVER
VICINITY MAP
NEW MEXICO
OKLAHOMA
ARK.
LA.
TEXAS
MEXICO
GULF OF MEXICO

10. GENERAL.- There are now 17 cities and communities which are dependent upon the Edwards Underground Reservoir as the source of their municipal water supplies. Among them are Uvalde, Sabinal, Hondo, San Antonio, New Braunfels, San Marcos, and Kyle. San Antonio, the state's third largest city, overlies a portion of the Edwards Underground Reservoir, and is the largest city in the United States which obtains its entire water supply from underground sources. Approximately 850,000 people (of which about 700,000 reside in Bexar County) depend on the reservoir as their only source of water supply. Among those are the personnel of five large military installations. The six counties which overlie the artesian reservoir, Kinney, Uvalde, Medina, Bexar, Comal, and Hays, pumped from the underground reservoir approximately 239.3 million gallons per day (268,200 acre-feet) from some 4,000 wells in 1962. The record amount of pumping occurred in 1956 at the height of the most recent drought period (1947-1956) and totaled about 282.9 mgd (317,100 acre-feet).

11. The total springflow in 1962 from major springs along the southern edge of the Balcones escarpment was about 286.6 mgd (321,300 acre-feet). This total springflow consisted of discharges from Leona Springs at Uvalde, San Antonio and San Pedro Springs at San Antonio, Comal Springs at New Braunfels, and San Marcos Springs at San Marcos. The total discharge from the aquifer in 1962 from both wells and springs is graphically shown on figure 1.

12. The average annual recharge to the artesian aquifer has been computed to be slightly in excess of 500,000 acre-feet per year for the entire period of record and about 423,200 acre-feet per year for the period 1935-56. This period represents a complete cycle from a period of high runoff through a period of critical drought. The minimum annual recharge recorded was 44,000 acre-feet in 1956 at the end of the most recent drought period and the maximum annual recharge recorded was 1,711,000 acre-feet in 1958. The discharge from the aquifer during 1962 more than doubled the recharge for that year. Figure 2 graphically illustrates the recharge-discharge relationship of the aquifer between the years 1934 and 1962.

13. The above information indicates that the discharge of 589,500 acre-feet from the aquifer in 1962 exceeded the average annual recharge for the entire period of record by about 90,000 acre-feet per year. Subsequent compilations of information indicates that the reservoir has continued on a depletion schedule since 1962 and storage in the aquifer has been reduced in order to meet the current demands.

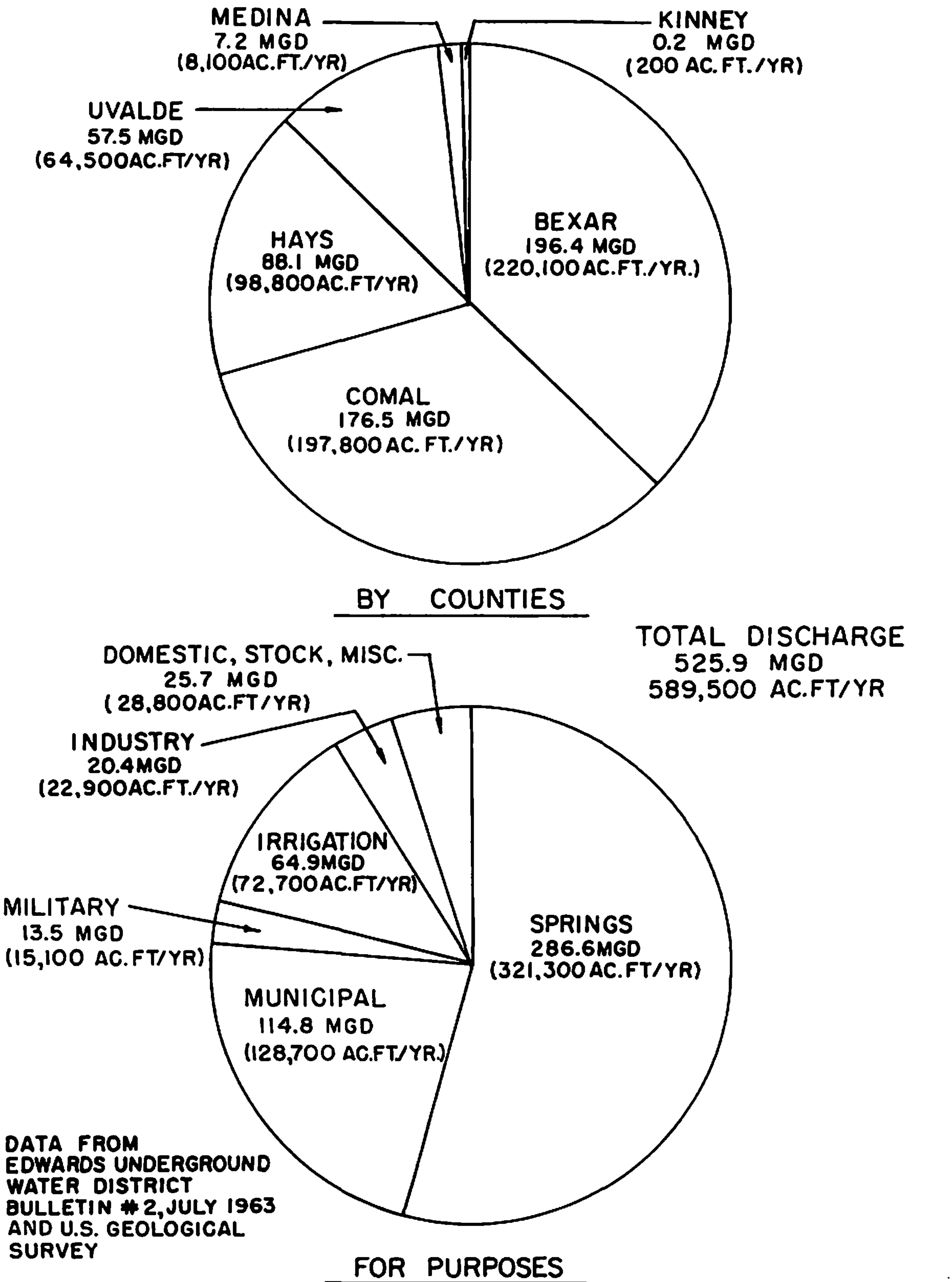
14. Along the southern edge of the underground reservoir lies a zone of bad water that is charged with hydrogen sulfide. This water contains dissolved solids with concentration in excess of 1000 parts

per million. Further south of the bad water line the dissolved solid concentration is as high as 5000 ppm with a chloride concentration as great as 2000 ppm. Since there is rather a fine line along the southern boundaries of the artesian reservoir between the zones of good and bad water, there remains a constant threat that the bad water will encroach on the important well fields in the San Antonio area should the reservoir level be drawn lower than the recorded low elevation of 612 feet msl or a depth greater than 110 feet (Beverly Lodges well) at San Antonio. It is feared that pressure differentials caused by sustained heavy pumping would cause the water gradient to reverse, thereby causing the bad water to move northward into the well fields.

15. Hydrologic studies made in connection with this report conclude that sustained pumping of 234,000 acre-feet per year from areas to the west of Comal County will draw the reservoir down to the historic low elevation of 612 feet msl at San Antonio during a recurrence of the 1947-1956 drought period under present conditions of watershed development. Records show that this safe pumping quantity has been exceeded each year since 1962. Figure 3 illustrates the effects of several sustained pumping rates on the Edwards Underground Reservoir under existing conditions of recharge.

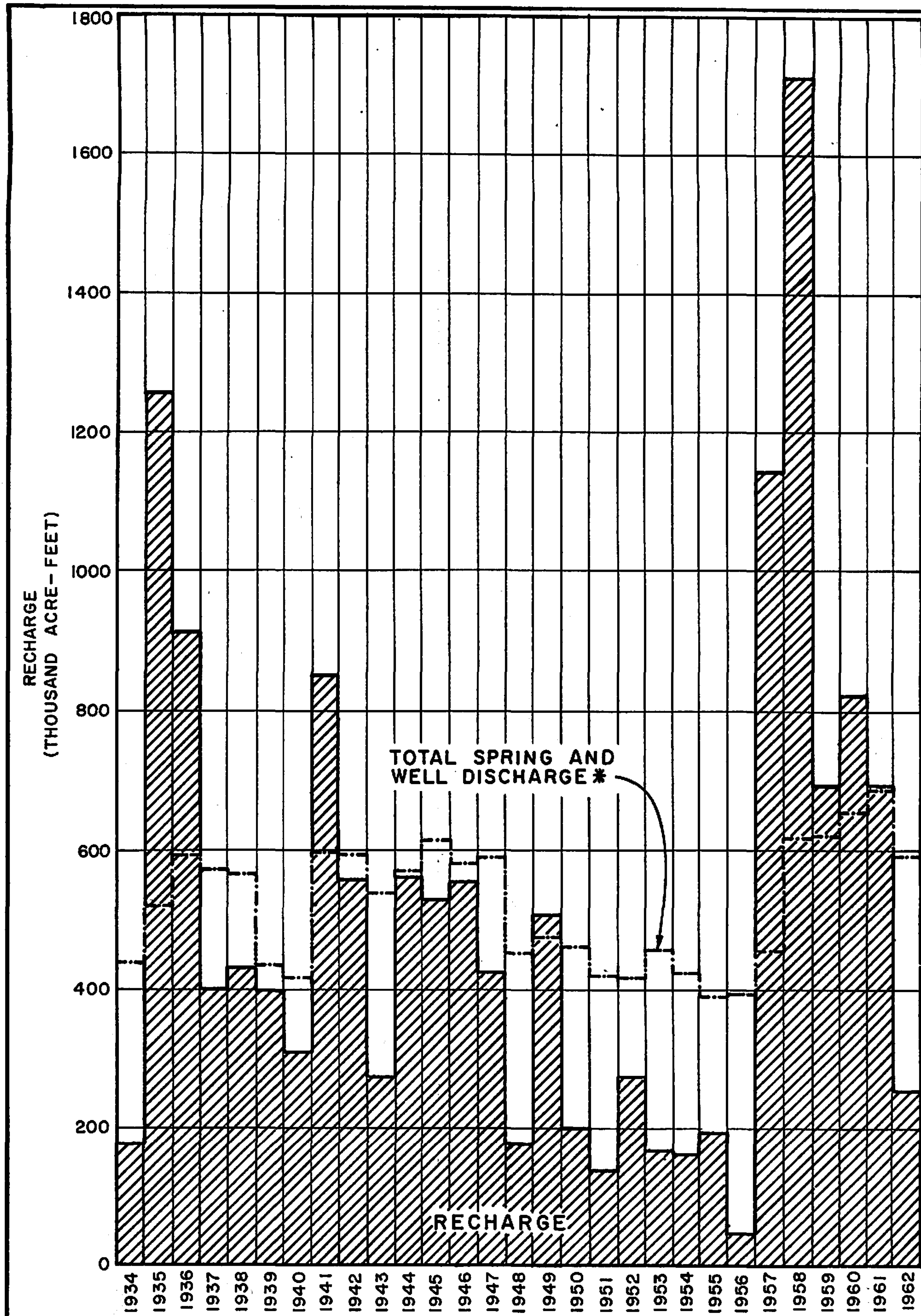
16. Projections of the Public Health Service indicate that by the year 2025 the water demands of the entire Edwards Reservoir area will be 1117.8 mgd (1,253,000 acre-feet per year) and by the year 2075 they will be 1752.5 mgd (1,964,000 acre-feet per year). Of this total demand, 82 percent is expected to originate in the San Antonio area. Municipal and rural demands alone in the San Antonio area are expected to reach 479.3 mgd (537,000 acre-feet per year) by the year 2025. The recorded water uses and projected demands are shown in table 5 and the estimated demands and resources are graphically illustrated on figures 4 and 5.

17. Based on the projections of increased water use in the area, it is apparent that the future water requirements cannot be satisfied by the Edwards Underground Reservoir as now constituted. The only existing supplemental surface-water supply in the area is Canyon Reservoir project on the Guadalupe River recently completed by the Corps of Engineers. This project will provide the area with a dependable yield of 86 mgd (96,400 acre-feet per year). Medina Reservoir on the Medina River currently furnishes water for irrigation in the vicinity of the reservoir; however, leakage from the reservoir and the downstream Diversion Reservoir makes the project virtually ineffective during periods of moderate to severe drought. In the absence of sources of water supply other than those discussed above, it is evident that the quantity of water pumped from the Edwards Underground Reservoir will continue to increase. It is also clearly indicated that the increased pumping rate will result in a severe reduction in the springflows and the levels in the wells will be

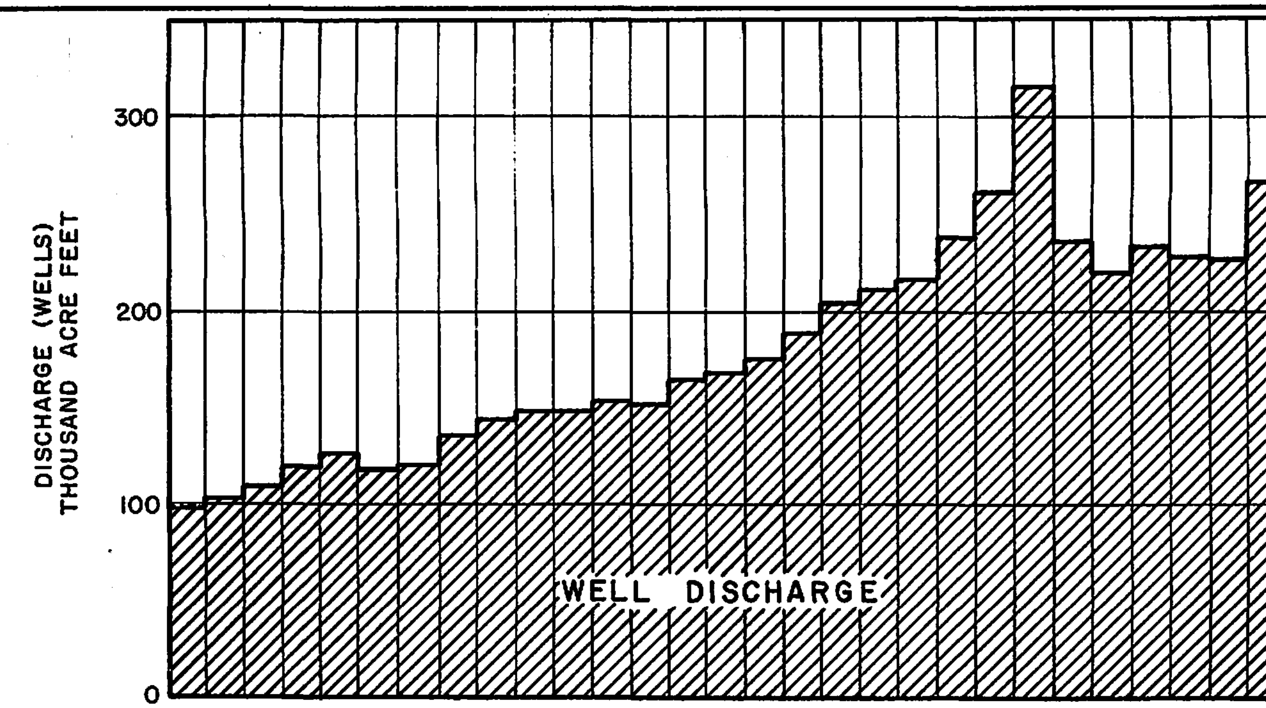


DISCHARGE FROM THE
EDWARDS UNDERGROUND RESERVOIR (1962)

FIGURE 1



*Does not include flow from Hueco Springs



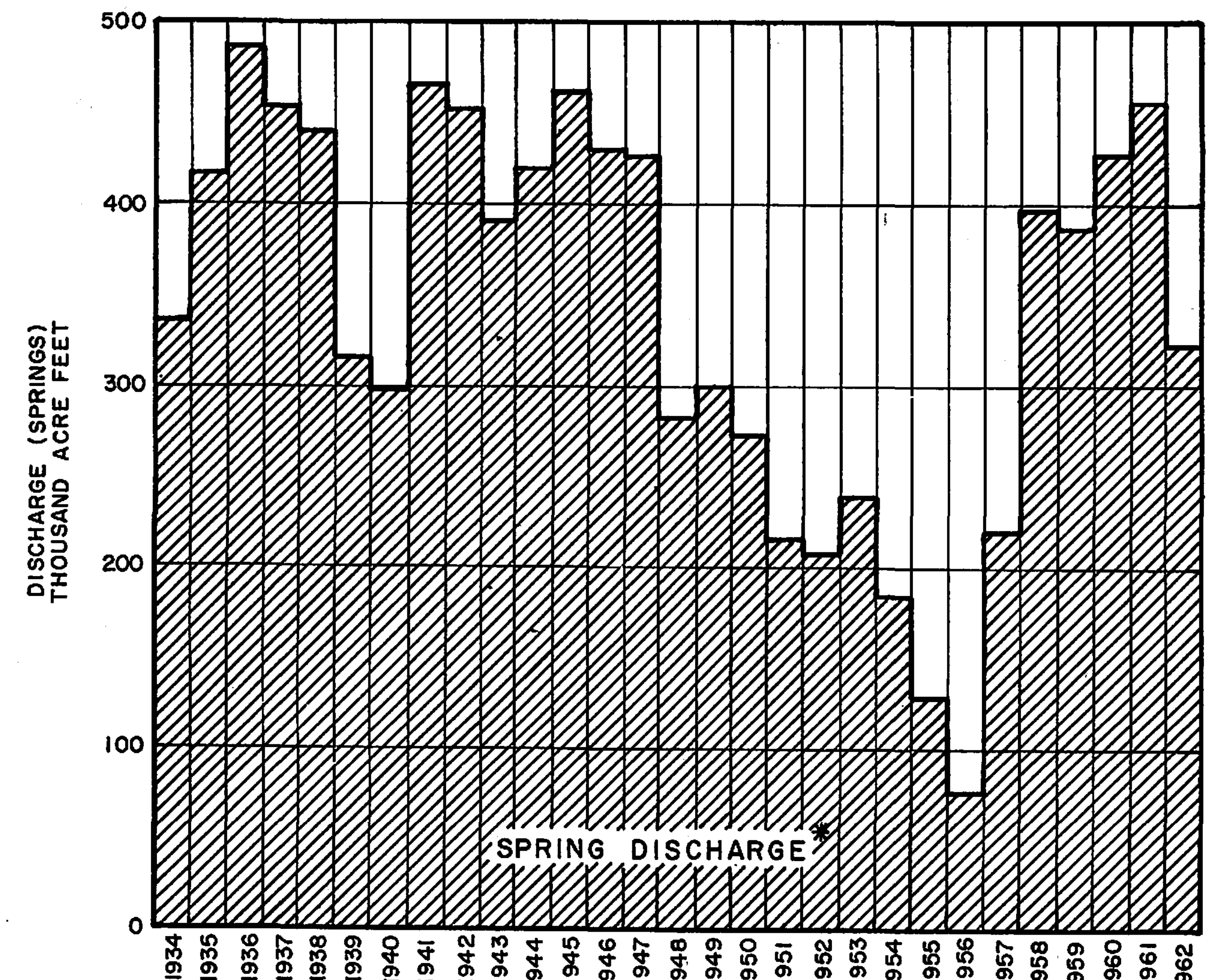


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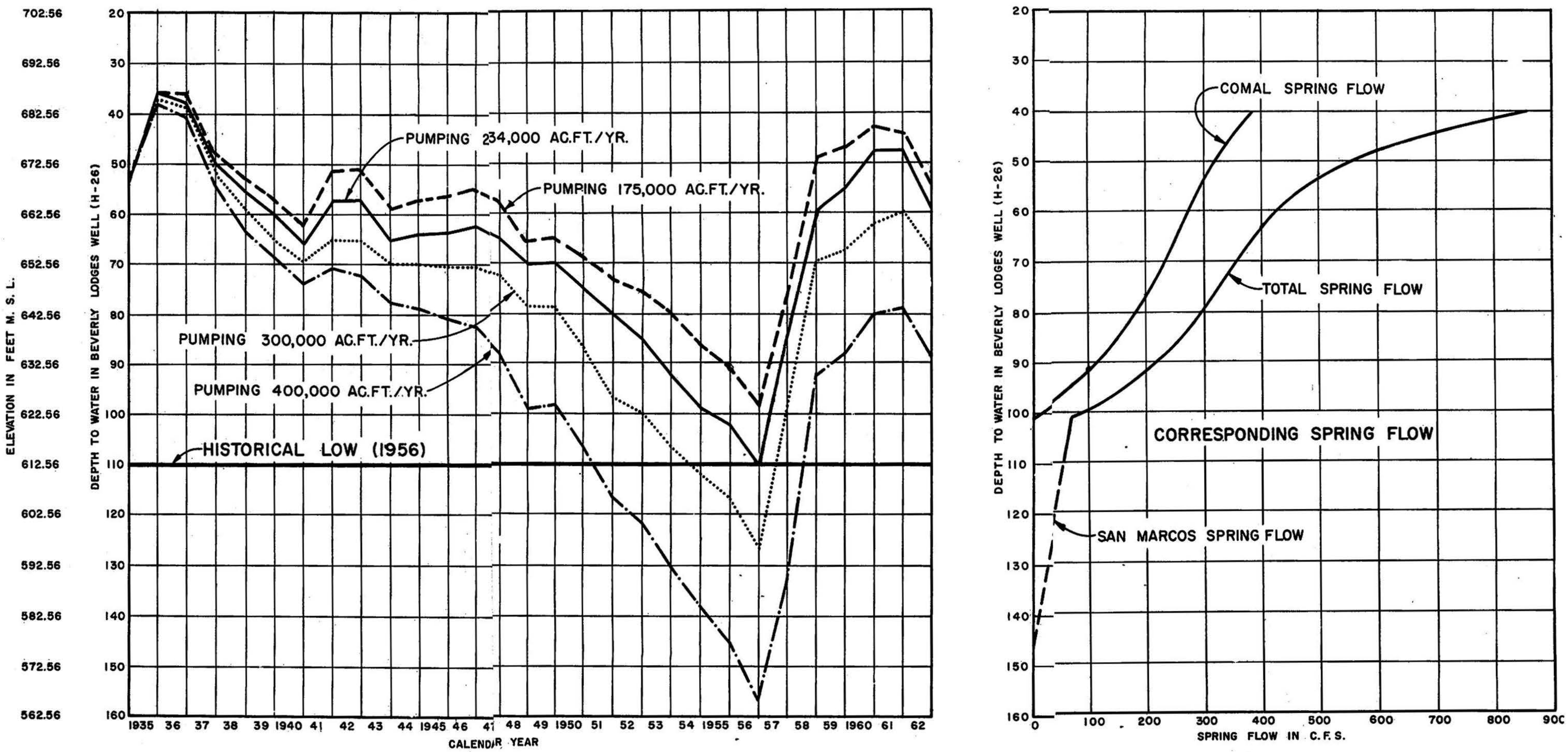
FIGURE 2
RECHARGE AND DISCHARGE



NOTE:
For hydrologic routings above El. 682.0 spring flow curves were extended.

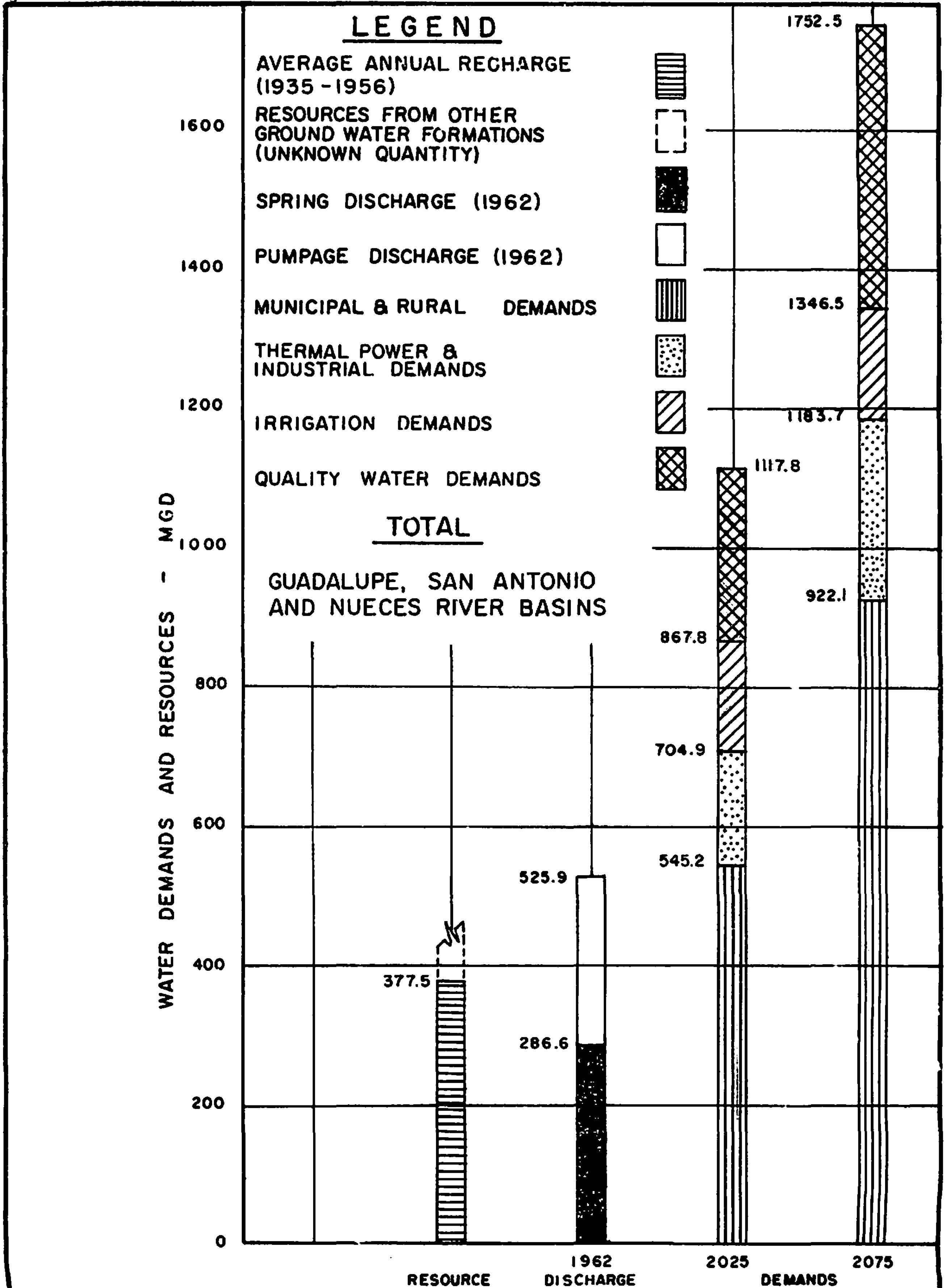
FIGURE 3
EFFECTS OF CONSTANT PUMPAGE ON WATER LEVELS IN THE EDWARDS UNDERGROUND RESERVOIR - EXISTING CONDITIONS

TABLE 5

WATER REQUIREMENTS

Item	Nueces River Basin	San Antonio River Basin	Guadalupe River Basin	Total
		Year 1962 Water Use in MGD (1)		
Municipal and Rural	6.1	139.7	6.6	152.4
Industrial and Power	1.6	19.8	0.5	21.9
Irrigation	35.3	29.4	0.3	65.0
Total	43.0	188.9	7.4	239.3
		Year 2025 Water Requirements in MGD (2)		
Municipal and Rural	19.9	479.3	46.0	545.2
Industrial and Power	8.7	135.7	15.3	159.7
Irrigation	58.5	60.6	43.8	162.9
Quality Control	-	250.0	-	250.0
Total	87.1	925.6	105.1	1,117.8
		Year 2075 Water Requirements in MGD (2)		
Municipal and Rural	29.3	819.9	72.9	922.1
Industrial and Power	13.7	217.9	30.0	261.6
Irrigation	58.5	60.6	43.7	162.8
Quality Control	-	406.0	-	406.0
Total	101.5	1,504.4	146.6	1,752.5

(1) Determined by the Geological Survey; use from the aquifer.
(2) Determined by the Public Health Service; demands of the 14 counties comprising the Edwards Reservoir area.



EDWARDS UNDERGROUND RESERVOIR

FIGURE 4

WATER DEMANDS AND RESOURCES

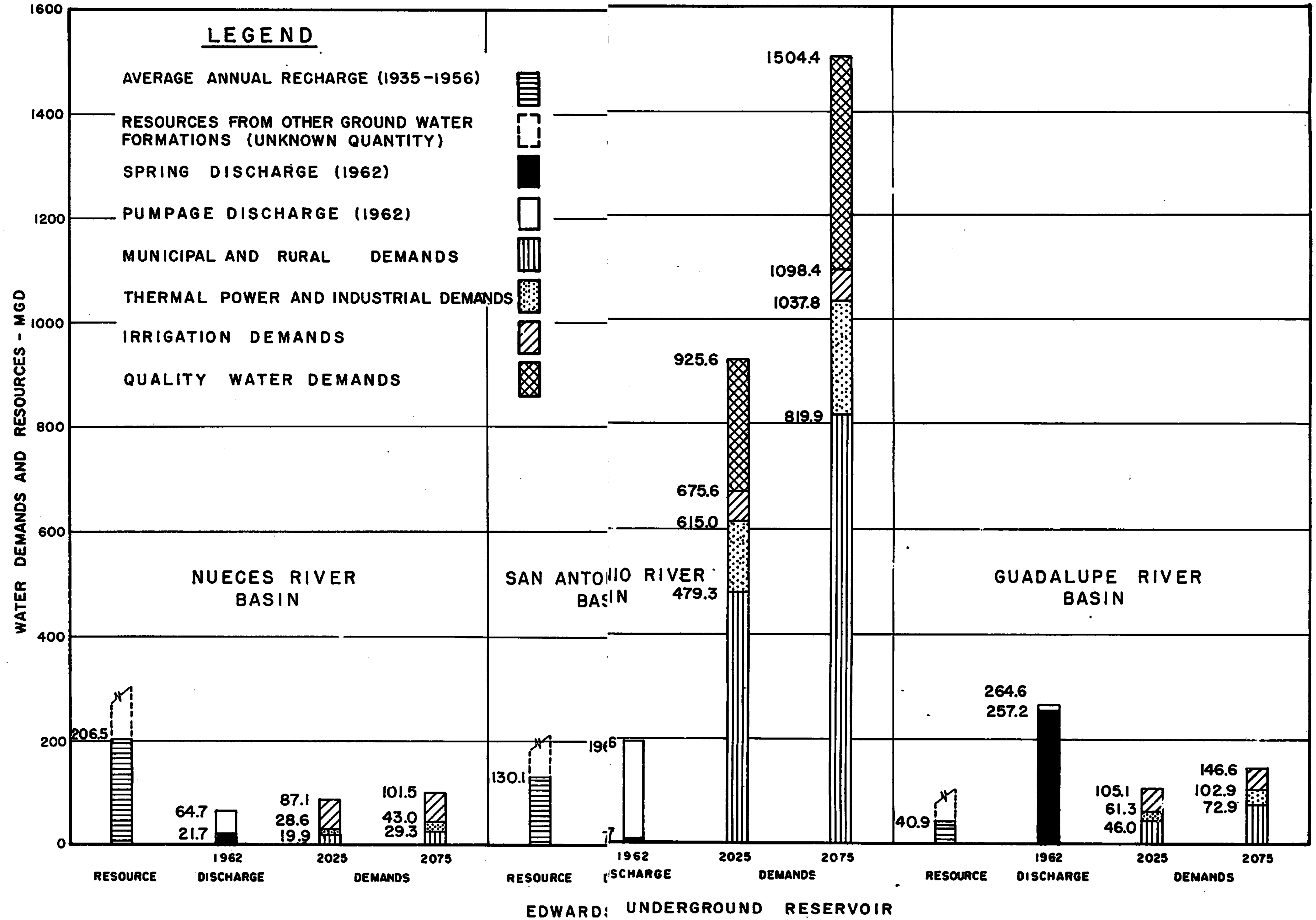


FIGURE 5
WATER DEMANDS AND RESOURCES

lowered. Because of this expected continued depletion of the underground reservoir, the area is confronted with dwindling water supplies and the problem of providing additional resources to meet the expected increase in water demand occasioned by improved living standards, increased population, irrigation of additional lands, and industrial growth.

18. MUNICIPAL AND RURAL REQUIREMENTS.- In 1962 the water demand on the underground reservoir for municipal and rural purposes was 152.4 million gallons per day (171,000 acre-feet per year). Based on the expected increase in population in the area and the resulting increased water demands, it is estimated that the 2025 requirement for municipal and rural purposes will be 545.2 mgd (611,000 acre-feet per year) and that these requirements will be 922.1 mgd (1,034,000 acre-feet per year) by 2075. Approximately 90 percent of the 1962 use from the aquifer for municipal and rural purposes and 90 percent of the future requirements for these purposes in the Edwards Reservoir area are for Bexar County. These include the demands of the city of San Antonio and the military reservations in the vicinity. Sufficient resources as described in the previous paragraph are available on a dependable basis to satisfy the expected future municipal and rural requirements to about the year 1993.

19. INDUSTRIAL AND THERMAL POWER REQUIREMENTS.- An important ingredient in the economic expansion and growth of an area, and the corresponding economic well-being of the population, is the presence of industry. At present, the major industrial growth being experienced in the Edwards area is centered in and near the city of San Antonio. In 1962 the water used for industrial and thermal power generation purposes in the Edwards area totaled 21.9 million gallons per day (25,000 acre-feet), of which 19.8 mgd (22,000 acre-feet) were used in the San Antonio area. Based on economic and population projections the water requirements of the Edwards area for industrial and thermal power purposes are expected to reach 159.7 mgd (179,000 acre-feet per year) by the year 2025 and continue to increase and reach 261.6 mgd (293,000 acre-feet per year) by the year 2075. Under present conditions of development in the Edwards area available resources amount to 294.8 mgd (330,000 acre-feet per year), which would be sufficient to satisfy the combined municipal, rural, industrial, and thermal power demands until about the year 1983.

20. IRRIGATION.- Within the Edwards Reservoir area there are approximately 290,000 acres of land suitable for sustained permanent-type irrigation. In 1962 some 45,000 acre-feet (40 mgd) of surface water was used to irrigate about 25,000 acres. In this same year about 73,000 acre-feet (65 mgd) of ground water from the artesian aquifer was used to irrigate some 33,000 acres. Prior studies by others indicate that the lack of adequate water resources in the semi-arid regions in the western portions of the area, the lowered water

levels in the aquifer, and higher priority demands for the available water will preclude the full development of the potential irrigated areas. Therefore, the water demand for irrigation is expected to rise to about 162.9 mgd (183,000 acre-feet per year) by the year 2025 and then remain relatively constant. Medina Reservoir on the Medina River currently furnishes water from a conservation storage space of 254,000 acre-feet to irrigate up to 35,000 acres. However, leakage from the main reservoir and the Diversion Reservoir downstream makes the project virtually ineffective during periods of moderate to severe drought. The Nueces River Master Plan Study, published by the Nueces River Conservation and Reclamation District in March 1958, proposed construction of Tom Nunn Hill Reservoir which would include storage for water supply purposes. The proposed reservoir would contain 50,000 acre-feet of conservation storage and would have a dependable yield, during a recurrence of the most severe drought period of record, of about 4.0 mgd (4,300 acre-feet per year). With the inclusion of the yield of Tom Nunn Hill Reservoir, sufficient resources are available in the Edwards area to satisfy the projected municipal, rural, industrial, thermal power and irrigation requirements until about the year 1972.

21. WATER QUALITY CONTROL REQUIREMENTS.- In any large or growing metropolitan area, disposal of municipal and industrial waste is a prime problem. Even with the best available means of treatment and disposal of wastes, pollution of the streams below the outfall of the sewage disposal plants will result. The Public Health Service has determined that water needs for quality control along the San Antonio River downstream from the city to eliminate this health hazard will approach 250.0 mgd (280,000 acre-feet per year) by the year 2025 and 406.0 mgd (455,000 acre-feet per year) by the year 2075.

22. FLOOD PROBLEMS.- The streams of the Edwards Plateau flow in narrow valleys and canyons through rugged hill country. The steep gradient of the streams concentrates storm waters rapidly, resulting in floods of high peak discharges but of short durations. These flood peaks diminish quickly as they pass the Balcones escarpment into the wider valleys of the coastal plains. Floods originating below the fault zone normally have lower peak discharges and longer durations. A brief discussion of the flood problems existing in the study area is presented in the following paragraphs. Only those portions of the three river basins that would be affected by flood-control projects constructed upstream from the Edwards Underground Reservoir for flood-control purposes are considered to be within the scope of this report.

a. Guadalupe River Basin.- The major flood problem areas in the Guadalupe River Basin lie along the Blanco River, the San Marcos River and the Guadalupe River downstream from the mouth of the San Marcos River. Flood damages to agricultural, urban, oilfield, utility and transportation facilities in this portion of the Guadalupe River Basin total approximately $1,080,000 annually at present; however, with the projected increase in population and industrial expansion in the lower basin without additional flood control improvements, the average annual damages are expected to double in the next 50 years. In the Edwards Reservoir area local flood problems exist in the cities of San Marcos and New Braunfels. Floodwaters originating on tributary areas of the San Marcos River in and upstream from San Marcos and backwater from floods on the Blanco River cause average annual damages to the city estimated at $104,300. The authorized Blieders Creek Reservoir will partially alleviate the serious flood problem in the city of New Braunfels and Canyon Reservoir would substantially reduce flood damages along the main stem of the Guadalupe River downstream from the project.

(1) For the purpose of analysis of the remaining flood problems which exist in the Guadalupe River Basin, the Canyon, Blieders Creek, and Cuero flood control projects were considered as existing and in operation. The Cuero Reservoir (stage II) on the Guadalupe River and Sandies Creek is a flood control and water conservation project recommended for construction in reports by the Texas Water Commission, the Guadalupe-Blanco River Authority, the U. S. Study Commission - Texas, and the Bureau of Reclamation.

(2) Estimates were made of the annual flood damages along a reach of the Guadalupe River, within the Edwards Reservoir area, from the vicinity of the community of Comfort to the headwaters of Canyon Reservoir. These annual damages were computed to be approximately $16,500.

b. San Antonio River Basin.- The more severe flood damages in the San Antonio River Basin have been largely concentrated in the metropolitan area of the city of San Antonio. The San Antonio River and its tributaries within the city have spilled floodwaters over their banks into the low-lying areas of the city on numerous occasions. Other flood damages within the basin occur to agricultural lands, transportation facilities and utilities along the lower reaches of the main stem and principal tributaries. Completion of the San Antonio Channel Improvement project in the city of San Antonio will virtually eliminate flood damages within the city. The new stream channels through the city will have capacities to carry floodflows greater than any of record. For the purpose of analysis of the remaining flood problems which exist in the San Antonio River Basin, the San Antonio Channel Improvement project was considered as completed and in operation. No projects for flood control were recommended for the Edwards Reservoir area in the U. S. Study Commission - Texas report, and investigations made for this report indicated that, upon completion of the San Antonio Floodway project, the remaining damages in the Edwards area would be insufficient to justify additional flood control projects. The remaining flood problem areas in this basin are not within the scope of this report.

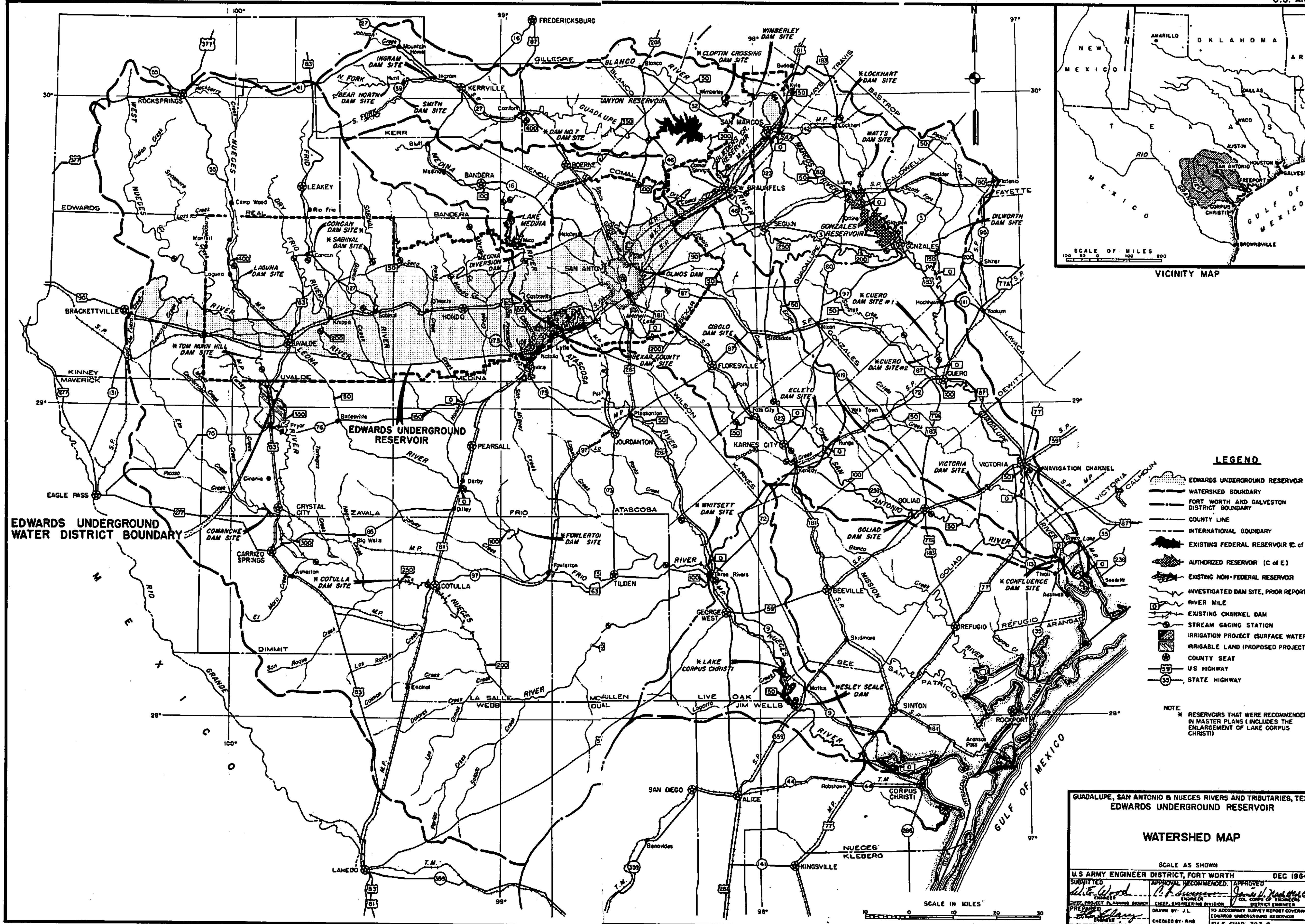
c. Nueces River Basin.- The greatest flood damages in the Nueces River Basin are experienced in areas along the main stem of the Nueces River downstream from the Balcones fault zone in the "winter garden" area near the communities of Crystal City, Carrizo Springs, and Cotulla. Heavy losses are experienced in this area during severe floods from destruction of crops and irrigation facilities, and from land erosion and weed infestation. Some urban damages are experienced in the communities of Crystal City, Cotulla, and Three Rivers. The flood of record on the Nueces River at Uvalde in June 1935 had a peak discharge of 616,000 second-feet and caused damages along the river estimated to be in excess of $10 million. The average annual damages to property along the Nueces River are estimated at $716,100 under present conditions of development. Flood damages are also experienced in and near the town of D'Hanis where floodwaters from Seco and Parker Creeks cause extensive damages to agricultural and urban areas. Along the West Nueces, Dry Frio, Frio, and Sabinal Rivers and other streams in the Edwards Plateau country the principal flood damages are sustained from loss of livestock and extensive ranch fencing.

23. RECREATION.- The demands for outdoor recreation have greatly accelerated in recent years and should increase in the future. Much of this recreation activity is concerned with the use and enjoyment of our water resources. Regardless of the measure used (the number of visitors to Federal and State recreation areas, number of fishing license holders, or number of outboard motors in use) it is clear that Americans are seeking outdoor recreation as never before. Many benefits are derived by the general public from outdoor recreation: it provides the incentive for healthful exercise necessary for individual physical fitness; it promotes health; it is valuable for education in the world of nature; and it satisfies simple recreational needs. Water is a key factor of outdoor recreational development and serves as a magnet. Americans from both urban and rural areas show a strong urge for water-oriented recreation.

24. The Edwards Plateau has long been noted for its scenic beauty and, if properly developed, could become one of the outstanding recreation areas in the state. With the addition of a considerable water surface in this area the recreational potential will be greatly increased. The warm climate is ideal for all types of water-oriented recreation.

25. FISH AND WILDLIFE.- The hill country of the Edwards Plateau abounds in spring-fed perennial streams and timbered lands. The streams usually are clear and provide productive fish habitat. The principal fish species are largemouth bass, catfish, and sunfish. Wildlife resources are diverse and present large populations of white-tailed deer, wild turkeys, mourning doves, and fox squirrels. Private groups and conservation agencies have succeeded in establishing exotic animal species, such as European boar, black buck antelope, axis deer, and auodad and mouflon sheep.

26. Fish and wildlife are living natural resources and, like other living things, they are initially associated with the land and water. A great deal is at stake in the preservation and development of our fish and wildlife resources since they are vitally important to our economy and way of living. The recreational value of fish and wildlife is of profound significance to the well being of people, possibly even more so than the food value of this resource. In our way of life, we no longer have to hunt and fish for food, but the pleasure and sport of hunting and fishing are widely enjoyed. The opportunity to hunt and fish will not automatically remain. Fish and wildlife resources must be considered in the overall plan of improvement for the Edwards Underground Reservoir area. The recommendations of the Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, will be given every consideration in the development of projects in this area.


VICINITY MAP
LEGEND
EDWARDS UNDERGROUND RESERVOIR
WATERSHED BOUNDARY
FORT WORTH AND GALVESTON DISTRICT BOUNDARY
COUNTY LINE
INTERNATIONAL BOUNDARY
EXISTING FEDERAL RESERVOIR (C. of E.)
AUTHORIZED RESERVOIR (C of E)
EXISTING NON-FEDERAL RESERVOIR
INVESTIGATED DAM SITE, PRIOR REPORTS
RIVER MILE
EXISTING CHANNEL DAM
STREAM GAGING STATION
IRRIGATION PROJECT (SURFACE WATER)
IRRIGABLE LAND (PROPOSED PROJECT)
COUNTY SEAT
U S HIGHWAY
STATE HIGHWAY
NOTE
RESERVOIRS THAT WERE RECOMMENDED IN MASTER PLANS (INCLUDES THE ENLARGEMENT OF LAKE CORPUS CHRISTI)
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT BOUNDARY
SCALE IN MILES
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
WATERSHED MAP
SCALE AS SHOWN
U.S ARMY ENGINEER DISTRICT, FORT WORTH
DEC 1964
SUBMITTED
ENGINEER
APPROVAL RECOMMENDED
ENGINEER
CHIEF, ENGINEERING DIVISION
APPROVED
COL. CORPS OF ENGINEERS
DISTRICT ENGINEER
PREPARED
ENGINEER
DRAWN BY: J.L.
CHECKED BY: RHB
TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
FILE GUAD 707-2

INVESTIGATED PROJECTS

27. OBJECTIVES.- The plan of improvement was formulated with a view to the following objectives: to provide flood protection where economically feasible to portions of the rural and urban areas of the Guadalupe, San Antonio, and Nueces River Basins by construction of projects upstream of the Balcones fault zone in the Edwards Reservoir area; to provide an effective means of increasing the recharge of the Edwards Underground Reservoir; to provide additional water conservation storage to meet the projected future water supply requirements and develop to the extent feasible the resources of the Edwards area; and to provide for the development of the fish-wildlife and general recreation potentials in proposed reservoirs.

28. PLANNING CONSIDERATIONS.- Plan formulation studies require that the elements of any plan meet the following conditions: (a) that they be compatible with existing and planned improvements in the three river basins; (b) that there is not a more economical means of accomplishing the same purpose; (c) that the projects proposed in this report be designed to the size, where practicable, that will yield the greatest excess benefits over costs; and (d) that the proposed plan be flexible in that it may be constructed in steps or expanded as the needs may require.

29. RECHARGE INVESTIGATIONS.- During the period 1935-1956 the average annual recharge to the Edwards Underground Reservoir was 423,200 acre-feet. For this same period the average annual discharge from the aquifer was 523,700 acre-feet, with 352,400 acre-feet per year being discharged through major springs along the Balcones fault zone. Pumping during this same period averaged only 171,300 acre-feet. The excess discharges depleted storage in the underground reservoir by approximately 2,200,000 acre-feet. Consideration of methods to increase the dependable yield of the aquifer for pumping involved: (1) control of the major springs to prevent heavy loss of reservoir storage; and, (2) control of the recharge to the underground reservoir by construction of surface reservoirs on principal streams in the watershed of the aquifer.

30. To control the major springs consideration was given to construction of ring dikes around the springs to equalize the hydrostatic head in the underground reservoir. Comal Springs, the largest of the group, consists of a number of springs issuing from fissures in the Edwards limestone along the base of the Comal Springs fault. The springs extend for about 500 yards along the escarpment in a highly developed area. Because of the intense faulting in the area there could be no assurance that construction of a ring dike along the entire length of the Comal Springs fault where the springs emit would prevent the artesian pressure from increasing and causing springs to break out in a number of other locations. Studies were also made of the feasibility of construction of a grout curtain across a narrow portion of the

Edwards Underground Reservoir southwest of Comal Springs. The location would be in an area northeast of San Antonio where the artesian aquifer narrows to approximately five miles in width. Based on information developed from the exploration boring in this area, as described in appendix III, the top 432 feet of the 482 feet of Edwards and associated limestones penetrated were highly broken and solutioned, with some large cavities in this portion. To substantially reduce the flow in this area would require construction of a grout curtain about 5 miles in length, 430 feet in height and to depths below the ground surface as great at 700 feet. In addition to the high cost of such a project, the hydrostatic head within the aquifer would probably prevent successful construction of a grout curtain of this nature. A more detailed discussion is contained in Appendix III, Geology.

31. The base flow of most streams in the Edwards Plateau is lost to the underground reservoir where the streambeds cross the outcrop of the Edwards limestone in the Balcones fault zone. Additional water for recharge, therefore, must come from the floodflows which cannot be fully absorbed into the underground reservoir as they flow past the loss zone. Following major storms the runoff is frequently greater than the infiltration capacity along the streams and large volumes of water escape beyond the lower edge of the Edwards outcrop. From gage records of the Geological Survey it has been estimated that the infiltration rate along the streams in the Nueces River Basin where they cross the fault zone varies from about 500 to more than 1000 second-feet. Major storms during the past 30 years have produced peak discharges in the stream channels of the Nueces River Basin in excess of 600,000 second-feet. Along the streams in this basin, which contribute approximately 64 percent of their flow to the natural recharge of the underground reservoir, about 128,000 acre-feet per year of water resources pass the lower edge of the Edwards outcrop. This point on the streams is generally considered to be the downstream limit of the major recharge zone. Of the streams in the San Antonio River Basin only about 8 percent, or 15,900 acre-feet per year, of the average annual resources from the upper areas of the basin pass the lower edge of the Edwards outcrop. Cibolo, Salado, and Leon Creeks and other small tributary streams lose over 90 percent of their flow to the underground reservoir. Medina River, largest of the San Antonio River tributaries, has 93 percent of its resources above the lower edge of the Edwards outcrop impounded in Medina Reservoir. Of the quantity impounded, approximately half is lost to the Edwards aquifer through leakage from the reservoir and its irrigation facilities. In the Guadalupe River Basin only one stream, Dry Comal Creek, is a major contributor to the Edwards aquifer. It loses 71 percent of its flow and has an annual average of only 8,400 acre-feet of its resources passing the outcrop. A small quantity of recharge is realized from the Blanco River, about 10,900 acre-feet per year, with an additional 14,500 acre-feet per year being contributed by adjacent areas. An average of about 74,100 acre-feet per year of water passes the lower edge of the outcrop along this stream

and adjacent areas. The Guadalupe River, itself, is a noncontributor to the underground reservoir. Prior to construction of Canyon Reservoir an average of 246,000 acre-feet per year of water crossed the Edwards outcrop on this stream with no measurable loss. Table 6 at the end of this section lists the estimated average annual resources and the average annual recharge from each stream in the Edwards Reservoir area. The resources and recharge quantities are shown for the period 1935-1956.

32. From extensive studies and investigations made over the past 40 years by a number of Federal, State, and local governmental agencies, consulting engineers, and ground-water hydrologists, and from studies and investigations made by the Corps in connection with this report, it has been concluded that the most practical and effective means of increasing the recharge of the Edwards Underground Reservoir would be to provide surface storage, where feasible, in and upstream from the Balcones escarpment in the recharge area of the aquifer. The surface water reservoirs would impound floodflows from the watershed areas above the dam sites and would provide regulation of the recharge to the underground reservoir. The water would be released from the surface reservoirs at rates not to exceed the infiltration rates along the streams and allowed to enter the underground aquifer through existing natural recharge channels downstream from the dams. In this manner the projects would enable an increased volume of water to be utilized for recharge of the underground reservoir over the life of the projects.

33. PRELIMINARY STUDIES.- In the watershed area of the artesian aquifer preliminary field and office topographic, geologic, and hydrologic studies were made to locate potentially favorable dam and reservoir sites on the principal streams. A total of 21 possible sites were found for initial study. On the basis of results of water resource studies, as presented in table 6, and a review of flood damages that have been experienced in the area, the list of potentially favorable project sites was reduced to 13. It was found that the eight reservoir sites eliminated would develop insufficient resources and flood control benefits to justify the projects. The remaining 13 sites are discussed in more detail in paragraphs 41-46.

34. For the 13 projects selected for more study, detailed cost and benefit data were prepared and detailed field and office geologic, hydrologic, flood control, recreation, and other feasibility investigations and studies were made. In addition, preliminary studies were made to determine if provision of hydroelectric power facilities at Federal expense could be justified at any reservoir project under consideration in the drainage area of the Edwards Underground Reservoir.

35. For preliminary project justification studies on the 13 projects under consideration, cost estimates for the recharge projects were determined for a reservoir containing storage for 50-year flood control. All releases from the projects would be used for recharge of the Edwards aquifer. A value of 13.6 cents per 1,000 gallons of net increase in average annual recharge was used to evaluate the water conservation benefits. This value was determined by the Public Health Service and was based on alternate cost of water to replace that available for pumping in the San Antonio area. For preliminary justification purposes only, it was assumed that all increased recharge would be available for pumping. For projects containing conservation storage for purposes other than recharge the water supply benefits were based on the cheapest alternate source of water in the vicinity of the projects. Annual charges for all investigated projects were based on an interest rate of 3-1/8 percent and an amortization period of 100 years.

36. SPECIFIC STUDIES.- The following paragraphs give a summary description of the more detailed investigations made during preparation of this report.

a. Economic studies.- An economic base study has been made to measure recent economic growth and to estimate future growth in the Edwards Reservoir area. Projections of industrial development, population, employment, and income have been made to assist in measurement of the probable increase in water resource requirements and the development within the flood plains. A detailed analysis is contained in Appendix V, Economic Base Study.

b. Flood control studies and investigations.- Field and office studies and investigations have been made of flood problems in the Edwards Reservoir area. The investigations were extended to include areas downstream in the Gulf Coastal Plain which would be affected by projects within the Edwards area. The studies included an analysis of the flood problems, delineation of areas subject to flooding, and evaluation of the average annual damages and benefits that would accrue from provision of flood-control improvements in the Edwards Reservoir area. Details of the flood-control studies are described in Appendix IV, Flood Control Economics.

c. Geologic investigations.- Geologic conditions at 10 dam sites were investigated for the construction of recharge reservoirs in the Nueces and San Antonio River Basins. The sites chosen for investigation were located on the Nueces, Dry Frio, Frio, and Sabinal Rivers and on Seco, Hondo, and Cibolo Creeks. Additional investigations were also made at the existing Medina Dam. Six of the sites were located in the Edwards Plateau upstream from the heavy seepage loss areas associated with the Balcones fault zone. These investigated dam sites are situated in areas where the streams have cut through the Edwards and Comanche Peak limestones into the underlying Glen Rose limestone, which formation has generally proven capable of containing water. Core drilling, pressure testing, and other geologic investigations were made at five of the six sites to determine foundation conditions for proposed structures and to determine if the dams and reservoirs could be expected to be relatively watertight. Four of the ten recharge project sites are located in or adjacent to the Balcones fault zone and were investigated as "dry-pool" reservoirs, or reservoirs which would not contain permanent storage. Core drilling and pressure testing were performed at one site on Cibolo Creek within the fault zone to investigate the possibility of using this reservoir for "pump-up" storage, or storage pumped into the reservoir from the aquifer when water levels in the underground were high.

(1) Foundation and other geologic investigations were made at three dam site locations in the Guadalupe River Basin. Projects in this area would not be for recharge purposes but would contain storage for flood-control, conventional water supply, recreation, and fish and wildlife purposes. Investigations were made at two sites on the upper Guadalupe River upstream from the Balcones fault zone and Canyon Reservoir. A selected project would operate in conjunction with the Canyon Reservoir for developing to the extent feasible the total water resources above this project. A third project was investigated in this basin on the Blanco River.

(2) Results of investigations at Medina Dam and a detailed description of the geology of the dam sites and the general geology of the area are presented in appendix III.

d. Hydrologic investigations.- Extensive hydrologic investigations have been made to determine the quantity of additional water resources that could be developed for recharge of the Edwards Underground Reservoir and other water conservation purposes by construction of surface reservoirs on the streams of the Edwards Plateau. To determine the best method of regulating the surface reservoirs for recharge of the aquifer three basic plans of operation were investigated. Two of the methods involved holding the water in surface conservation pools and the third method provided for the release of all storage at recharge rates following each runoff period. Studies based on each of the three methods of operation were evaluated to determine the net increase in the springflow and in the quantity of water available for pumping. These methods of operation and the determination of the most favorable method are discussed in paragraphs 37-40.

(1) Dependable yield and evaporation studies were made for reservoirs located upstream from the Balcones fault zone, which were considered capable of containing permanent conservation pools.

For all the projects investigated, flood-control studies were made to determine the storage requirements to control the floods of record on the individual streams. The investigations also included studies of sediment requirements and structural requirements for the spillway, outlet works, and embankment.

(2) In order to determine the dependable yield of the underground reservoir and to evaluate the effect of the recharge structures on the yield of the aquifer, a number of hydrologic routings of water resources through the underground reservoir were made under existing and modified recharge conditions. The period of routing, 1935-56, was adopted because it represents one complete cycle from a period of high runoff through a period of critical drought. To determine the yield of the Edwards Reservoir which might be associated with various levels of drawdown, routings through reservoir storage were made assuming several constant pumping rates. However, because of the risk of pollution of the Edwards Reservoir by drawing it down below the historical low, a minimum control elevation of 612 feet msl of the water surface of the underground reservoir at San Antonio was used in the evaluation of all recharge plans. The routings were made for a number of combinations of surface reservoirs regulated under the three basic plans of operation.

(3) Additional hydrologic studies were made to determine the effects of investigated reservoirs on yields of downstream existing reservoirs, including Wesley Seale Reservoir (Corpus Christi) on the lower Nueces River. Studies were also made to determine the effects on the yields of downstream reservoirs proposed by the Guadalupe-Blanco River Authority and the Nueces River Conservation and Reclamation District; namely, Cuero Reservoir on the Guadalupe River and Tom Nunn Hill and Cotulla Reservoirs on the Nueces River. The effects of the investigated reservoirs on yields of existing and proposed downstream reservoirs are discussed in paragraph 90. A summary analysis of other hydrologic investigations is contained in subsequent paragraphs and sections of this appendix and a detailed analysis is presented in Appendix II, Hydrology and Hydraulic Design.

e. <u>Recreation</u>.- Studies have been made of the needs for lands and facilities for recreation and fish and wildlife purposes within the Edwards Reservoir area. For determination of benefits for recreation the studies include the use and projection of data compiled for existing Corps of Engineers' projects. A detailed analysis of recreation studies is presented in Appendix VI, Recreation and Fish and Wildlife.

f. <u>Reports of other agencies</u>.- The Public Health Service has prepared an analysis of the future water requirements for water supply and water quality control to the year 2075 within the 14 counties comprising the Edwards Reservoir area. In addition, benefits which would accrue to water supply reservoirs under consideration have been developed. The report of the Public Health Service is attached to this appendix. The Bureau of Sport Fisheries and Wildlife has prepared a report on projects under consideration in the Edwards Reservoir area. This report is attached to appendix VI. A report by Isotopes, Inc., Westwood, New Jersey, has been prepared on the feasibility of using radioactive tracer studies as a means to further define flow paths and rates of flow in the Edwards Underground Reservoir. This report is attached to appendix III.

37. PLANS OF OPERATION FOR RECHARGE RESERVOIRS.- For operation studies on investigated recharge reservoirs, four project sites were used and these sites were located upstream of the Edwards outcrop in areas considered to be relatively watertight. The reservoir projects were Montell on the Nueces River, Concan on the Frio River, Sabinal No. 2 on the Sabinal River, and Hondo on Hondo Creek.

38. Three basic methods of operation of the four reservoirs were investigated. Under one method of operation the water would be retained in the surface reservoirs during periods when the water level in the underground aquifer was high and when rainfall and runoff from the uncontrolled areas kept the underground reservoir replenished. During periods of drought, when the water level in the underground reservoir is drawn down to some predetermined level and the natural recharge is small, the water would be released from the surface reservoirs to enter the aquifer to provide a dependable volume of water during the remaining years of the drought period to maintain, as a minimum, the water level in the underground reservoir at the predetermined elevation. Under this method of operation approximately 974,000 acre-feet of water would be impounded in the four reservoirs. Assuming no evaporation losses, these four reservoirs would increase the average annual recharge from these streams by about 72,000 acre-feet per year. However, by impounding this large quantity of water in surface reservoirs in this semiarid region and making no releases and recharge only during the critical drought, approximately 63,000 acre-feet of water resources would be lost by evaporation each year. The operation of the four projects under this plan would result in a net recharge to the aquifer of 9,000 acre-feet per year. In addition, water levels in the underground reservoir would average from 4 to 7 feet lower during most years of operation except during the latter years of a severe drought. Because of the lowered water levels in the aquifer, springflow would be substantially reduced throughout the entire period of operation without a significant increase in the quantity of water that could be pumped from the aquifer. For these reasons this method of operation was eliminated from further consideration.

39. Under the second method of operation, a constant release would be made of the dependable yield of the surface reservoirs for continuous recharge of the underground reservoir. By operation of the reservoirs in this manner the evaporation loss would be reduced

to about 54,000 acre-feet per year, and the net recharge from the four reservoirs would average 18,000 acre-feet per year. The construction of Hondo Reservoir and operating it in this manner would actually reduce the existing recharge from this stream by 2,400 acre-feet per year.

40. The high evaporation rate in this region prevents the efficient and effective recharge of the Edwards Underground Reservoir by storage of floodwaters in permanent conservation pools. Because of the high and urgent demands for water in the Edwards area and the high evaporation losses the third method of operation would be to release the water from the surface reservoirs as quickly as possible at a rate equal to the infiltration rate of the streams. The operation of "dry-pool" reservoirs would enable the development of maximum water resources at the dam sites with a minimum loss of the resources to evaporation. The net increase in recharge from the four reservoirs would average 72,000 acre-feet per year under this method of operation.

41. INVESTIGATED PROJECTS.- The investigated project sites in the Edwards Reservoir area are shown on plate 3 and are discussed in the following paragraphs in the order of their location on streams of the Nueces, San Antonio, and Guadalupe River Basins. The resources that could be developed at the investigated sites for recharge of the Edwards Underground Reservoir are shown in table 6. A summary of the preliminary justification studies is presented in table 7.

a. Nueces and West Nueces Rivers.- Flood control and water resource investigations were made at two dam sites on the main stem of the Nueces River, the Tom Nunn Hill site downstream from the Balcones fault zone near the city of Uvalde and the Montell site upstream from the fault zone and about 20 miles north of Uvalde.

(1) Flood control studies at the Tom Nunn Hill Reservoir site were made by the Corps in connection with the 1944 survey report on the Nueces River. An analysis of the volumes of floods experienced at this site indicated that 326,000 acre-feet of flood-control storage would be required to control the maximum flood of record. This, in addition to 110,000 acre-feet of conservation storage, is considerably more than is available at the site. In addition to the flood control storage limitation at the Tom Nunn Hill site, this site is downstream from the Balcones fault zone and outside the recharge area of the Edwards Underground Reservoir. A reservoir project is needed upstream from the fault zone to store floodflows and release them at a slower rate to control the recharge from this stream to the underground aquifer and to supply a portion of the water demands in the Tom Nunn Hill area.

(2) The investigations at the Montell site made in connection with this report indicated that a flood control and water conservation reservoir at this site could be economically justified. Sufficient storage is available to control the flood of record on this stream and to develop the maximum water resources at the site for conservation purposes. Because of the heavy loss of resources to evaporation from a reservoir surface in this area, a joint-storage plan for flood-control and recharge purposes was found to be the most effective as well as the most economical and produced the greatest excess benefits over cost. As shown in table 6, the average annual recharge from the Nueces River could be increased by 26,600 acre-feet per year by construction of a project at this site.

(3) Because of the water supply needs in the Tom Nunn Hill area investigations were made to provide a small permanent pool in the Montell Reservoir to produce the equivalent dependable yield of the Tom Nunn Hill Reservoir, computed to be approximately 4,300 acre-feet per year. Under natural conditions all of the low flows and much of the floodflow from the upper reaches of the Nueces River are lost to the underground reservoir as the stream flows across the Edwards outcrop. During the critical period 1947-1956, gage records indicated the Nueces River had a continuous flow at the Laguna gage. However, records for the gage below Uvalde (downstream from the outcrop) indicated no flow over a period of many months. On April 23, 1952, the average daily flow at the Laguna gage was 577 second-feet. The flow at this gage was continuous through May 26, 1952, at which time a discharge of 45 second-feet was recorded. During this entire period no flow was recorded at the gage below Uvalde. To insure the water reaching the Tom Nunn Hill area from the Montell Reservoir, investigations were made of a channel dam on the Nueces River upstream from the Edwards outcrop and a pipeline from the channel dam across the loss zone with sufficient capacity to supply 4,300 acre-feet per year to this area.

(4) The Federal cost for construction of a water supply reservoir at the Tom Nunn Hill site with a conservation storage capacity of 50,000 acre-feet has been estimated to be approximately $11,500,000. The annual charges for this project would be $394,900. The annual charge to furnish the 4,300 acre-feet per year, the computed dependable yield of the Tom Nunn Hill Reservoir, from a water supply only reservoir at the Montell site would be about $51,300. This annual cost, plus that estimated for the channel dam and pipeline, $46,000, totals $97,300. This indicates a saving of $297,600 per year. Obtaining the same quantity of water from the multiple-purpose Montell project in lieu of construction of Tom Nunn Hill Reservoir would increase this savings.

(5) In the event an additional quantity of water is desired for this downstream area in the Nueces River Basin, the additional water could be made available from the Montell Reservoir for approximately 12 cents per 1,000 gallons ($39/acre-feet), based on the

cost of a single-purpose project. The pipeline across the fault zone could also be extended further downstream from the Tom Nunn Hill area at a cost of about $50,000 per mile. Enlarging the Montell Reservoir to provide 10,000 acre-feet per year of dependable yield for downstream water supply purposes would decrease the recharge from the proposed project by approximately 18 percent.

(6) Based on preliminary investigations, a flood-control and recharge reservoir on the West Nueces River could not be justified. The stream flows across the Edwards limestone and gravel formations. It has no base flow and extensive losses occur throughout the length of the stream. At a site where a structure would control about 700 square miles or 77 percent of the drainage area, the increased recharge that could be developed would be only approximately 10,600 acre-feet per year. In addition, since a structure on this stream would have a detrimental effect on the dependable yield of Wesley Seale Reservoir (Lake Corpus Christi), no further consideration was given to developing a reservoir project on the West Nueces River.

b. Frio and Dry Frio Rivers.

(1) The dam site investigated on the Frio River is located upstream from the Edwards outcrop in the vicinity of Concan and in a relatively watertight zone of the Glen Rose limestone. Investigations showed that provision of 149,000 acre-feet of storage (including 7,800 acre-feet of reserve storage for 100-year sedimentation) in this project would control the estimated maximum flood of record on this stream and would increase the recharge to the underground reservoir by 21,500 acre-feet per year, based on a joint-storage plan and operating the reservoir to release the water after each rain. Operation of the reservoir in this manner would eliminate heavy losses to evaporation and would reduce storage requirements by about 287,000 acre-feet. A reservoir at the Concan site containing joint-storage for flood-control and recharge was found to be fully justified.

(2) A dam site, Davenport Hill, was investigated on the Dry Frio River at a location approximately 5 miles southeast of Reagan Wells and within the Balcones fault zone. Development of this site was not found to be economically justified. A reservoir to increase the available recharge from this stream by 8,300 acre-feet per year would require an annual expenditure of about $443,000 with benefits of about $320,000.

c. Sabinal River.- Detailed studies were made of two dam sites on the Sabinal River. Only a joint-storage reservoir for flood control and recharge could be justified. The most favorable location for a reservoir of this type was found to be at a site located about 11 miles north of the town of Sabinal. The structure would be founded on the Edwards limestone near the upstream limits of the outcrop. Structural foundation and topographic conditions are considered favorable. A reservoir at this location containing joint-storage of about 93,300 acre-feet would control the estimated flood of record and would increase the recharge to the underground from this stream by about 15,800 acre-feet per year. Leakage along joint systems, similar to that at Medina Dam, is expected but should present no problem in construction or stability of the structure. Siltation in the reservoir, because of its type and small quantity, is not expected to appreciably seal off or damage existing recharge channels leading from the reservoir area to the Edwards aquifer. Construction of the project would require an annual expenditure of about $483,000 and return net benefits each year of about $646,000.

d. Seco, Hondo, and Verde Creeks.

(1) Detailed investigations were made at two dam sites on Seco Creek and one site on Hondo Creek. Preliminary studies were made on Verde Creek and other small tributaries in the area. As shown in table 6 and on plate 3, construction of projects on the three principal streams and two of the smaller tributaries to control about 236 square miles would result in a net increase to recharge of only 9,200 acre-feet per year. Because of the high cost of reservoir construction and small benefits for flood control or recharge, no projects on these streams could be economically justified at this time.

(2) In connection with the 1944 survey report on the Nueces River the Corps made extensive investigations of a levee project on Seco Creek for the flood protection of the town of D'Hanis. The local protection project was not found to be economically justified at that time. Since a reservoir on Seco Creek could not be justified for flood control and recharge, further investigations were made in connection with this report to determine whether a local protection project could be economically justified at this time. Average annual damages of $18,700 have been experienced at D'Hanis and under future conditions are expected to be about $57,900; however, the annual charges for a flood protection project are estimated to be $127,000, resulting in a benefit-cost ratio of 0.45. Based on these studies, a local protection project at D'Hanis could not be economically justified.

e. Medina River.- Investigations made at Medina Dam to determine the feasibility of reducing leakage from the reservoir consisted chiefly of geologic mapping, core drilling, electric logging, and dye and water pressure testing. The explorations to date indicate that leakage from the lake occurs principally through a well-developed joint system. From observations made over the past two years, it is known that the springflow in the spillway channel is proportional to the head of the lake behind the Medina Dam. Some of the springs which flow when the reservoir is high cease to flow as the lake level drops and the discharge from those that continue to flow is reduced considerably.

(1) It cannot be definitely concluded, based on the limited exploration made to date, that leakage from the reservoir can be eliminated. It is felt that grouting could reduce the leakage from the reservoir; however, additional exploration would be necessary to determine the extent of work necessary to accomplish the desired results. A more detailed discussion of the geologic investigations at Medina Dam is contained in Appendix III, Geology.

(2) Hydrologic studies for this project indicate that leakage from the main reservoir, the diversion reservoir and irrigation distribution system contribute a yearly average of about 42,700 acre-feet of recharge to the Edwards Underground Reservoir. Due to water releases, leakage and evaporation the water surface is usually well below the maximum storage level and the reservoir has been capable of storing practically all floodflows without frequent overflows through the spillway section. If the reservoir were operated for recharge only, the increase in recharge from this stream would be about 20,900 acre-feet per year.

f. <u>Leon, San Geronimo and Salado Creeks</u>.

(1) It is estimated that construction of two detention reservoirs in the Leon Creek watershed and one on San Geronimo Creek to control about 84 square miles would increase the average annual recharge to the underground reservoir by about 1,400 acre-feet. However, since average annual flood damages in this area are small, there are insufficient flood-control and water supply benefits to justify construction of the three projects at this time.

(2) Since the Soil Conservation Service has prepared work plans to construct 16 floodwater detention structures on the Salado Creek watershed, only water resource investigations were made on this stream. It is estimated that the 16 reservoirs will increase the average annual recharge from this watershed by approximately 3,000 acre-feet per year if the water stored in the reservoirs is released after each rain to avoid loss of resources by evaporation.

g. <u>Cibolo Creek</u>.- Initial investigations were made at two sites on Cibolo Creek for construction of a dam and reservoir to contain permanent storage. The sites chosen for investigation were Bulverde at river mile 107.3 and Bat Cave at river mile 93.9.

(1) Hydrologic analysis of records of stream-gaging stations in the vicinity of Bulverde Dam site revealed that excessive losses in streamflow occur along the reach of Cibolo Creek above the site, and, as a result, only a small portion of the runoff available from the watershed upstream would be available for storage in the reservoir.

(2) In the Bat Cave area investigations were initiated with a view toward developing a dam site in close proximity to the city of San Antonio which would control the streamflows and also be available for supplemental storage of water pumped from the underground reservoir during periods when its water level was high. Preliminary geologic investigations at this site indicated that the reservoir area would be in an outcrop of the Glen Rose limestone, a formation normally watertight. Although the investigated dam site is located in an area of intense faulting, previous seepage studies showed that no appreciable streamflow losses occurred from the dam site upstream to Bulverde. More detailed investigations revealed that the Glen Rose limestone occurs only to an elevation of about 58 feet above the streambed and is overlaid by Comanche Peak and Edwards limestones, thus limiting the available storage space in the reservoir. Also, it was found that the elevation of the water table in the reservoir area is predominantly below the elevation of the Cibolo Creek channel. This fact, plus the high permeability of the creek bed and the probability that caverns and sinkholes in the adjacent area offer an underground escape route for the intermittent flow of the creek, make it doubtful that Bat Cave Dam and Reservoir area would be suitable for the permanent storage of water. In addition, evaporation studies revealed that a large portion of the water pumped from the underground reservoir would be lost when impounded in surface projects.

(3) Bat Cave Dam site was also studied for operation of a project containing joint-storage for flood-control and recharge purposes. Under existing conditions approximately 92 percent of the estimated water resources of Cibolo Creek above the lower edge of the Edwards outcrop currently recharge the underground reservoir. Construction of a joint-storage reservoir on this stream would increase the recharge by only approximately 4,400 acre-feet per year. Also, since average annual flood damages are minor along the reach of Cibolo Creek between the Bat Cave site and the headwaters of Cibolo Reservoir, proposed for construction by the Bureau of Reclamation, sufficient flood-control and water supply benefits are not available to justify further water resource development on Cibolo Creek at this time.

h. Dry Comal Creek.- Runoff from the watershed of Dry Comal Creek is considered to be a principal source of supply for Comal Springs at New Braunfels. Investigations by the Geological Survey conclude that water lost from the stream in the Edwards outcrop reappears in the springs near the mouth of the creek. It is believed that construction of a recharge reservoir on this creek would increase the springflow by about 1,300 acre-feet per year without a measurable effect on the underground reservoir.

i. Guadalupe River.- Since the Guadalupe River is virtually a non-contributor to the recharge of the Edwards Underground Reservoir, projects investigated on this stream were not intended to operate as recharge reservoirs but would contain storage for flood control, conventional water supply, recreation, and fish and wildlife purposes. Investigations were made at two sites on the upper Guadalupe River upstream from the Balcones fault zone and Canyon Reservoir. The sites selected for study were Comfort at river mile 402.8 and Dam No. 7 at river mile 351.3, the site proposed by the Guadalupe-Blanco River Authority.

(1) The structure investigated for the Comfort Dam consisted of an earth and rock-fill embankment with a gate-controlled spillway located in the river channel. Geologic investigations showed the bedrock to be a suitable foundation for the structure and the reservoir would be contained in the Glen Rose limestone. Hydrologic studies indicated that a reservoir with a conservation pool of 445,900 acre-feet would fully develop the available resources and provide a yield of 56,500 acre-feet per year (50 million gallons per day) or a total yield for the Comfort-Canyon system of 123,200 acre-feet per year (110 mgd). This is a net increase in yield of 26,800 acre-feet per year (24 mgd) over that developed by the Canyon project alone.

(2) The investigated Dam No. 7 consisted of an earth and rock-fill embankment with an uncontrolled spillway and an outlet works through the dam. This dam and reservoir would also be in the Glen Rose limestone formation. A reservoir with a conservation pool of 640,500 acre-feet would develop a dependable yield of the Canyon-Dam No. 7 Reservoir system of 142,700 acre-feet per year (127 mgd) or a net yield for the Dam No. 7 Reservoir of 46,400 acre-feet per year (41 mgd).

(3) The cost of water at the Comfort project would be 20.7 cents per 1,000 gallons as compared to 9.3 cents per 1,000 gallons at Dam No. 7. Since Canyon Reservoir on the Guadalupe River has been designed to control the flood of record above the dam site, flood control as a project purpose could not be justified in either of the two additional reservoirs, Comfort and Dam No. 7, considered for the upper basin.

(4) At the request of local interests, investigations were made to determine the feasibility of pumping the dependable yield of Comfort Reservoir across the basin divide into the watershed of Medina Reservoir. It was determined that the water could

be transported across the divide by pipeline for approximately 2.1 cents per 1,000 gallons. This would give a total cost of delivered water of 22.8 cents per 1,000 gallons.

(5) Because of the urgent need in the Edwards Reservoir area for an additional water supply to supplement that available from the underground reservoir, both surface water reservoirs were investigated and found to be justified; however, a reservoir at the Dam No. 7 site, the fartherest downstream, would develop a greater percentage of the resources of the stream at a lower unit cost than a project at the Comfort site.

(6) Additional studies were made to determine the effect on the basin yield which would result from an exchange of storage between Dam No. 7 and Canyon Reservoirs. Results of the hydrologic studies indicated that the yields (on a system basis) would be virtually the same. In addition, an increase in the conservation pool of Canyon Reservoir would have severe effects on the recreational facilities at this project. A recreation area has been constructed at Canyon Reservoir which is to be a model recreation area for the Corps of Engineers' projects in the Fort Worth District. This model recreation area is located on an island with access provided by a causeway about one mile in length. Increasing the conservation pool of the reservoir would necessitate increasing the height of the access road to the area. Also, the expected visitation for a larger water surface area would increase the extent of recreational facilities to be provided throughout the project area. The extensive development and subdivision by local interests which have already occurred would require payment of highly inflated prices for the lands necessary to provide the additional recreation facilities which would be required to satisfy the expected visitation. Since the increase in system yield afforded by an exchange of storage would be minor, about 1.3 mgd, it is proposed to provide all the additional water conservation storage in Dam No. 7 Reservoir and not reallocate storage space in Canyon Reservoir.

j. Blanco River.- Studies were made on the Cloptin Crossing Reservoir site, located at river 32.5 on the Blanco River, the site proposed by the Guadalupe-Blanco River Authority. Investigations revealed that a project at this location could be justified to contain storage and facilities for flood-control, conventional water supply, recreation, and fish and wildlife purposes. A conservation storage of 274,900 acre-feet would provide a dependable yield of 42,700 acre-feet per year (38 mgd). Operation of this project for conventional water supply purposes would have little or no effect on the water levels in the underground reservoir and would not have a significant effect on the natural recharge of the aquifer from this stream.

42. SUMMARY OF PLAN FORMULATION STUDIES.- Studies were made of all streams crossing the fault zone in the three river basins to determine the quantity of water that would be available for recharge of the Edwards aquifer. The principal areas in the watershed of the Edwards Underground Reservoir where additional water resources could be developed lie within the Guadalupe River Basin and the western portion of the Nueces River Basin. In the Guadalupe River Basin it was found that construction of projects would have little or no effect on recharge of the underground reservoir. However, projects for purposes other than recharge were studied and it was found that Dam No. 7 Reservoir on the Guadalupe River for water conservation and Cloptin Crossing Reservoir on the Blanco River for flood control, water conservation, fish and wildlife, and general recreation could be economically justified. Since only a very small percentage of the water resources of the San Antonio River Basin passes the lower edge of the Edwards outcrop, and since there are no appreciable flood damages in this area, no additional water resource development could be justified in this basin at this time. On major streams of the Nueces River Basin three reservoirs to contain joint-storage for flood control and recharge were found to be economically justified. These three are the Montell Reservoir on the Nueces River, Concan Reservoir on the Frio River, and Sabinal Reservoir on the Sabinal River.

43. As can be seen in table 6 and discussed in paragraph 29, Recharge Investigations, the recharge from the streams is very effective under natural conditions and for many of the smaller streams a relatively small quantity of water crosses the loss zone that could be made available for recharge purposes. The high cost of construction and the small quantities of water available preclude thorough investigation and development of these smaller streams at this time.

44. Attempts have been made to evaluate the benefits derived from the small uncontrolled recharge projects constructed in Uvalde County and described in paragraph 9, but because of the lack of stream gaging stations and strategically located recorder wells in the Edwards and associated limestones, the benefits are still conjectural. It is true that some floodwaters that would otherwise escape are diverted into the underground reservoir, but just how much or whether the expenditures are justifiable is not known. Runoff or floodwater is captured only after heavy rains and it is during these periods of abundant rainfall that the recharge is generally not necessary. Although large controlled recharge projects on major streams in the Edwards Plateau will capture and contain most of the runoff, there are areas where the small retention type structures possibly would be effective. One such area is Seco Creek where a suitable dam and reservoir site for controlled recharge could not be justified. Small dams and

injection wells along this creek might prove economically feasible and desirable but care should be exercised in locating recharge sites where it is certain the water will find its way into the Edwards Underground Reservoir. It is conceivable that in the operation of reservoirs on larger streams by withholding releases for a day or two during storms that more of the runoff from the uncontrolled areas will enter the aquifer than does under existing conditions, particularly from streams adjacent to projects. After a period of operation of the reservoirs a determination can then be made of their effect on the runoff from the uncontrolled areas and small retardation type structures may become economically feasible at that time.

45. Preliminary studies indicate that the inclusion of hydroelectric power facilities at Federal expense is not justified at the reservoir projects under consideration in the drainage areas of the Edwards Underground Reservoir. The high cost of power capacity, the low flow of the streams, and the lack of adequate regulatory storage combine to support this conclusion.

46. In accordance with section 2b of the Federal Water Pollution Control Act, as amended, consideration was given to use of storage in investigated reservoirs for streamflow regulation for water quality control. A pollution problem exists along the San Antonio River downstream from the City of San Antonio. However, projects that could be developed in the Edwards Reservoir area to yield a substantial quantity of water to partially alleviate this problem would have to be located in the adjoining river basins some distance from the problem area. Also, because of the serious water shortage anticipated for the future in this area, it is believed that high municipal and industrial water demands will preclude development of the available resources for other purposes. The methods and procedures used in determining the project purposes and allocated storages in the projects found justified in the preliminary analysis and final justification studies are described in the following section.

TABLE 6

RECHARGE PROJECT INVESTIGATIONS

Stream***	Estimated average annual resources above lower edge of Edwards outcrop (ac-ft)*	Estimated average annual recharge (ac-ft)*		****	Average annual runoff at lower edge of Edwards outcrop*		Drainage area** (sq. mi.)	
		Existing conditions	Modified conditions	Increase due to reservoir projects	Existing conditions	Modified conditions	Total	Controlled
GUADALUPE RIVER BASIN								
Blanco River and adjacent area	99,500	25,400	25,400	0	74,100	24,200(1)	514	307
Guadalupe River	246,000	0	0	0	246,000	74,100(2)	1,510	1,425
Dry Comal Creek	28,900	20,500	21,800	1,300	8,400	7,100	98	16
SUBTOTAL - Guadalupe River Basin	374,400	45,900	47,200	1,300	328,500	105,400		
SAN ANTONIO RIVER BASIN								
Cibolo Creek	58,900	54,100	58,500	4,400	4,800	400	258	238
Salado Creek	24,400	21,400	24,400	3,000(3)	3,000	0	118	118
Leon and San Geronimo Creek	29,300	27,600	28,900	1,300	1,700	400	152	84
Medina River	94,300	42,700	63,600	20,900(4)	6,400(5)	17,700(6)	630	613
SUBTOTAL - San Antonio River Basin	206,900	145,800	175,400	29,600	15,900	18,500		
NUECES RIVER BASIN								
Verde Creek	18,700	14,600	17,000	2,400	4,100	1,700	108	63
Hondo Creek	23,500	18,300	22,200	3,900	[illegible],200	1,300	136	95
Tributary areas	13,700	10,700	11,400	700	3,000	2,300	79	19
Seco Creek	15,400	12,000	14,200	2,200	3,400	1,200	89	59
Sabinal River	33,900	17,600	33,400	15,800	16,300	500	214	210
Blanco and Hackberry Creeks	4,100	2,100	2,100	-	2,000	2,000	26	-
Little Blanco Creek	2,500	1,300	1,300	-	1,200	1,200	16	-
Frio River	65,000	40,000	61,500	21,500	25,000	3,500	432	391
Two Tributaries	2,700	1,700	1,700	-	1,000	1,000	18	-
Dry Frio River	27,000	17,100	25,400	8,300	9,900	1,600	140	117
Leona River	6,800	4,300	4,300	-	2,500	2,500	35	-
Deep Creek	3,500	2,200	2,200	-	1,300	1,300	18	-
Nueces River	98,700	64,400	91,000(7)	26,600(7)	34,300	3,400	784	707
Indian Creek	6,400	4,200	4,200	-	2,200	2,200	51	-
Four Tributaries	7,700	5,000	5,000	-	2,700	2,700	61	-
West Nueces River	29,800	16,000	26,600	10,600	13,800	3,200	905	700
SUBTOTAL - Nueces River Basin	359,400	231,500	323,500(7)	92,000(7)	127,900	31,600		
TOTAL - Edwards Reservoir Area	940,700	423,200	546,100(7)	122,900(7)	472,300	155,500		

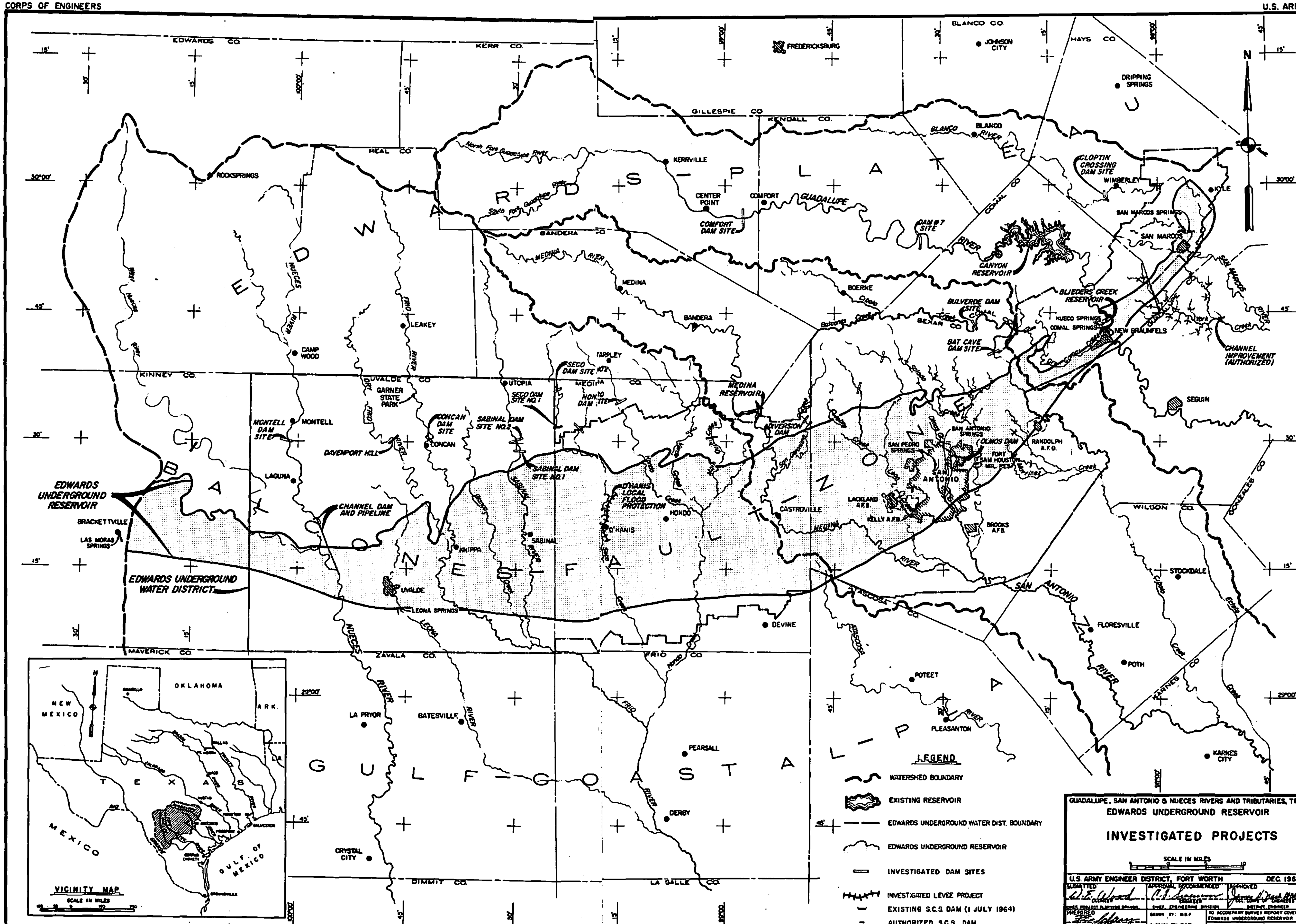
* The annual resources, recharge a[illegible] runoff (exclusive of springflow) at the lower edge of the Edwards outcrop are averages for the period 1935-56.
** The drainage area at lower edge [illegible] the Edwards outcrop, as indicated on plates 2 and 3, appendix II.
*** Location of dam sites shown on p[illegible]te 3.
**** Increase in recharge creditable [illegible] investigated reservoir project as shown on plate 3 and in table 7.
(1) Reduced by estimated net inflow [illegible] 49,900 ac-ft/yr to Cloptin Crossing Reservoir.
(2) Reduced by estimated net inflow [illegible] 171,900 ac-ft/yr to Dam No. 7 - Canyon Reservoir system.
(3) Using 16 SCS structures on Salad[illegible] Creek (1962 Work Plan).
(4) Based on extrapolation of data by John J. Vandertulip, "Surface Runoff That Passes the Lower Edge of the Edwards Limestone Outcrop Between the Nueces River and the Blanco River." (No release f[illegible] irrigation)
(5) Does not include approximately 4[illegible]200 ac-ft/yr combined loss to evaporation and use for irrigation.
(6) Assuming no use for irrigation. [illegible]oes not include approximately 13,000 ac-ft/yr loss to evaporation.
(7) Does not include 4,300 ac-ft/yr [illegible] mgd) to be delivered to downstream areas.

TABLE 7

PRELIMINARY RESERVOIR JUSTIFICATION

Stream	Site	Storage in 1,000 acre-feet: 50-year F.C.	Storage: W.C.	Storage: Sed.	Storage: Total	Dependable yield 1,000 acre-feet per year	Increased resources for recharge ac-ft/yr	First Cost $1,000	Annual charges $1,000	Benefits - $1,000: F.C.	Benefits: W.C.(2)	Benefits: Total	B/C ratio
Interest rate: 3-1/8% - Amortization: 100 years.													
West Nueces River	-	239.0(1)	-	12.0	251.0	-	10,600	32,000	1,175.0	450.5	481.5	932.0	0.79
Nueces River	Montell	239.3(1)	1.0	12.0	252.3	4.3	26,600	30,916	1,149.4	453.5	1,118.8(3)	1,572.3	1.4
Dry Frio River	Davenport Hill	52.6(1)	-	2.9	55.5	-	8,300	12,000	443.0	20.0	300.0	320.0	0.72
Frio River	Concan	141.2(1)	-	7.8	149.0	-	21,500	14,255	546.2	58.4	816.8	875.2	1.6
Sabinal River	Sabinal #1	89.1(1)	-	4.2	93.3	-	15,800	12,799	483.3	45.5	600.1	645.6	1.3
	Sabinal #2	77.18(1)	-	4.12	81.3	-	15,500	14,123	524.1	44.6	588.7	633.3	1.2
Seco Creek	Seco #1	22.9(1)	-	1.9	24.8	-	2,200	7,162	270.0	70.0	96.3	166.3	0.62
	Seco #2	15.0(1)	-	1.3	16.3	-	1,300	7,442	279.7	42.5	58.4	100.9	0.36
Hondo Creek	Hondo	33.8(1)	-	2.7	36.5	-	3,900	8,396	316.0	21.5	160.5	182.0	0.58
Cibolo Creek	Bat Cave	17.0(1)	-	3.0	20.0	-	4,400	10,813	396.0	-	192.6	192.6	0.49
Guadalupe River	Comfort	163.7	446.6	12.8	623.1	26.8	-	49,048	1,832.1	38.3	2,061.0	2,099.3	1.1
	Dam No. 7	-	640.5	17.5	658.0	46.4	-	38,169	1,409.0	-	1,617.0	1,617.0	1.1
Blanco River	Cloptin Crossing	104.8	274.8	9.2	388.8	44.2	-	19,180	732.6	613.3	653.0	1,266.3	1.7

(1) Used as joint flood control and water conservation storage with all releases for recharge of the Edwards Underground Reservoir.
(2) Water conservation benefits for recharge computed on basis of 13.6¢ per 1000 gallons of increased resources. For conventional water supply storage water conservation benefits were based on cost of cheapest alternative source to supply the same dependable yield.
(3) Consists of $1,010,500 benefits for recharge and $108,300 benefits for downstream water supply.


GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
INVESTIGATED PROJECTS
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC. 1964
SUBMITTED
APPROVAL RECOMMENDED
APPROVED
PREPARED
FILE: GUAD. 707-2
LEGEND
WATERSHED BOUNDARY
EXISTING RESERVOIR
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
INVESTIGATED DAM SITES
INVESTIGATED LEVEE PROJECT
EXISTING S.C.S. DAM (1 JULY 1964)
AUTHORIZED S.C.S. DAM
EDWARDS PLATEAU
BALCONES FAULT ZONE
GULF COASTAL PLAIN
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
CHANNEL DAM AND PIPELINE
CONCAN DAM SITE
SABINAL DAM SITE NO.2
SABINAL DAM SITE NO.1
SECO DAM SITE
SECO DAM SITE NO.1
HONDO DAM SITE
MONTELL DAM SITE
D'HANIS LOCAL FLOOD PROTECTION
MEDINA RESERVOIR
DIVERSION DAM
OLMOS DAM
BAT CAVE DAM SITE
BULVERDE DAM SITE
BLIEDERS CREEK RESERVOIR
CANYON RESERVOIR
DAM #7 SITE
COMFORT DAM SITE
CLOPTIN CROSSING DAM SITE
CHANNEL IMPROVEMENT (AUTHORIZED)
EDWARDS CO.
KERR CO.
REAL CO.
KINNEY CO.
UVALDE CO.
MEDINA CO.
BANDERA CO.
GILLESPIE CO.
KENDALL CO.
BLANCO CO.
HAYS CO.
COMAL CO.
BEXAR CO.
WILSON CO.
GONZALES CO.
KARNES CO.
ATASCOSA CO.
FRIO CO.
ZAVALA CO.
MAVERICK CO.
DIMMIT CO.
LA SALLE CO.
ROCKSPRINGS
KERRVILLE
CENTER POINT
COMFORT
FREDERICKSBURG
JOHNSON CITY
DRIPPING SPRINGS
BLANCO
WIMBERLEY
KYLE
SAN MARCOS SPRINGS
SAN MARCOS
BOERNE
MEDINA
BANDERA
TARPLEY
UTOPIA
LEAKEY
CAMP WOOD
GARNER STATE PARK
MONTELL
LAGUNA
DAVENPORT HILL
CONCAN
KNIPPA
SABINAL
D'HANIS
HONDO
CASTROVILLE
UVALDE
LEONA SPRINGS
BRACKETTVILLE
LAS MORAS SPRINGS
HUECO SPRINGS
COMAL SPRINGS
NEW BRAUNFELS
SEGUIN
SAN ANTONIO SPRINGS
SAN PEDRO SPRINGS
FORT SAM HOUSTON MIL. RES.
SAN ANTONIO
RANDOLPH A.F.B.
LACKLAND A.F.B.
KELLY A.F.B.
BROOKS A.F.B.
DEVINE
STOCKDALE
FLORESVILLE
POTH
POTEET
PLEASANTON
KARNES CITY
LA PRYOR
BATESVILLE
PEARSALL
DERBY
CRYSTAL CITY
GUADALUPE RIVER
BLANCO RIVER
MEDINA RIVER
NUECES RIVER
FRIO RIVER
SABINAL RIVER
LEONA RIVER
SAN ANTONIO RIVER
ATASCOSA RIVER
SAN MARCOS RIVER
North Fork Guadalupe River
South Fork Guadalupe River
West Nueces River
VICINITY MAP
NEW MEXICO
OKLAHOMA
ARK.
LA
TEXAS
MEXICO
GULF OF MEXICO
SCALE IN MILES

SELECTION OF THE PLAN

47. GENERAL.- On the basis of the foregoing preliminary studies the only projects that warranted more detailed studies are Montell, Sabinal (No. 1), Concan, Cloptin Crossing and Dam No. 7 Reservoirs. It was found that the other investigated projects would not develop sufficient benefits to justify their construction at this time or in the foreseeable future. The following paragraphs describe the methods used in the economic analysis of the five projects found worthy of more detailed study. They will describe the methods used to compute benefits for the three recharge reservoirs, Montell, Concan, and Sabinal, based on the joint-storage plan (flood-control and recharge) and the benefits for the projects in the Guadalupe River Basin for flood control, conventional water supply, recreation, and fish and wildlife. A summary of criteria for determination of project costs is also presented. In addition to the benefit and cost data, results of the maximization of excess benefits studies and results of studies to determine the final selection of projects for the plan of improvement are presented in the following paragraphs.

48. BENEFITS FOR RECHARGE.- From the preliminary studies it was determined that the most favorable plan of operation for the recharge reservoirs involved release of all inflows after each rain to enable the development of maximum water resources at the dam sites with a minimum loss of the resources to evaporation. The only permanent storage that would be maintained in the three recharge reservoirs under consideration, Montell, Concan, and Sabinal, would be in the Montell Reservoir. In this project 2,200 acre-feet of permanent storage would be maintained to provide a firm yield of 4,300 ac.ft./yr. for a downstream water supply. The 2,200 acre-feet would consist of 1,000 acre-feet of conservation storage and 1,200 acre-feet of sediment reserve.

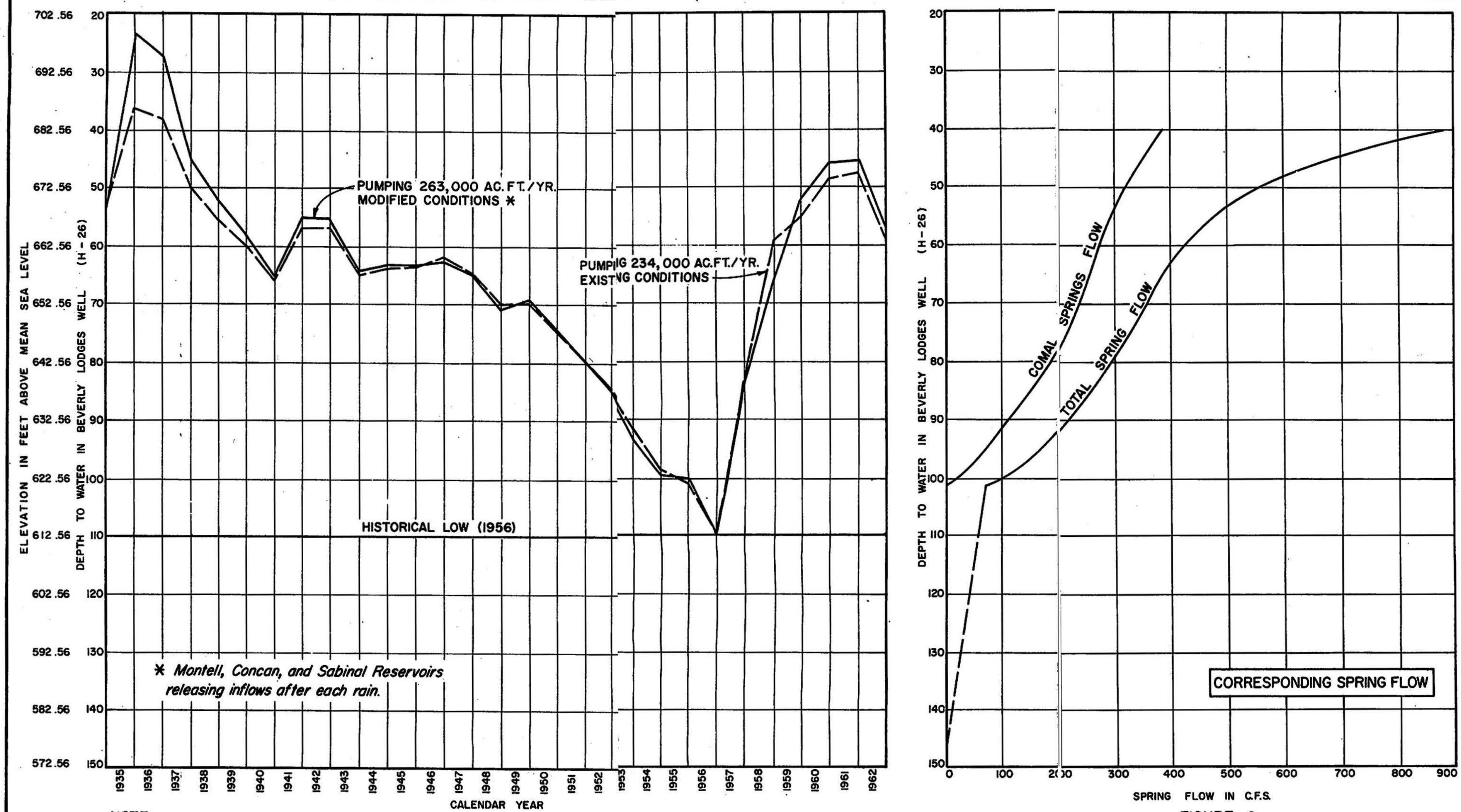
49. To evaluate the effect of the recharge reservoirs on the yield of the underground reservoir, hydrologic routings through the aquifer were made of water resources developed by the surface projects. Because of the severe water shortage in the Edwards Reservoir area, surface reservoir project sizes were used which would develop maximum or near maximum water resources at the site and would control the flood of record. Hydrologic studies determined that reservoirs containing 50-year joint-storage for flood control and recharge would contain the flood of record with no reservoir spills at Concan and Sabinal Reservoirs. The 50-year joint-storage would control the flood of record at Montell Reservoir with discharges during passage of this flood of about 4,800 second-feet from the reservoir, a nondamaging rate in the channel of the Nueces River. The flood of record on the Nueces River has a frequency of approximately once in 57 years. Resources that could be developed by projects at the three sites containing the 50-year joint storage were determined and used for routings through

the underground reservoir. This storage would develop a net increase in resources available for recharge of 26,600 ac.ft./yr. at Montell Reservoir, 21,500 ac.ft./yr. at Concan Reservoir, and 15,800 ac.ft./yr. at Sabinal Reservoir.

50. Routings through the aquifer were made under existing and modified recharge conditions. The entire period of routing extended from 1935 through 1962, but the portion of this routing used to evaluate the effect of the recharge projects was limited to the period 1935-1956. This period represents a cycle from a period of high runoff through a period of critical drought. A minimum control elevation of 612 feet msl of the water surface of the underground reservoir at San Antonio was used in the evaluation of all recharge plans.

51. Because of the nature of the underground reservoir, the yield is realized through discharges from both wells and springs. The major springs along the southern limits of the Balcones escarpment are natural outlets for the Edwards Reservoir and are uncontrolled. Flow from these springs, however, is dependent on water levels in the underground reservoir. For the period of analysis, 1935-1956, the average annual recharge would be increased by the Montell, Concan, and Sabinal Reservoirs by 63,900 ac.ft./yr., from 423,200 to 487,100 ac.ft./yr. From the routings, as graphically shown in figure 6, the safe yield for pumping may be increased from 234,000 ac.ft./yr. under existing recharge conditions to 263,000 ac.ft./yr. The remainder of the increased recharge, 34,900 ac.ft./yr. would be discharged from the aquifer principally through the major springs. Approximately 4,000 acre-feet per year of this additional springflow would be discharged from Leona Springs in the Nueces River Basin, 13,300 ac.ft./yr. from San Antonio and San Pedro Springs in the San Antonio River Basin, and 17,600 ac.ft./yr. from Hueco, Comal, and San Marcos Springs in the Guadalupe River Basin.

52. As described in its report, attached to this appendix, the Public Health Service evaluated both the quantity of water available for pumping and the increased springflow. Based on the evaluations, it was determined that the most reasonable alternative project for the recharge reservoirs was Cuero Reservoir on the Guadalupe River. The recharge benefits were evaluated as being equal to the cost of delivered water from the alternative source, taking into account the differential costs of pumping and treatment. Credit was taken only for the increase in pumping and springflow attributable to the recharge projects. The computed values, or unit benefits, for the additional water available for pumping and the additional springflow are as follows:



NOTE:
For Hydrologic Routing above EL. 682, Springflow Curves were extended.

FIGURE 6
EFFECTS OF CONSTANT PUMPAGE ON WATER LEVELS IN THE EDWARDS UNDERGROUND RESERVOIR
MONTELL, CONCAN, & SABINAL RESERVOIRS IN OPERATION

	Unit benefit
a. Increase in yield available for pumping, ¢/1,000 gallons	13.6
b. Increase in springflow, ¢/1,000 gallons:	
(1) Leona Springs	2.0
(2) San Antonio and San Pedro Springs	16.0
(3) Hueco, Comal, and San Marcos Springs	7.3
c. Electrical energy saved due to reduced pumping head, $/kilowatt-hour	.006

The method of computing the unit benefits is described in the Public Health Service report. The benefits thus determined were prorated to the three recharge reservoirs according to the project's individual contribution to the total increase in average annual recharge.

53. For maximization studies to determine the most economical project size, estimates of costs and benefits were made on a smaller size project at each of the recharge reservoir sites to control a flood of 35-year frequency and a larger size project to control a flood of 75-year frequency. The recharge benefits were computed based on the resources developed by these storages.

54. BENEFITS FOR CONVENTIONAL WATER SUPPLY.- Preliminary investigations and studies indicate that construction of three reservoirs to provide conservation storage for purposes other than recharge could be justified. The projects are Montell, Cloptin Crossing and Dam No. 7. The Public Health Service has determined, after investigation of various possibilities, that single-purpose water supply reservoirs at the three sites would be the most reasonable alternatives to the three projects under consideration. The yield of the single-purpose projects would be the same as the yield from conservation storage to be provided for municipal and industrial water supply purposes in the projects under consideration. The estimated cost of the alternative projects was based on non-Federal financing and interest rates for publicly-owned projects.

55. BENEFITS FOR REDUCTION IN FLOOD DAMAGES.- The average annual benefits for flood damage reduction accruing to the various projects were determined by use of discharge-damage and discharge-frequency relationships. The flood-control benefits assigned to each investigated project were based on the reduction of average annual damages in the flood-plain area downstream from the project. Flood-control benefits were computed for each investigated project for a range of flood

frequencies including 35-year, 50-year, 75-year and, in some instances, 10-year and 100-year frequencies. Studies made in connection with the determination of flood-control benefits for Cloptin Crossing Reservoir on the Blanco River assumed Cuero Reservoir (stage II) to be an existing project. Under this condition, flood-control storages in Cloptin Crossing of 50-year frequency or less provided benefits only to the area between Cloptin Crossing and Cuero Reservoirs; however, for flood-control storages in excess of 50-year frequency, benefits could be claimed for additional protection afforded to areas below Cuero Reservoir. In addition, the provision of flood-control storage in Cloptin Crossing Reservoir would result in a reduction in flood-control storage requirements in Cuero Reservoir. Therefore, the benefits resulting from this reduction were credited to Cloptin Crossing Reservoir. The benefits creditable to the projects for reduction in flood damages have been increased by an allowance to reflect the economic trends and future development anticipated in the flood plain during the period 1975 to 2075. Benefits which would be expected to accrue from the recommended projects have been estimated on the basis of a useful project life of 100 years. Those benefits which are expected to accrue from future flood-plain development have been reduced to an average annual equivalent value by compound interest methods. Determination of the average annual damages and benefits creditable to the investigated projects are fully described in Appendix IV, Flood Control Economics.

56. BENEFITS FOR RECREATION.- The general recreation and fish and wildlife benefits assigned to the projects investigated were based on the average annual visitation expected at each reservoir. Recreation visitations were apportioned to fish and wildlife recreation and to general recreation on a 35-65 percentage basis, respectively. The fish and wildlife recreation visitation was estimated to consist of 1.0 percent hunters and 99.0 percent fishermen. Benefits for every type of recreation were based on an initial value of $0.50 per visitor day. For the number of visitors estimated to participate in hunting and fishing an additional unit value of $1.00 per hunter and $0.50 per fisherman was applied. A discussion of the recreation potential of projects investigated in the Edwards Reservoir area and a determination of recreation benefits creditable to the projects are presented in Appendix VI, Recreation and Fish and Wildlife.

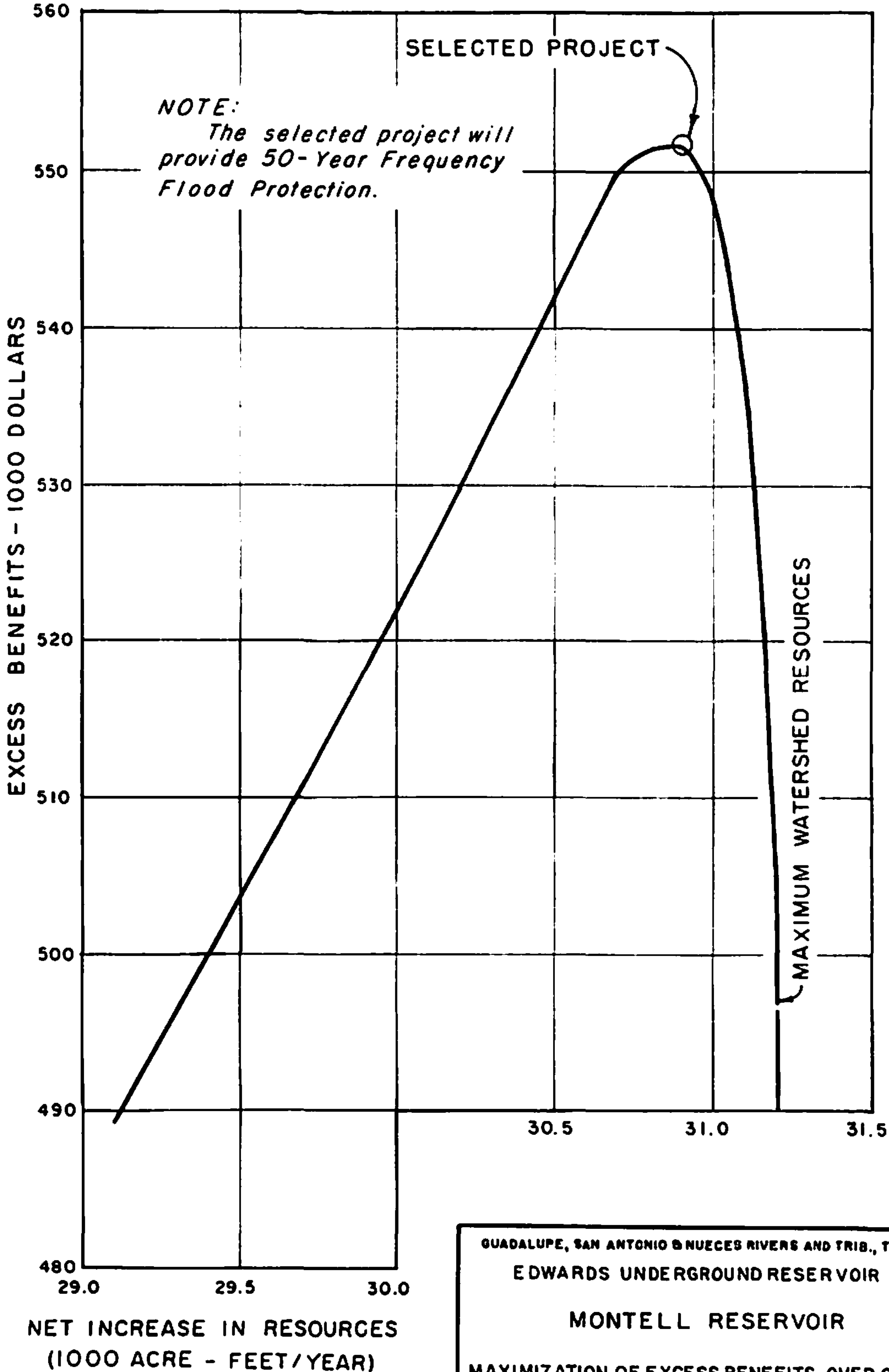
57. COSTS.- The estimates of first cost include all initial expenditures for physical construction of the project, lands and damages, relocations, reservoir clearing, engineering and design, and supervision and administration. The annual charges for the projects include interest and amortization of investments at an interest rate of 3-1/8 percent for a 100-year period of amortization, operation and maintenance costs and annual equivalent costs of major replacements. The first costs and annual charges were based on July 1964 price levels.

58. INDIVIDUAL PROJECT STUDIES.- With the probable elements of the plan of improvement having been selected on the basis of the preliminary studies, further analysis of each of these projects was made to determine its most economical size, the purposes to be included, and the justification of each increment. The basis of these studies were cost-capacity curves determined from preliminary design and cost estimates for various size projects covering the probable range in storage at each site. Also, benefit-capacity curves for flood control and water supply were determined for the same range in storage covered by the cost-capacity curves. The benefits for flood control and water supply were computed for the various sizes as discussed in paragraphs 48 to 55. By use of these curves the flood-control and water supply storages that would return the maximum excess benefits for each project were determined. The following paragraphs a and b discuss the studies undertaken for each project under more detailed consideration.

a. Recharge projects.- It has been determined that the most economical method of operation, with respect to water resources, of this type project is to release the water to the underground reservoir as rapidly as possible immediately following each rain. The storage space in a reservoir operated in this manner serves both the flood-control and water supply purposes jointly. The projects under study for recharge of the Edwards Underground Reservoir include Montell, Concan, and Sabinal Reservoirs. The benefit-capacity curves used in the project maximization studies of these reservoirs include the combined benefits for flood control and water supply.

(1) Montell Reservoir.- As previously determined, Montell Reservoir should contain sufficient storage to develop a dependable yield of 4,300 acre-feet per year for downstream use. The remaining storage space would be for joint use for flood control and recharge purposes. The principal benefits that can be realized by the construction of this project are from increasing the available water resources and from the reduction in flood damages downstream. The maximization studies indicated that a reservoir of sufficient size to increase the net resources by about 30,900 acre-feet would return the maximum excess benefits, as shown in figure 7. This size project would provide a net increase of 26,600 acre-feet annually to the Edwards Underground Reservoir and a dependable yield of 4,300 acre-feet for downstream use.

(a) The joint use of storage space in this reservoir is sufficient to control a flood of 50-year frequency at this site and to withhold releases for two days. The maximum watershed resources that could be developed would yield 31,200 acre-feet. To extend the project to this size would result in a reduction in excess benefits of about $54,000 or 9.8 percent. Extending the project is not considered warranted because of the loss in excess



GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIB., TEXAS

EDWARDS UNDERGROUND RESERVOIR

MONTELL RESERVOIR

MAXIMIZATION OF EXCESS BENEFITS OVER COSTS

MULTIPLE PURPOSE STORAGE FOR FLOOD CONTROL, RECHARGE AND OTHER WATER CONSERVATION PURPOSES benefits for such a small increase in yield. The reservoir of the selected size would have a total controlled storage of 252,300 acre-feet, of which 12,000 acre-feet would be for 100-year sediment accumulation, 1,000 acre-feet for dependable yield, and 239,300 acre-feet for joint use for flood-control and recharge purposes.

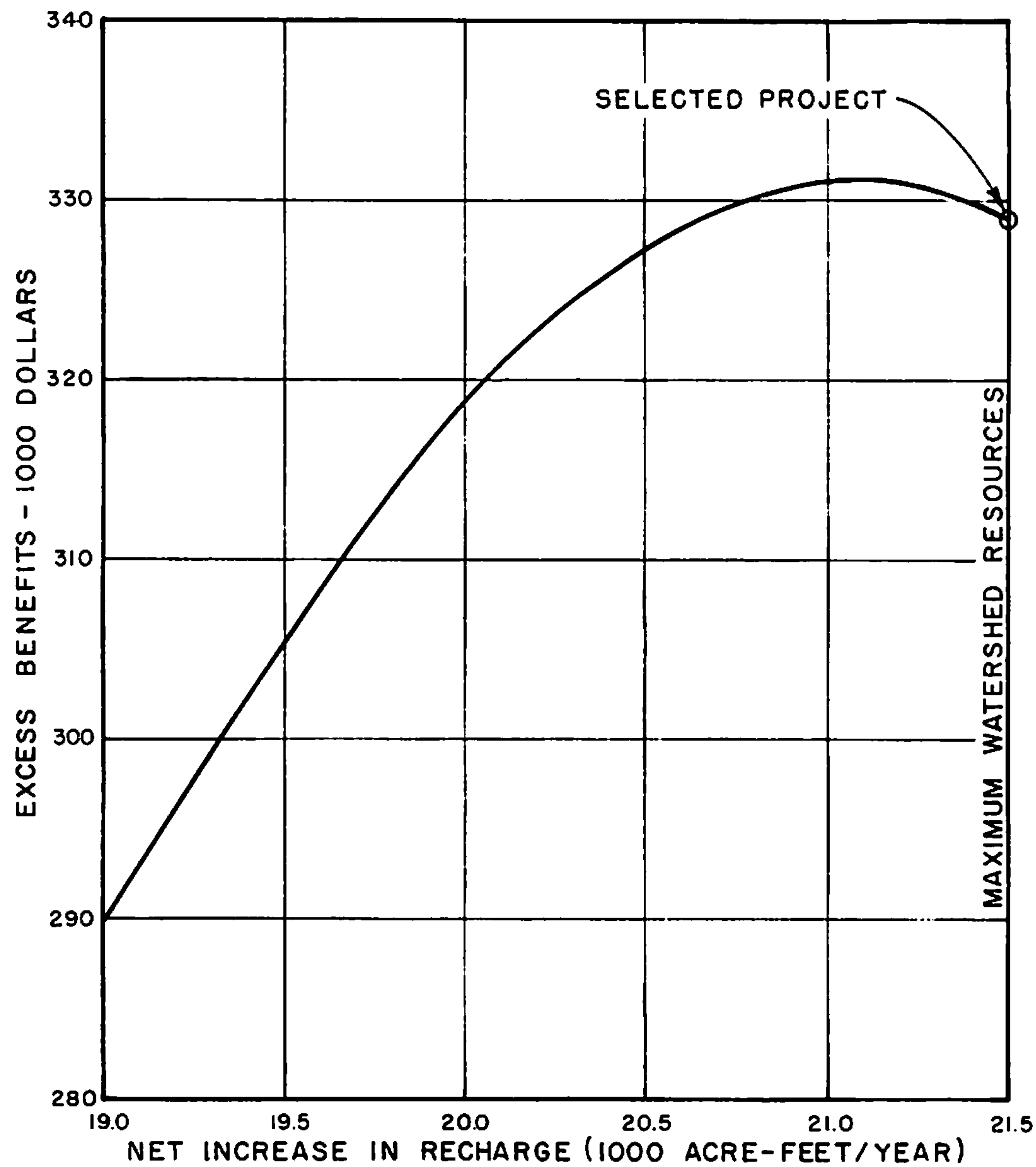
(b) In addition to the flood-control and water supply features sufficient facilities would be added to develop the recreational potentialities of the project. Paragraph 66 and appendix VI discuss the recreational aspects of the project. Also, the addition of the channel dam and pipeline for water supply to downstream areas is included as a project feature as discussed in paragraph 63.

(2) Concan Reservoir.- The principal benefits that can be realized by the construction of this reservoir are from increasing the water recharge to the Edwards Underground Reservoir. Under the method of operation of this type reservoir, benefits for flood prevention will also be realized; however, in this area they would be relatively small. The maximization studies involving the joint-storage operation indicated that a reservoir of sufficient size to increase the net recharge by about 21,100 acre-feet would return the maximum excess benefits, as shown in figure 8. This size project would also be adequate to control the flood of record at this site. The total increase in watershed resources that could be realized at this site is about 21,500 acre-feet. To extend the project to realize the full watershed resources would reduce the excess benefits by only $2,000, or a reduction of 0.6 percent of the maximum excess benefits of $331,000. Since the reduction in excess benefits would be insignificant, it is considered that extension of the project to develop the yield of 21,500 acre-feet would be in the best interest of developing the basin resources to the fullest.

(a) The proposed project will control floods of 50-year frequency at the site. The reservoir would have a total controlled storage of 149,000 acre-feet, of which 7,800 acre-feet would be for 100-year sediment accumulation and 141,200 acre-feet for joint use for flood-control and recharge purposes. Sufficient storage is included to withhold releases for two days.

(b) In addition to the flood control and water recharge features of the project, sufficient facilities would be added to develop the recreational potentialities of the project. Paragraph 70 and appendix VI discuss the recreational aspects of this project.

(3) Sabinal Reservoir.- Like Concan Reservoir, the principal benefits that can be realized by the construction of



NOTE:
The selected project will provide 50-Year Frequency Flood Protection.

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIB., TEXAS
EDWARDS UNDERGROUND RESERVOIR

CONCAN RESERVOIR

MAXIMIZATION OF EXCESS BENEFITS OVER COSTS

JOINT STORAGE FOR FLOOD CONTROL AND RECHARGE PURPOSES

FIGURE 8

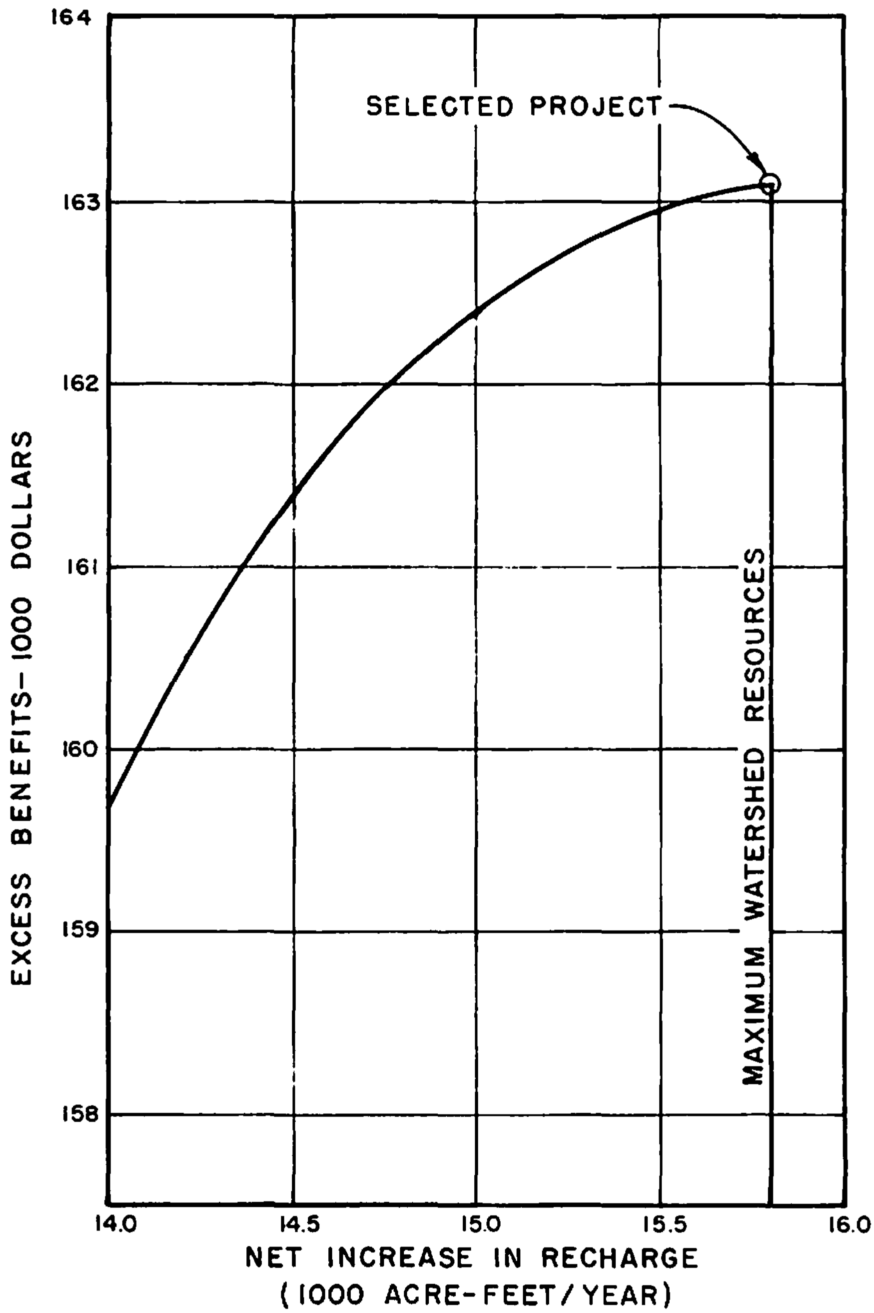
Sabinal Reservoir are from increasing the water recharge to the Edwards Underground Reservoir. The flood control benefits that can be realized from the joint operation of the storage space are relatively small. The maximization studies involving the joint-storage operation indicate that a reservoir of sufficient size to increase the net recharge by about 15,800 acre-feet, the full watershed resources at this site, would return the maximum excess benefits, as shown in figure 9.

(a) The proposed project would control the hypothetical 50-year flood. The reservoir would have a total storage capacity of 93,300 acre-feet, of which 4,200 acre-feet would be for 100-year sediment accumulation and 89,100 acre-feet would be for joint use for flood control and recharge purposes. Sufficient storage is included to permit withholding releases for two days.

(b) In addition to the flood control and recharge features, sufficient facilities would be added to develop the recreational potentialities of the project. Paragraph 74 and appendix VI discuss the recreational aspects of the project.

b. <u>Conventional surface storage reservoirs</u>.- Since the Blanco and Guadalupe Rivers are not major contributors to the Edwards Underground Reservoir, the projects at the Cloptin Crossing and Dam No. 7 sites were investigated as conventional surface storage reservoirs for water supply and flood control purposes.

(1) <u>Cloptin Crossing Reservoir</u>.- It was determined that a reservoir at the Cloptin Crossing site would be very effective in reducing flood damages along the Blanco River, particularly in the San Marcos area. In determining the flood-control benefits for this project it was assumed that the proposed Cuero Reservoir was in operation. The benefits to water supply and flood control that would be creditable to this project are about equal. By means of the cost-capacity and benefit-capacity curves for this project it was determined that the maximum excess benefits will be realized from a project having a total storage of 305,000 acre-feet (see figure 10), of which 180,300 acre-feet would be for water supply; 115,000 acre-feet for flood control; and the remainder for sediment accumulation. This water supply storage will develop a dependable yield of 36,200 acre-feet per year, and the flood control storage will control a flood of 75-year frequency, which is greater than the flood of record. The total watershed resources that could be developed would yield 42,700 acre-feet per year. It is considered in the best interest of the area to extend the project to develop the full watershed resources. In doing so, the maximum excess benefits would be reduced about $34,600 or by 5.8 percent, which is relatively insignificant.



NOTE:
The selected project will provide 50- Year Frequency Flood Protection.

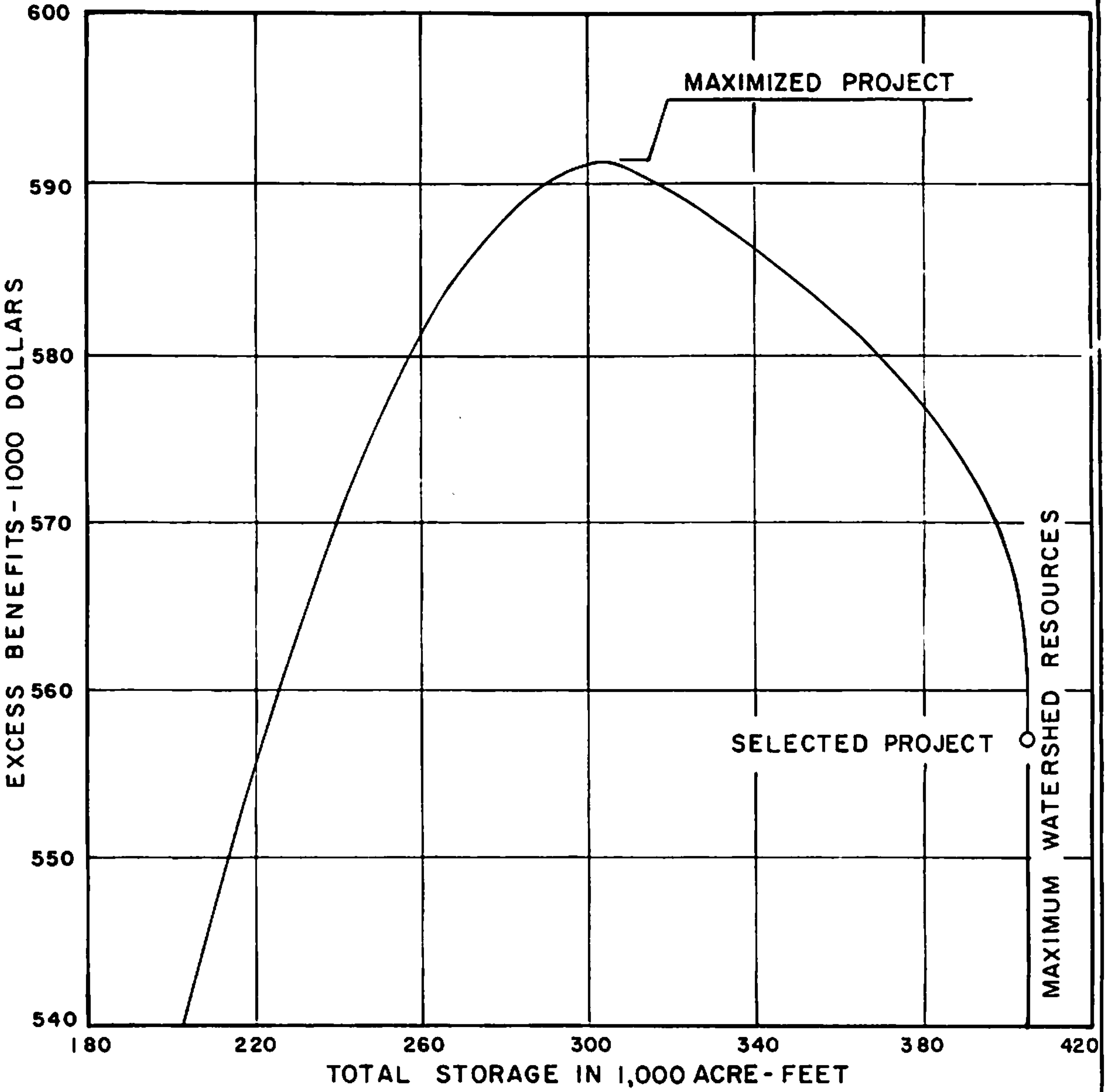
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIB., TEXAS
EDWARDS UNDERGROUND RESERVOIR

SABINAL RESERVOIR

MAXIMIZATION OF EXCESS BENEFITS OVER COSTS

JOINT STORAGE FOR FLOOD CONTROL AND RECHARGE PURPOSES

FIGURE 9



NOTE: - THE MAXIMIZED STORAGE TOTALS 305,000 Ac.-Ft. As Follows:
115,000 Ac.-Ft., F.C.
180,800 Ac.-Ft., W.C.
9,200 Ac.-Ft., Sed.
YIELD = 36,200 Ac.-Ft.

THE SELECTED PROJECT
TOTAL 404,000 Ac.-Ft.
119,900 Ac.-Ft., F.C.
274,900 Ac.-Ft., W.C.
9,200 Ac.-Ft., Sed.
YIELD = 42,700 Ac.Ft.

NOTE:
The selected project will provide 75-Year Frequency Flood Protection.

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIB., TEXAS
EDWARDS UNDERGROUND RESERVOIR

CLOPTIN CROSSING RESERVOIR

MAXIMIZATION OF EXCESS BENEFITS OVER COSTS
DUAL PURPOSE STORAGE FOR WATER CONSERVATION AND FLOOD CONTROL

FIGURE 10

(a) The proposed reservoir would have a total storage of 404,000 acre-feet, of which 274,900 acre-feet would be for water conservation; 119,900 acre-feet for flood control; and 9,200 acre-feet for 100-year sediment accumulation.

(b) In addition to the flood control and water conservation features of the reservoir, sufficient facilities would be added to develop the recreational potentialities of the project. Paragraph 78 and appendix VI discuss the recreational aspects of the project.

(2) Dam No. 7 Reservoir.- Because of the severe water shortage indicated for the future in the Edwards Reservoir area, a project at the Dam No. 7 site was investigated to develop to the fullest extent feasible the water resources of the Guadalupe River upstream from Canyon Reservoir. Since provision of flood-control storage in the Dam No. 7 project could not be justified and the project is proposed for local interest development, no maximization studies were made on this reservoir project.

59. ECONOMIC JUSTIFICATION.- Tests were made to determine that each project purpose or joint-purpose of the investigated reservoir projects was incrementally justified, or that the benefits afforded by the added purpose exceeded the incremental annual costs of adding that purpose. The results of these tests are presented in table 8. Tests were also made to assure that the reservoir projects were justified as a unit or element in the plan as a last added project. Final justification analysis was made on the basis of assigning fair share benefits to the individual projects. The results of the last added and fair share benefit tests are shown in the following tabulation:

LAST ADDED AND FAIR SHARE BENEFITS

(In thousand dollars)

Reservoir project	Annual charges	Last added benefits	B/C	Fair share benefits	B/C
Montell	1,237.5	1,804.9	1.5	1,802.4	1.5
Concan	599.5	889.8	1.5	889.6	1.5
Sabinal	440.6	661.4	1.5	659.9	1.5
Cloptin Crossing	1,035.7	2,597.8	2.5	2,597.8	2.5

Table 9 shows a summary of the justification of all elements of the plan recommended for authorization in this report.

TABLE 8

INCREMENTAL JUSTIFICATION

(In thousand dollars)

Item	Annual benefits	Annual charges	B/C
MONTELL RESERVOIR			
Water conservation only	88.3	97.2	0.91
Joint-use flood control-recharge added	1,612.6	1,114.3	1.4
Triple-purpose W.C. and F.C.-recharge	1,700.9	1,211.5	1.4
Recreation added	101.5	26.0	3.9
Multiple-purpose W.C., F.C.-recharge, and recreation	1,802.4	1,237.5	1.5
Joint-use flood control-recharge	1,612.6	1,165.5	1.4
Water conservation added	88.3	46.0	1.9
Triple-purpose F.C.-recharge and W.C.	1,700.9	1,211.5	1.4
Recreation added	101.5	26.0	3.9
Multiple-purpose F.C.-recharge, W.C., Recreation	1,802.4	1,237.5	1.5
CONCAN RESERVOIR			
Joint-use project F.C.-recharge	876.1	592.2	1.5
Recreation added	13.5	7.3	1.8
Multiple-purpose F.C.-recharge and recreation	889.6	599.5	1.5
SABINAL RESERVOIR			
Joint-use project F.C.-recharge	646.4	433.3	1.5
Recreation added	13.5	7.3	1.8
Multiple-purpose F.C.-recharge and recreation	659.9	440.6	1.5
CLOPTIN CROSSING RESERVOIR			
Flood control only	659.0	504.8	1.3
Water conservation added	653.0	318.8	2.0
Dual-purpose F.C. and W.C.	1,312.0	823.6	1.6
Water conservation only	653.0	645.0	1.0
Flood control added	659.0	178.6	3.7
Dual-purpose W.C. and F.C.	1,312.0	823.6	1.6
Recreation added	1,285.8	212.1	6.1
Multiple-purpose W.C., F.C., and recreation	2,597.8	1,035.7	2.5

TABLE 9

FIRST COSTS, ANNUAL CHARGES, ANNUAL BENEFITS, AND BENEFIT-COST RATIO
PROPOSED PROJECTS
EDWARDS UNDERGROUND RESERVOIR AREA
(July 1964 price level)
(Interest rate 3-1/8% - Amortization, 100 years)
(In thousand dollars)

	Montell	Concan	Sabinal	Cloptin Crossing	Totals
FIRST COSTS	32,545.0(1)	15,650.0	11,413.0	24,440.0	84,048.0
ANNUAL CHARGES	1,237.5(2)	599.5	440.6	1,035.7	3,313.3
ANNUAL BENEFITS	1,802.4	889.6	659.9	2,597.8	5,949.7
Flood control	(602.1)	(59.3)	(46.3)	(659.0)	(1,366.7)
Water supply	(1,098.8)	(816.8)	(600.1)	(653.0)	(3,168.7)
Recreation	(101.5)	(13.5)	(13.5)	(1,285.8)	(1,414.3)
BENEFIT-COST RATIO	1.5	1.5	1.5	2.5	1.8

(1) Includes $900,000 estimated first cost of channel dam and pipeline.

(2) Includes $46,000 for annual charges for channel dam and pipeline.

PROPOSED PROJECTS

60. GENERAL.- To provide controlled recharge storage for the underground reservoir and additional water supply facilities for all useful purposes for the people of the Edwards Reservoir area, and to provide flood protection to the downstream areas of the Guadalupe and Nueces River Basins, the following plan of development is proposed:

a. For authorization and construction by the Federal Government.-

(1) Montell Reservoir, including a channel dam and pipeline in lieu of Tom Nunn Hill Reservoir, on the Nueces River for flood control, recharge, additional water supply for downstream areas of the Nueces River Basin, and for recreation and fish and wildlife purposes.

(2) Concan Reservoir on the Frio River for flood control, recharge and recreation.

(3) Sabinal Reservoir on the Sabinal River for flood control, recharge and recreation.

(4) Cloptin Crossing Reservoir on the Blanco River for flood control, water conservation, and for recreation and fish and wildlife purposes.

b. For construction by local interests.- Dam No. 7 Reservoir on the Guadalupe River for water conservation.

61. The following paragraphs describe in more detail elements of the proposed plan. The general location of the projects is shown on plate 4. Pertinent data concerning the earth and rock-fill embankments, outlet works, spillways, reservoir storages, land requirements, relocations, and design floods for the projects recommended for authorization and construction by the Federal Government are presented in table 10.

62. MONTELL RESERVOIR.- The proposed Montell Dam would be constructed at river mile 401.6 on the Nueces River, about 20 miles northwest of Uvalde. The structure would consist of an earth and rock-fill dam with an outlet works and an uncontrolled spillway. The reservoir would have a total controlled storage of 252,300 acre-feet, consisting of 239,300 acre-feet of joint-storage for 50-year flood control and recharge, 1,000 acre-feet of conservation storage for water supply, and 12,000 acre-feet of storage for sediment reserve. A small permanent pool of 2,200 acre-feet, consisting of 1,000 acre-feet of conservation storage and 1,200 acre-feet of sediment reserve, would be maintained to provide a dependable yield of 4,300 acre-feet per year (4 million gallons per day). Water in the permanent pool would be confined mostly within the channel of the Nueces River. The joint-storage provided in

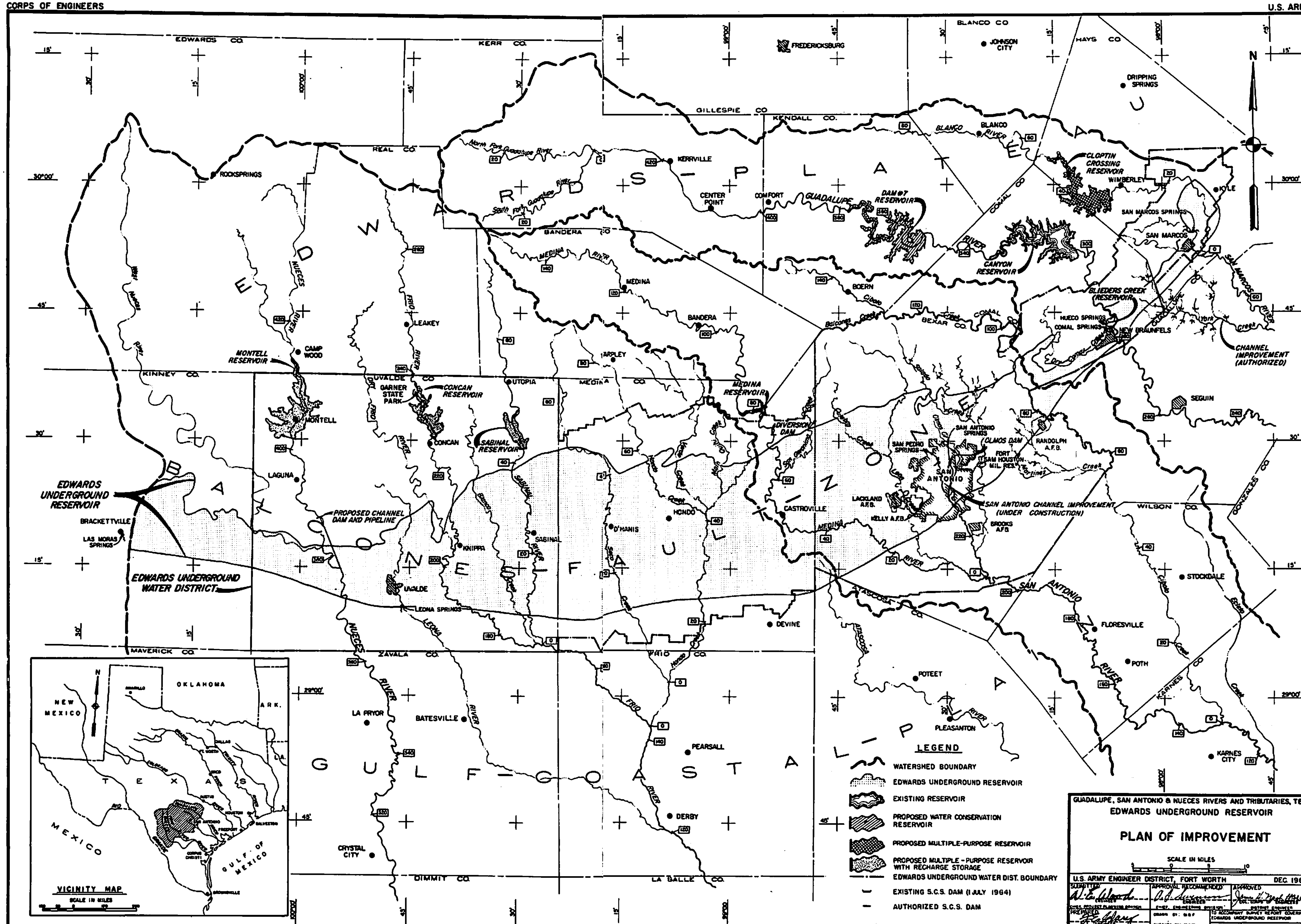
the project would increase the average annual recharge to the underground reservoir by about 26,600 acre-feet.

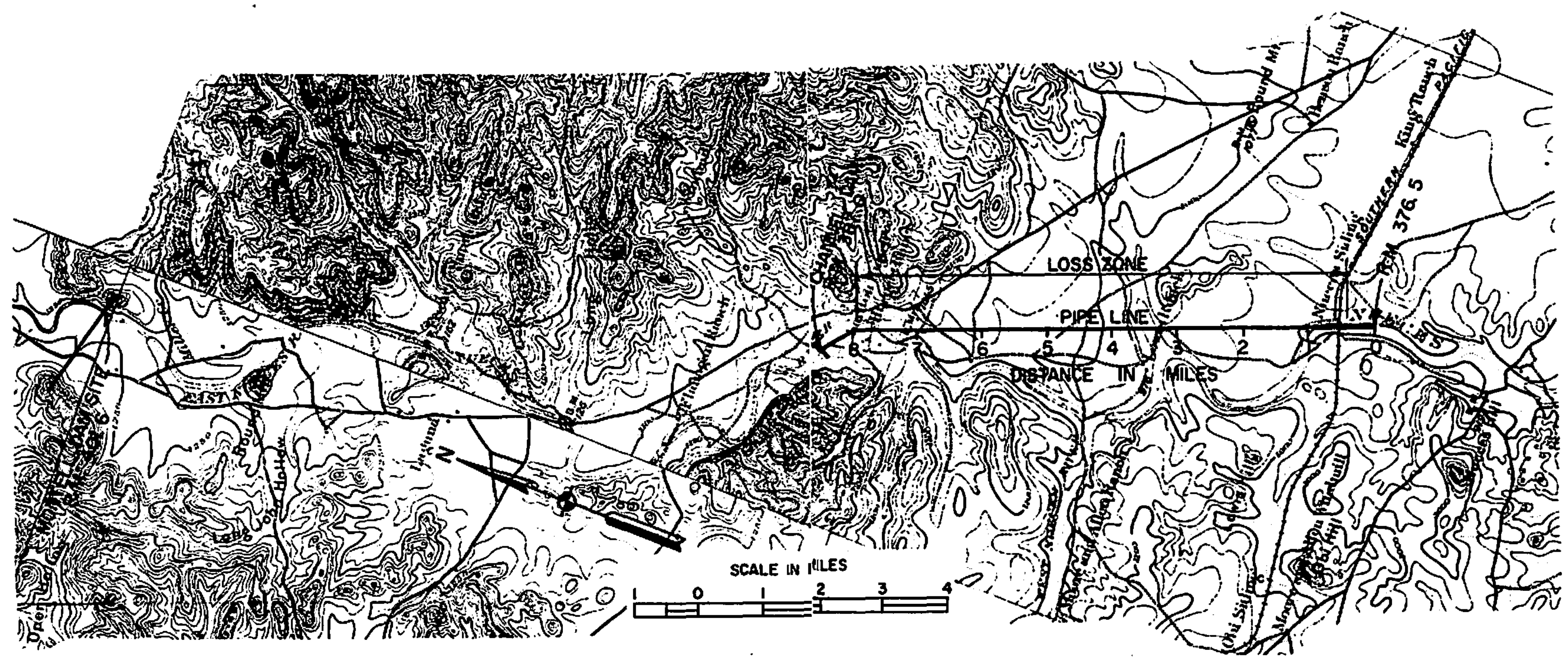
63. In addition to the Montell Dam and Reservoir, a low channel dam would be constructed at about river mile 387, about 14 miles downstream from the reservoir. From the channel dam a gate-controlled 24-inch pipeline would be constructed to extend downstream across the "loss zone" on the Nueces River, a distance of about 8.5 miles to the vicinity of Tom Nunn Hill, about river mile 376.5. The pipeline would transport 4,300 acre-feet per year (4 mgd) by gravity flow to the area.

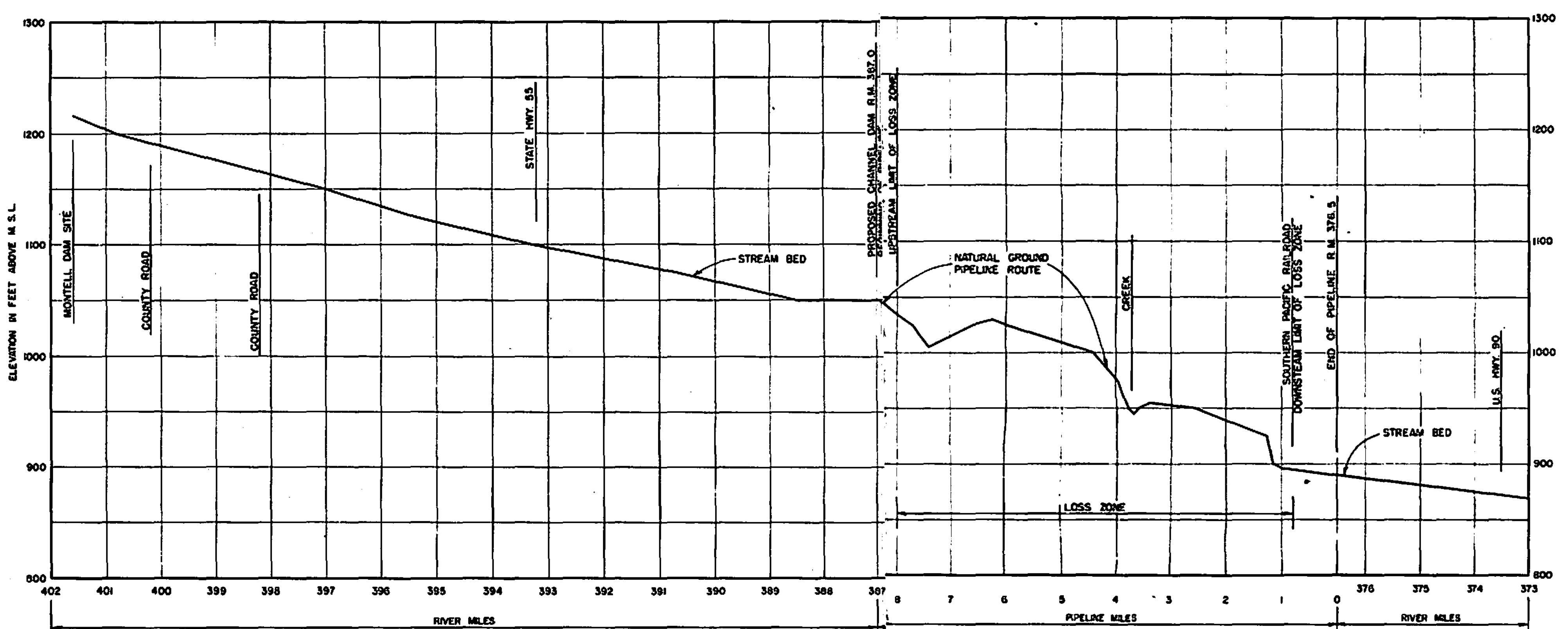
64. The 1,000 acre-feet of conservation storage in Montell Reservoir along with the channel dam and pipeline facilities would provide the equivalent dependable yield of the Tom Nunn Hill Reservoir, a project proposed in the master plan of the Nueces River Conservation and Reclamation District. The proposed Montell Dam would be constructed upstream of the major zone of faulting in the Balcones fault system. Foundation conditions at the site are structurally satisfactory for the proposed project. The Glen Rose formation is exposed in the valley walls and is bedrock in the valley. No appreciable stream losses have been reported upstream from the site; however, several small faults or fracture zones exist in the reservoir area and some minor leakage is anticipated. Although five minor faults have been mapped in the reservoir area, none of these faults cross the dam site.

65. The plan of operation adopted for the project provides for the release of all inflows after each rain, with exception of that required to maintain the small permanent pool. The maximum rate of release would be approximately 1,000 second-feet, the estimated infiltration rate of the stream in the Edwards outcrop area. The storage required to control the 50-year flood has been increased slightly to allow for the withholding of releases for two days. It is anticipated that the withholding period would allow a greater percentage of runoff from the uncontrolled area to infiltrate into the aquifer before regulated releases are commenced.

66. Recreation development is proposed for the Montell project at two separate areas, at the dam and reservoir and at the channel dam 14 miles downstream. The facilities at the reservoir would include overlook facilities, park and picnic areas, an access road to the water and a boat ramp. In the vicinity of the channel dam, an area known as Chalk Bluff, additional overlook facilities, park and picnic areas, an access road and foot trails to the river are proposed. Water for the pipeline to the Tom Nunn Hill area would be ponded behind this channel dam. Additional water released from the Montell Reservoir would flow over the channel dam and recharge the underground aquifer in the Edwards outcrop area downstream from


GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
PLAN OF IMPROVEMENT
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC. 1964
SUBMITTED
APPROVAL RECOMMENDED
APPROVED
PREPARED
FILE: GUAD. 707-2
LEGEND
WATERSHED BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR WITH RECHARGE STORAGE
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EXISTING S.C.S. DAM (1 JULY 1964)
AUTHORIZED S.C.S. DAM
VICINITY MAP
SCALE IN MILES
NEW MEXICO
OKLAHOMA
ARK.
LA.
TEXAS
MEXICO
GULF OF MEXICO
EDWARDS PLATEAU
BALCONES FAULT ZONE
GULF COASTAL PLAIN
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
PROPOSED CHANNEL DAM AND PIPELINE
MONTELL RESERVOIR
CONCAN RESERVOIR
SABINAL RESERVOIR
MEDINA RESERVOIR
DIVERSION DAM
OLMOS DAM
DAM #7 RESERVOIR
CLOPTIN CROSSING RESERVOIR
CANYON RESERVOIR
BLIEDERS CREEK RESERVOIR
CHANNEL IMPROVEMENT (AUTHORIZED)
SAN ANTONIO CHANNEL IMPROVEMENT (UNDER CONSTRUCTION)
EDWARDS CO.
KERR CO.
REAL CO.
BANDERA CO.
GILLESPIE CO.
KENDALL CO.
BLANCO CO.
HAYS CO.
COMAL CO.
BEXAR CO.
GUADALUPE CO.
KINNEY CO.
UVALDE CO.
MEDINA CO.
WILSON CO.
GONZALES CO.
MAVERICK CO.
ZAVALA CO.
FRIO CO.
ATASCOSA CO.
KARNES CO.
DIMMIT CO.
LA SALLE CO.
ROCKSPRINGS
KERRVILLE
FREDERICKSBURG
JOHNSON CITY
DRIPPING SPRINGS
CENTER POINT
COMFORT
WIMBERLEY
KYLE
SAN MARCOS SPRINGS
SAN MARCOS
BOERNE
MEDINA
BANDERA
LEAKEY
CAMP WOOD
TARPLEY
UTOPIA
GARNER STATE PARK
MONTELL
CONCAN
LAGUNA
BRACKETTVILLE
LAS MORAS SPRINGS
KNIPPA
UVALDE
LEONA SPRINGS
SABINAL
D'HANIS
HONDO
CASTROVILLE
LACKLAND A.F.B.
KELLY A.F.B.
SAN PEDRO SPRINGS
SAN ANTONIO SPRINGS
FORT SAM HOUSTON MIL. RES.
SAN ANTONIO
RANDOLPH A.F.B.
BROOKS A.F.B.
HUECO SPRINGS
COMAL SPRINGS
NEW BRAUNFELS
SEGUIN
DEVINE
STOCKDALE
FLORESVILLE
POTH
POTEET
PLEASANTON
KARNES CITY
LA PRYOR
BATESVILLE
PEARSALL
DERBY
CRYSTAL CITY
NUECES RIVER
FRIO RIVER
SABINAL RIVER
MEDINA RIVER
GUADALUPE RIVER
BLANCO RIVER
SAN MARCOS RIVER
SAN ANTONIO RIVER
ATASCOSA RIVER
LEONA RIVER
North Fork Guadalupe River
South Fork Guadalupe River
West Nueces River
Cibolo Creek
Balcones Creek





GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

EDWARDS UNDERGROUND RESERVOIR

NUECES RIVER

PIPELINE FOR WATER SUPPLY

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
W. E. Wood, ENGINEER, CHIEF, PROJECT PLANNING BRANCH	C. F. [illegible], ENGINEER, CHIEF, ENGINEERING DIVISION	[illegible], COLONEL, CE, DISTRICT ENGINEER
PREPARED: [illegible], ENGINEER, CHIEF, GENERAL INVESTIGATIONS SECTION	DRAWN BY: T.L.W. CHECKED BY: R.H.S.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR. FILE: GUAD. 707-2

the channel dam. The flow at the channel dam would range from 6 to 1,000 second-feet with flows in excess of 6 second-feet occurring about 99 percent of the time. The recharge operation of the project and the constant flow of the stream would provide a scenic attraction for sightseers, campers, and fishermen. A further analysis of this water resource development with its recreational attraction is contained in paragraph 91 of this report and in Appendix VI, Recreation and Fish and Wildlife. A summary of the estimated first costs and annual charges for the proposed Montell Reservoir, channel dam and pipeline are presented in table 11 and a reservoir map and design details of the dam and appurtenant works are shown on plates 6 and 7. The detailed estimates of first costs are presented as an attachment to this appendix.

67. CONCAN RESERVOIR.- The Concan Reservoir is proposed for construction by the Federal Government at river mile 226.2 on the Frio River to provide joint-storage for 50-year flood control and recharge of the Edwards Underground Reservoir. The total controlled storage proposed for this project is 149,000 acre-feet, which includes 7,800 acre-feet of reserve storage for 100-year sedimentation. Provision of 141,200 acre-feet of joint-storage in the reservoir would contain the flood of record on this stream. This storage would also develop the maximum water resources of the stream above the dam site.

68. The structure would consist of an earth and rock-fill dam with an uncontrolled spillway and an outlet works through the dam. Foundation conditions at the site are structurally satisfactory for the proposed structure. The Glen Rose formation comprises the bedrock in the valley section and left abutment; however, due to faulting which has lowered the right abutment relative to the left abutment, the Glen Rose, Comanche Peak, and Edwards limestones outcrop below the top of dam elevation and comprise the right abutment. Foundation exploration and geologic mapping did not reveal any unusual leakage conditions although several minor faults were noted. Further investigations would be required to determine what influence, if any, these faults would have on leakage from the proposed reservoir.

69. The plan of operation proposed for this project provides for release of all inflows after each rain. The rate of release have been tentatively planned at 750 second-feet, the estimated infiltration rate of the stream in the Edwards outcrop area. No permanent storage would be provided in the reservoir. The storage required for 50-year flood control has been increased slightly to permit two-day withholding before regulated releases would commence. Operation of the reservoir under this plan would increase the average annual recharge from this stream by approximately 21,500 acre-feet.

TABLE 10

PERTINENT DATA
PROPOSED RESERVOIRS
PLAN OF IMPROVEMENT
EDWARDS UNDERGROUND RESERVOIR AREA

	MULTIPLE PURPOSE RESERVOIRS			
	Montell Reservoir	Cloptin Crossing Reservoir	Concan Reservoir	Sabinal Reservoir
DRAINAGE AREA				
Square miles	707	307	371	210
SPILLWAY DESIGN FLOOD				
Peak inflow, cfs	893,900	414,900	592,500	381,800
Volume, acre-feet	821,300	353,000	489,400	249,000
Volume, inches	21.78	21.56	23.47	22.23
Peak outflow, cfs	581,000(1)	196,400(1)	433,000(1)	270,600

RESERVOIR	Montell Elev.(2) (feet)	Montell Area (acres)	Montell Capacity (ac-ft)	Montell Capacity (inch)	Cloptin Crossing Elev.(2) (feet)	Cloptin Crossing Area (acres)	Cloptin Crossing Capacity (ac-ft)	Cloptin Crossing Capacity (inch)	Concan Elev.(2) (feet)	Concan Area (acres)	Concan Capacity (ac-ft)	Concan Capacity (inch)	Sabinal Elev.(2) (feet)	Sabinal Area (acres)	Sabinal Capacity (ac-ft)	Sabinal Capacity (inch)
Top of dam	1371.0	-	-	-	1023.0	-	-	-	1399.5	-	-	-	1244.0	-	-	-
Maximum design water surface	1366.0	10,180	533,100	14.14	1017.5	9,600	573,000	35.00	1394.2	5,670	280,600	13.46	1238.8	3,860	135,200	12.07
Top of flood control pool and spillway crest	1331.0(3)	6,200	252,300	6.69	998.0	7,730	404,000	24.67	1366.5(3)	3,830	149,000	7.15	1226.5(3)(5)	2,990	93,300	8.33
Top of conservation pool	1237.0	260	2,200	0.06	980.5	6,060	283,400	17.31	-	-	-	-	-	-	-	-
Sediment storage - Total	1331.0	-	12,000	0.32	978.0	-	9,200	0.56	1366.5	-	7,800	0.37	1226.5	-	4,200	0.37
Sediment storage - Conservation Pool	1237.0	-	1,200	0.03	980.5	-	8,500	0.52	-	-	-	-	-	-	-	-

	Montell Reservoir	Cloptin Crossing Reservoir	Concan Reservoir	Sabinal Reservoir
STORAGE SUMMARY				
Flood control, ac-ft	239,300(4)	119,900	141,200(4)	89,100(4)
Water conservation, ac-ft	1,000	274,900	-	-
Sediment, ac-ft	12,000	9,200	7,800	4,200
Total	252,300	404,000	149,000	93,300
DAM				
Type	Earth and rock fill	Earth and rock fill	Earth and rock fill	Earth and rock fill
Total length, feet	7,360	7,520	2,955	2,150
Embankment section:				
Type	Earth and rock fill	Earth and rock fill	Earth and rock fill	Earth and rock fill
Total length, feet	7,360	7,520	2,955	1,500
Height above streambed, feet	158.0	200.0	164.0	114.0
Freeboard, feet	5.0	5.5	5.3	5.2
Crown width, feet	30	30	40	30
Side slopes:				
Upstream	1 on 3.5	1 on 3.5	1 on 3.5	1 on 3.0
Downstream	1 on 3.0	1 on 3.0	1 on 3.0	1 on 3.0
SPILLWAY				
Type	Broadcrested	Broadcrested	Broadcrested	Gated
Net length, feet	960	760	1,030	240
Gates:				
Type	-	-	-	Tainter
Number	-	-	-	6
Size (width x height)	-	-	-	40' x 30'
Spillway discharge, cfs:				
Maximum design water surface	570,600	187,200	425,300	270,600
OUTLET WORKS				
Type	Gate-controlled conduit	Gate-controlled conduit	Gate-controlled conduit	Gate-controlled sluices
Number of conduits	1	1	1	2
Dimensions	15' diameter	13' diameter	13' diameter	3'-0" x 6'-0"
Invert elevation, feet	1216.0	855.0	1240.0	1130.0
Control	3 - 5'-8" x 12' tractor-type gates	2 - 6' x 13' tractor-type gates	2 - 6' x 13' tractor-type gates	2 - 3' x 6' slide gates
RELOCATIONS				
Roads and highways:				
U. S. highways, miles	-	-	0.3	-
State highways, miles	10.5	-	-	-
F.M. highways, miles	-	-	-	6.0
State park roads, miles	-	-	0.2	-
County roads, miles	1.8	1.3	6.3	-
Access roads, miles	4.5	-	-	-
Bridges, feet	390	400	100	-
Utilities:				
Power lines, miles	27	2.0	5.0	8.7
Telephone lines, miles	20	2.0	5.0	8.7
Cemetery graves	340	-	-	-
LANDS				
Dam and reservoir				
Clearing, acres	260	3,750	-	-
Land acquisition:				
Fee simple, acres	700	8,390	400	400
Flood easement, acres	6,140	-	3,960	3,000
(Guide taking line)	(1336.0)	(1003.0)	(1371.5)	(1229.5)
Recreation				
Clearing, acres	80	2,420	30	30
Land acquisition:				
Fee simple, acres	100	2,210	10	10
PIPELINE AND CHANNEL DAM				
Channel dam height (feet)	6			
Pipeline				
Diameter (inches)	24			
Length (miles)	8.5			
Control	Gate valve			

(1) Includes discharge through outlet works as follows: 10,400 9,200 7,700
(2) All elevations refer to mean sea level.
(3) Top of controlled storage - joint storage for flood control and recharge purposes.
(4) Joint-storage for flood control and recharge.
(5) Top of controlled storage and top of gate elev. 1226.5; spillway crest elev. 1196.5.

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TABLE 11

SUMMARY OF FIRST COST AND ANNUAL CHARGES
PROPOSED MONTELL RESERVOIR
NUECES RIVER

Item	Costs
FIRST COST	
First Cost:	
Lands and damages (reservoir and recreation areas)	$ 1,492,500
Relocations	1,752,000
Reservoir (clearing - reservoir and recreation areas)	53,000
Dam:	
Embankment	6,112,000
Spillway	15,529,000
Outlet works	2,268,000
Access roads	80,000
Recreation facilities	225,500
Buildings, grounds, and utilities	268,000
Permanent operating equipment	100,000
Engineering and design	2,050,000
Supervision and administration	1,715,000
Subtotal estimated reservoir first cost	$31,645,000
Estimated first cost channel dam and pipeline	900,000
Total estimated Federal first cost	$32,545,000

ANNUAL CHARGES

(3-1/8% interest rate: 100-year amortization)

	Channel dam and pipeline	Reservoir	Total project
Construction period	1 yr	5 yr	-
Investment:			
First cost	$900,000	$31,645,000	$32,545,000
Interest during construction	-	2,472,000	2,472,000
Total investment	$900,000	$34,117,000	$35,017,000
Annual Charges:			
Interest on investment	$ 28,100	$1,066,200	$1,094,300
Amortization charge	1,300	51,500	52,800
Operation, maintenance and replacement	16,600	73,800	90,400
Total annual charges	$46,000	$1,191,500	$1,237,500

Preauthorization cost (not included in first cost) $50,000

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TABLE 11

SUMMARY OF FIRST COST AND ANNUAL CHARGES
PROPOSED [illegible] RESERVOIR
NUECES RIVER

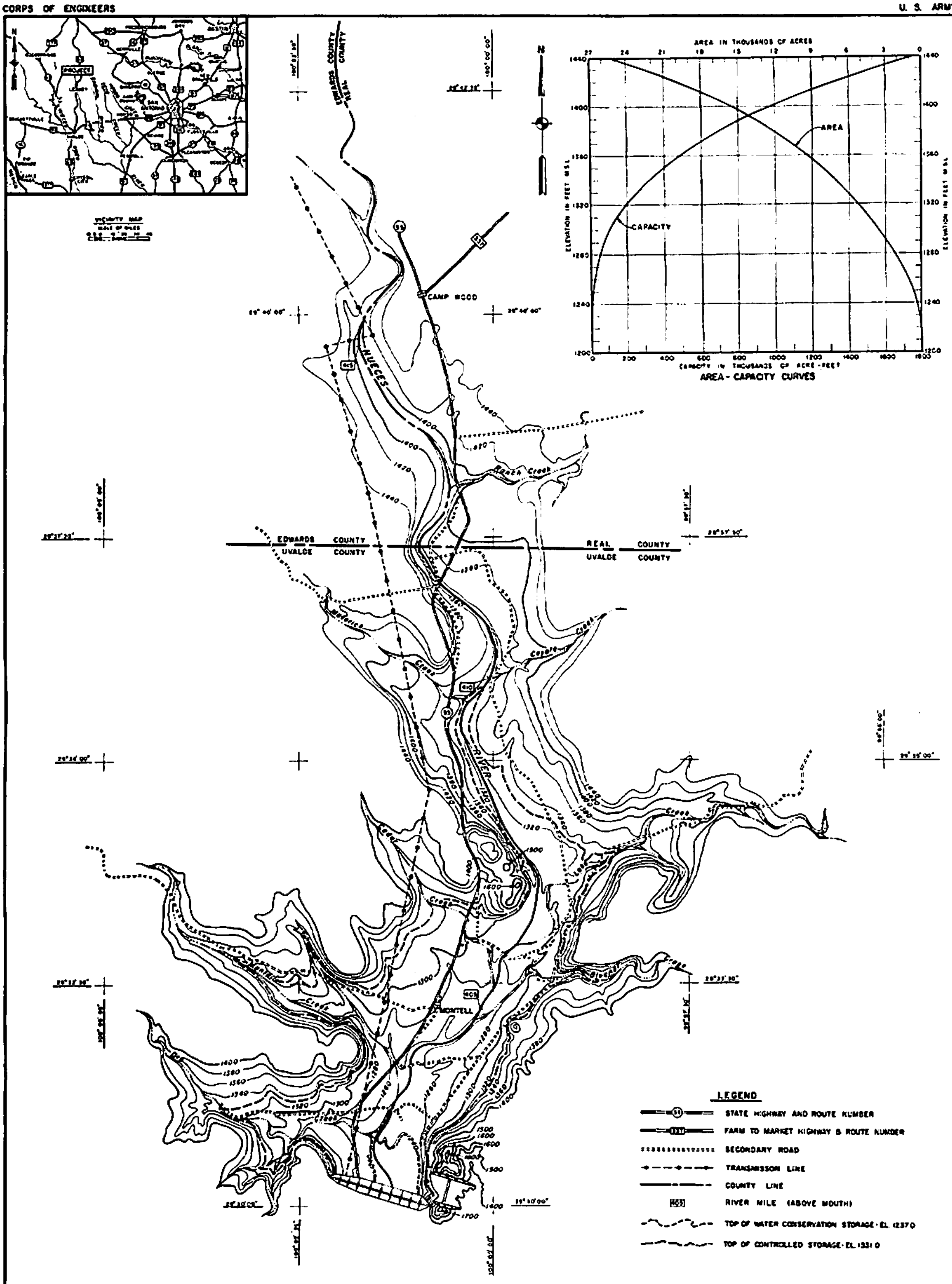
Item	Cost
FIRST COST	
Flood Gates:	
Lands and damages (reservoir and recreation areas)	$ 1,[illegible]70,000
Relocations	1,722,[illegible]
Reservoir (clearing - reservoir and recreation areas)	[illegible],000
Dam:	
Embankment	6,112,000
Spillway	15,[illegible]22,000
Outlet works	2,[illegible]
Access roads	[illegible]0,000
Recreation facilities	[illegible]
Buildings, grounds, and utilities	[illegible]
Permanent operating equipment	[illegible]
Engineering and design	1,[illegible]0,000
Supervision and administration	1,[illegible],000
Subtotal estimated reservoir first cost	$31,[illegible],000
Estimated first cost channel dam and pipeline	740,000
Total estimated Federal first cost	[illegible]

ANNUAL CHARGES

(3-1/8% interest rate: 100-year amortization)

	Channel dam and pipeline	Reservoir	Total project
Construction period	1 yr	5 yr	-
Investment:			
First cost	$740,000	$31,[illegible]5,000	$32,[illegible]
Interest during construction	-	2,472,000	2,472,[illegible]
Total investment	$740,000	$34,117,000	$34,[illegible]
Annual Charges:			
Interest on investment	$ 28,100	$1,050,200	$1,0[illegible]
Amortization charge	1,200	51,700	52,[illegible]
Operation, maintenance and replacement	10,000	75,200	8[illegible]
Total annual charges	$46,000	$1,191,200	$1,237,[illegible]

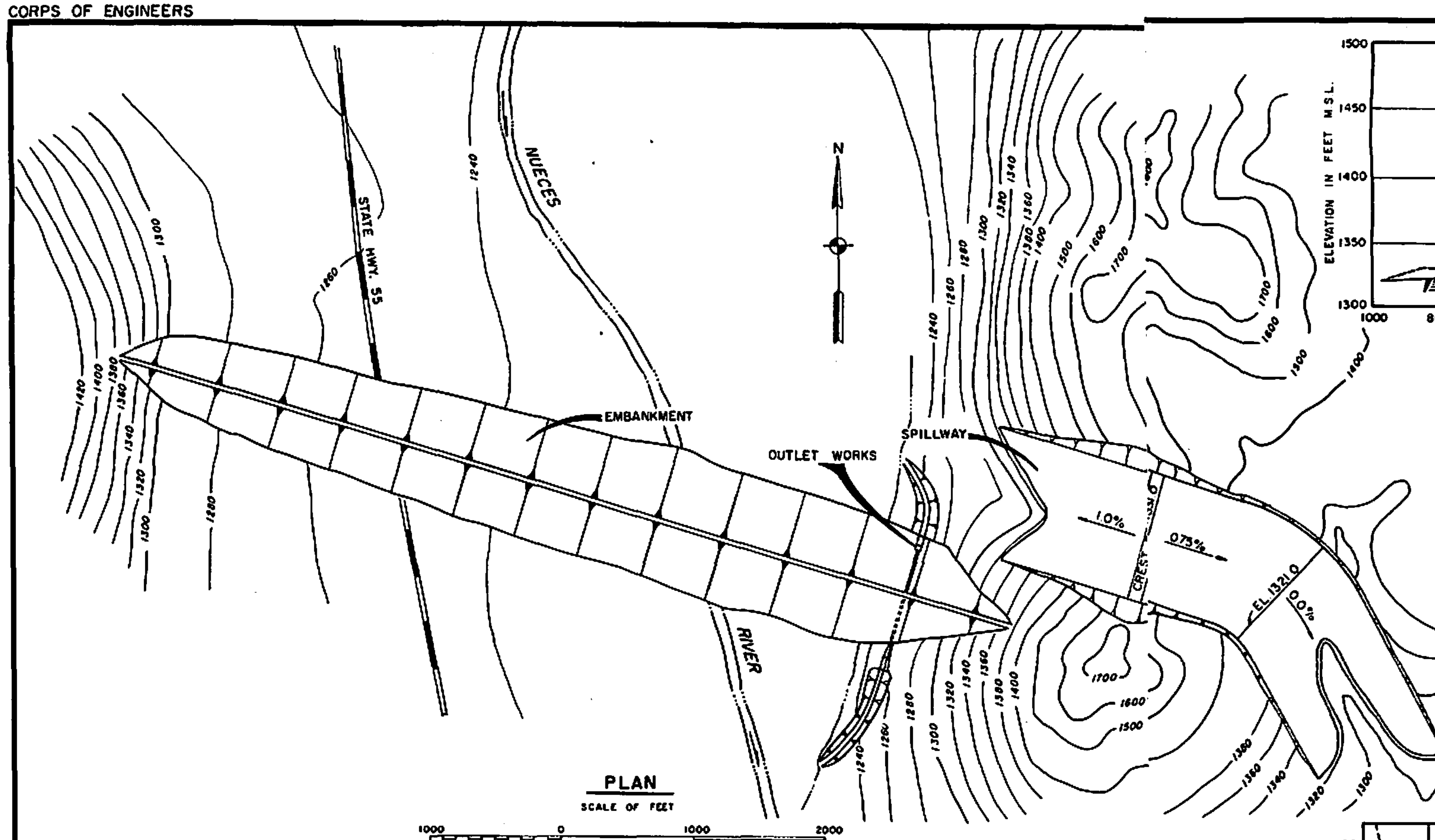
Preauthorization cost (not included in first cost) [illegible]



GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
NUECES RIVER
RESERVOIR MAP
MONTELL RESERVOIR
SCALE AS SHOWN

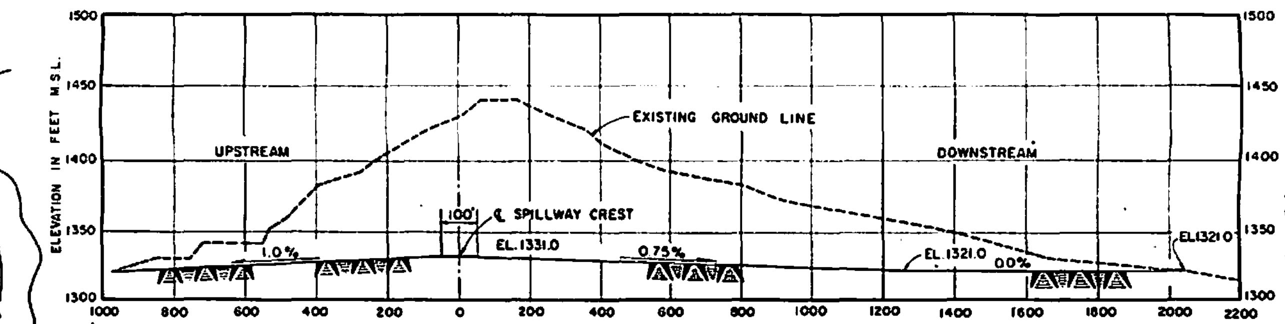
U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC 1964

FILE: QUAD. 707-2

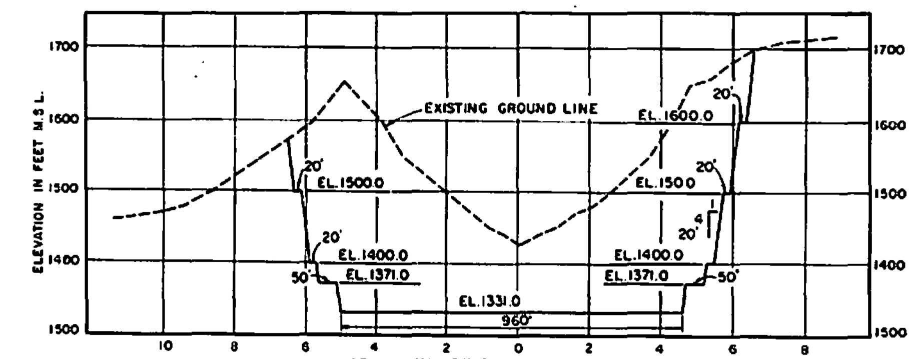


PLAN

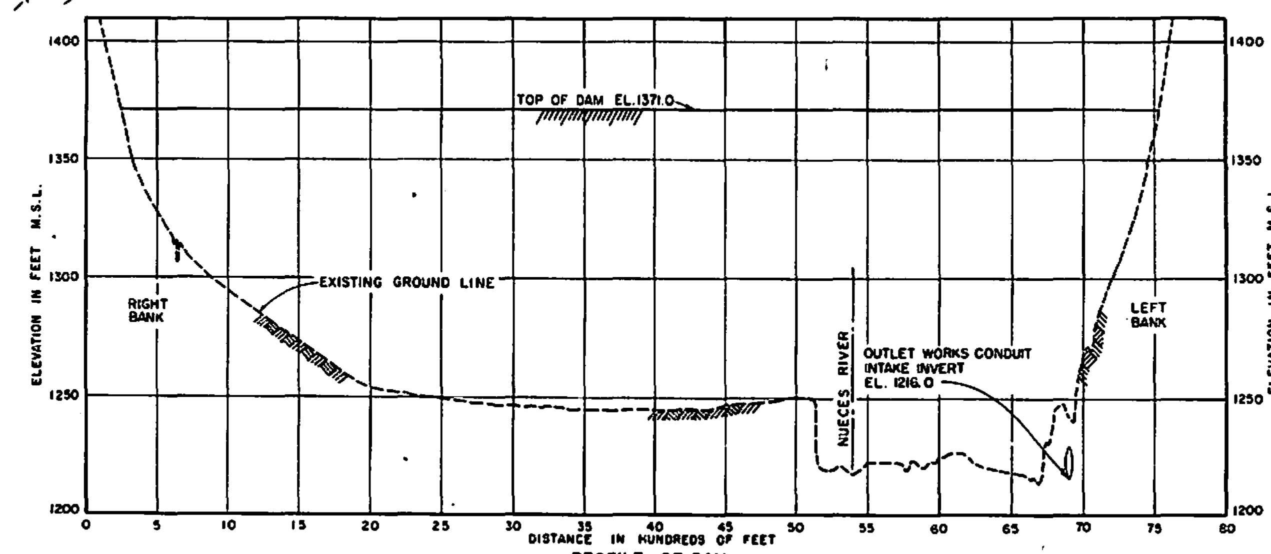
SCALE OF FEET



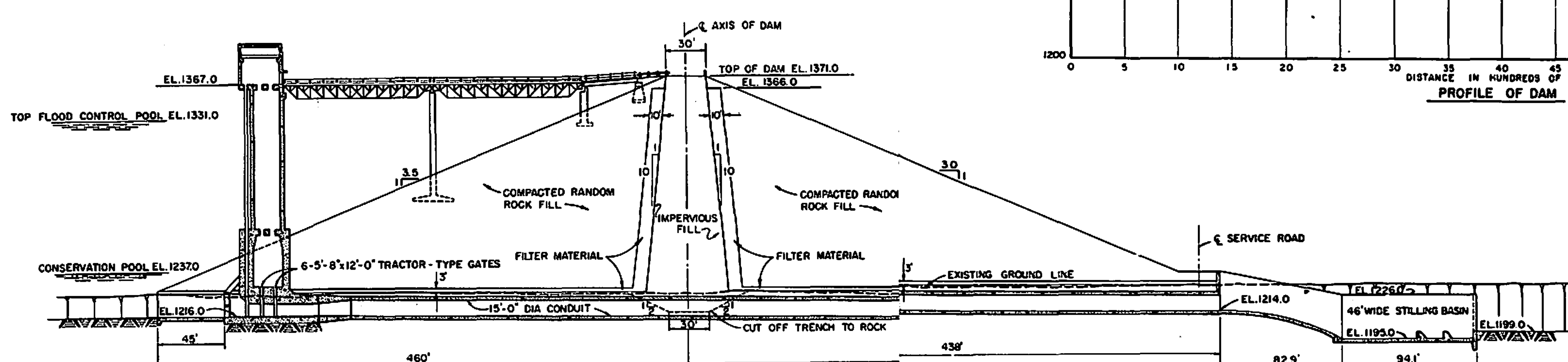
SPILLWAY PROFILE



SPILLWAY SECTION AT WEIR



PROFILE OF DAM



EMBANKMENT SECTION - OUTLET WORKS PROFILE

NOT TO SCALE

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

EDWARDS UNDERGROUND RESERVOIR

NUECES RIVER

PLAN, PROFILES AND SECTIONS

MONTELL DAM SITE

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED: W. E. Wood, CHIEF, PLANNING & REPORTS BRANCH
APPROVAL RECOMMENDED: C. T. ..., CHIEF, ENGINEERING DIVISION
APPROVED: ..., COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ..., CHIEF, CIVIL ENGINEERING SECTION
DRAWN BY: A.M.F. — CHECKED BY: W.R.B.
TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
FILE: GUAD. 707-2

70. Although no permanent pool would be maintained at the Concan project, some recreation development has been included as a part of the project. The Frio River is a perennial stream and will have flow most of the time, except during infrequent periods of severe drought. For the 39-year period prior to 1963 the average flow of the stream in this area was 96 second-feet. Only during the critical drought, 1947-56, the Frio River in this area had no recorded flow for about five months. In addition, large quantities of floodwater would be stored in the reservoir for considerable periods of time. The release of these floodwaters to recharge the underground reservoir would provide a scenic attraction to sightseers. For these reasons sufficient overlook, park and picnic facilities for the general public are proposed for inclusion in the project. A summary of the estimated first cost and annual charges for the proposed Concan Reservoir is presented in table 12 and a reservoir map and design details of the dam and appurtenant works are shown on plates 8 and 9, respectively. The detailed estimate of first cost is presented as an attachment to this appendix.

71. SABINAL RESERVOIR.- The Sabinal Dam and Reservoir is proposed for Federal construction at river mile 42.3 on the Sabinal River. The proposed location is just inside the upstream limits of the Edwards outcrop in the Balcones fault zone. The reservoir would contain 89,100 acre-feet of joint-storage for 50-year flood control and recharge and 4,200 acre-feet of reserve storage for 100-year sedimentation. The joint-storage would be sufficient to control the flood of record on this stream without spills. This storage would also develop the maximum water resources of the stream above the dam site and would contribute 15,800 acre-feet per year of additional recharge to the Edwards aquifer.

72. The structure would consist of an earth and rock-fill dam with a gated spillway in the river channel controlled by six 40' x 30' tainter gates. The structure would be founded on the Edwards limestone, which is considered to be satisfactory for foundation requirements. Leakage along joint systems, similar to that at Medina Dam, is expected but should present no problem in construction or stability of the structure.

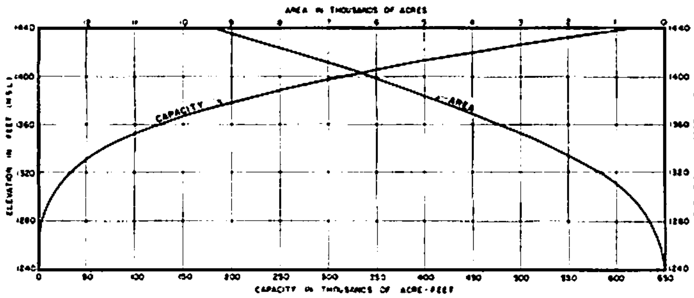
73. No permanent pool would be maintained in the Sabinal Reservoir. All inflows would be released after each rain at a rate tentatively established at 500 second-feet, the estimated infiltration rate of the streambed in the Edwards outcrop area. The storage required for 50-year flood control has been increased slightly to permit two-day withholding before regulated releases would commence.

74. Although no permanent storage would be maintained in the reservoir, some recreation development has been included in the proposed plan for the project. Approximately 25 percent of the time

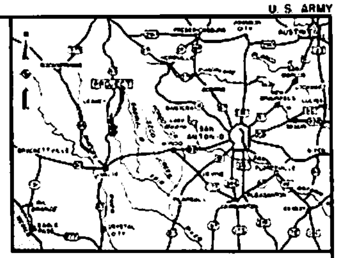
TABLE 12

SUMMARY OF FIRST COST AND ANNUAL CHARGES
PROPOSED CONCAN RESERVOIR
FRIO RIVER

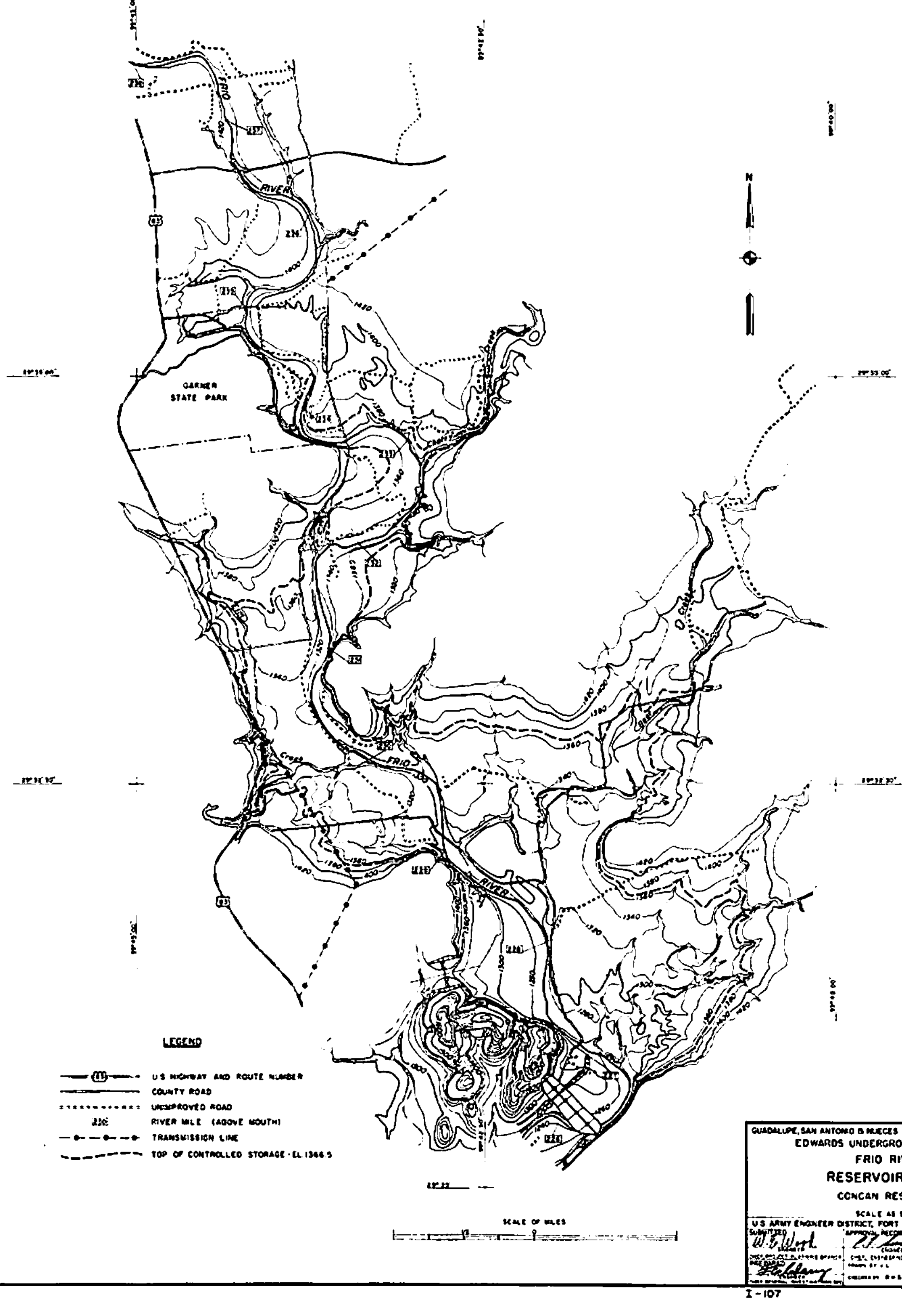
Item	Costs
FIRST COST	
First Cost:	
Lands and damages	$ 2,157,000
Relocations	569,000
Reservoir (clearing)	3,000
Dam	
Embankment	6,292,000
Spillway	2,426,000
Outlet works	1,972,000
Access roads	95,000
Recreation facilities	57,000
Buildings, grounds, and utilities	259,000
Permanent operating equipment	30,000
Engineering and design	1,015,000
Supervision and administration	775,000
Total estimated first cost	$15,650,000
ANNUAL CHARGES	
(3-1/8% interest rate: 100-year amortization)	
Construction period	4 yr
Investment:	
First cost	$15,650,000
Interest during construction	978,000
Total investment	$16,628,000
Annual Charges:	
Interest on investment	519,600
Amortization charge	25,100
Operation, maintenance and replacements	54,800
Total annual charges	$ 599,500
Preauthorization cost (not included in first cost)	$40,000



AREA - CAPACITY CURVE



VICINITY MAP



GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX

EDWARDS UNDERGROUND RESERVOIR

FRIO RIVER

RESERVOIR MAP

CONCAN RESERVOIR

SCALE AS SHOWN

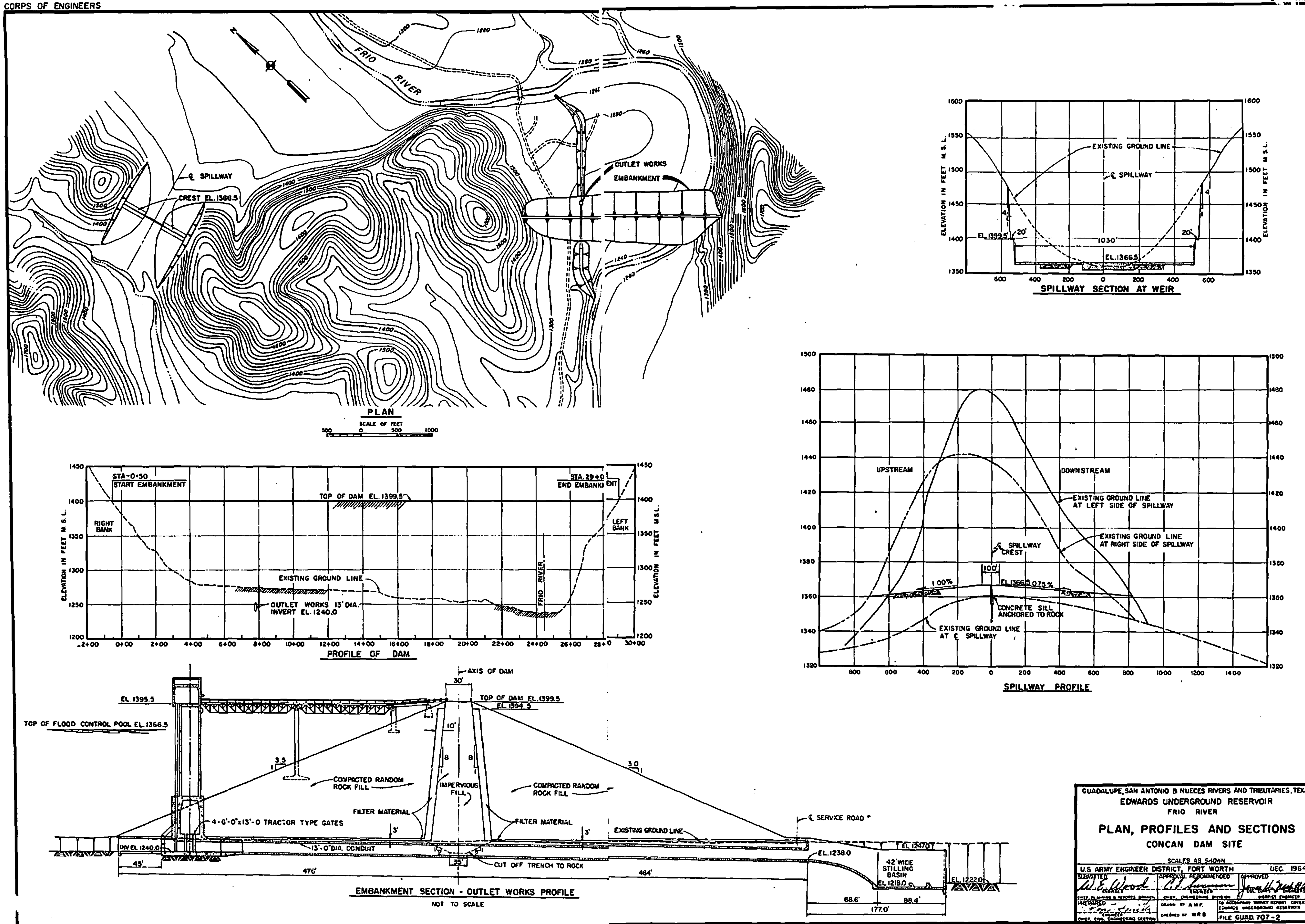
U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC. 1964

SUBMITTED W. E. Wood | APPROVAL RECOMMENDED | APPROVED

CHIEF, ENGINEERING DIVISION | DISTRICT ENGINEER

FILE GUAD 707-2

CORPS OF ENGINEERS



GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
FRIO RIVER

PLAN, PROFILES AND SECTIONS
CONCAN DAM SITE

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC 1964

SUBMITTED / APPROVAL RECOMMENDED / APPROVED

TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR

FILE GUAD. 707-2

the Sabinal River will not have flow at the dam site even though during the 20-year period of record prior to 1963 the average rate of flow of the stream in this area was 37 cubic-feet per second. The greatest attraction to the public, however, would occur at times when large quantities of floodwater have been stored in the reservoir and are being released to recharge the underground aquifer in the immediate proximity of the dam. Because of the anticipated interest of the general public in the flood-control and recharge operations of the project, sufficient overlook, park and picnic areas for the public are proposed.

75. A summary of the estimated first costs and annual charges for the proposed Sabinal Reservoir is presented in table 13 and a reservoir map and design details of the dam and appurtenant works are shown on plates 10 and 11, respectively. The detailed estimate of first cost is presented as an attachment to this appendix.

76. CLOPTIN CROSSING RESERVOIR.- A multiple-purpose reservoir for flood control, water conservation, and recreation and fish and wildlife is proposed for Federal construction on the Blanco River at the Cloptin Crossing site, river mile 32.5. The project would contain 119,900 acre-feet of flood control storage, 274,900 acre-feet of water conservation storage, and 9,200 acre-feet of storage for sediment accumulation. It has been found that providing 75-year frequency flood control in the Cloptin Crossing Reservoir would produce the greatest excess benefits over costs in reducing flood damages downstream and this amount of flood-control storage is included in the proposed project. The provision of 274,900 acre-feet of conservation storage in the Cloptin Crossing Reservoir would fully develop the resources of the Blanco River watershed upstream from the dam site and would provide a dependable yield of 38 million gallons per day (42,700 acre-feet per year).

77. The structure proposed for the Cloptin Crossing Dam would consist of an earth and rock-fill embankment, an outlet works through the dam and an uncontrolled spillway. The dam would be founded on the upper member of the Glen Rose limestone and the reservoir storage would be confined in the upper and lower members of the formation. Rock at the site is a suitable foundation for the proposed structure. Hydraulic pressure tests in the borings along the dam axis indicated that leakage through the bedrock would be insignificant. Geologic mapping in the reservoir area did not reveal any unusual leakage conditions. Field investigations indicated that some of the streamflow would be lost in the upper limits of the reservoir; however, seepage measurements show that the water would be regained further downstream before reaching the dam site.

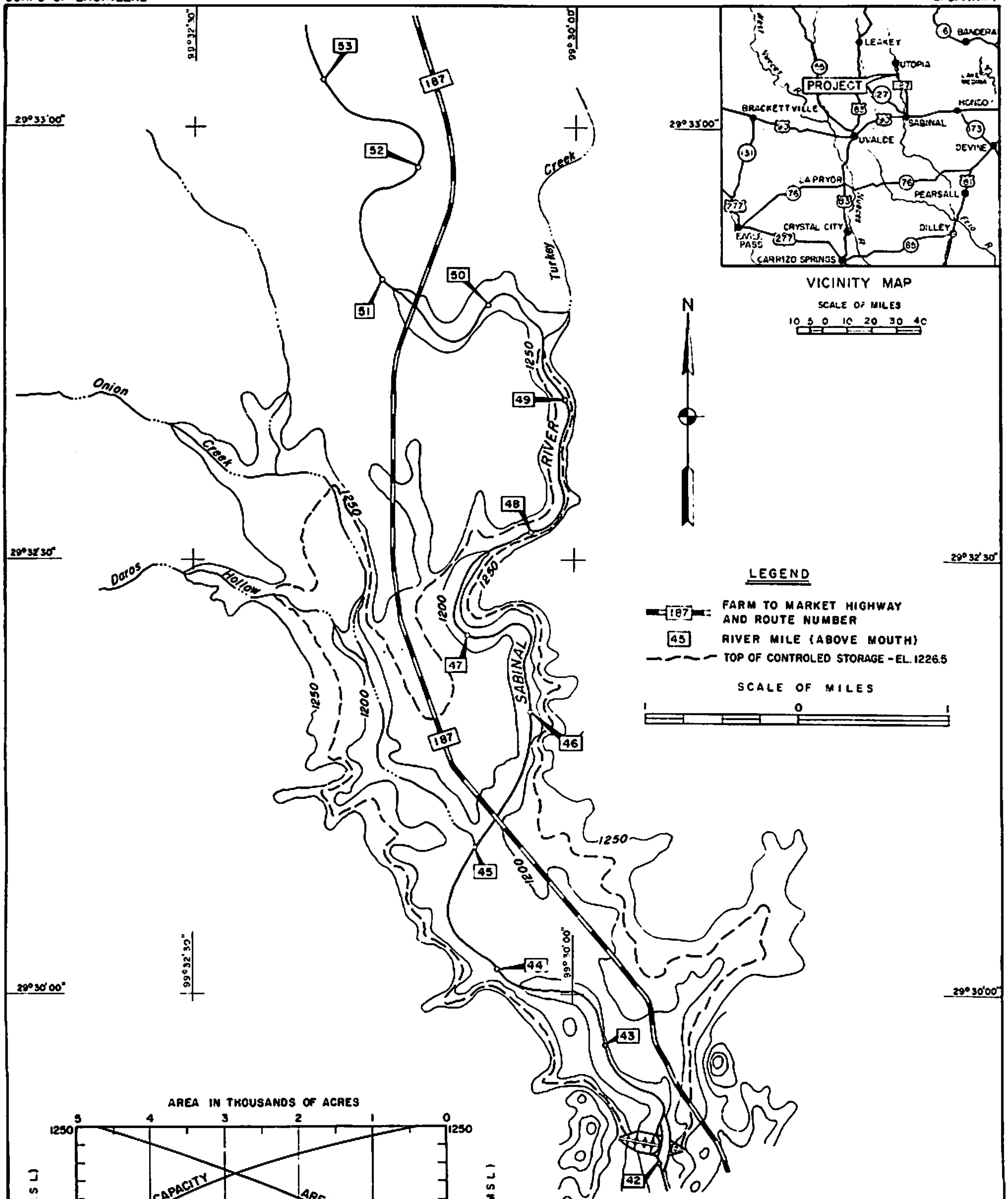
78. Full development of basic recreation facilities would be accomplished at this project. The facilities would include additional lands, parking areas, access roads, boat ramps, and picnic areas.

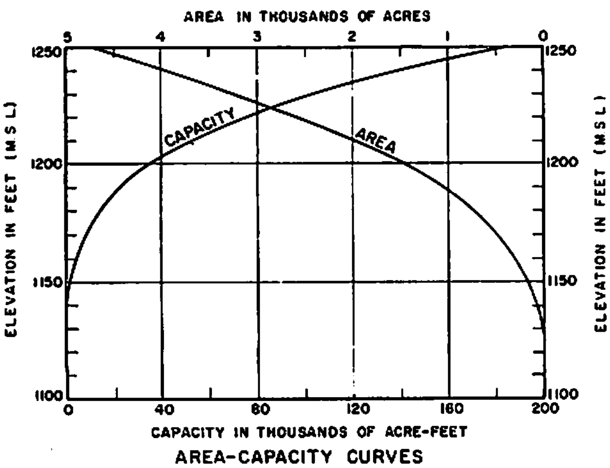
TABLE 13

SUMMARY OF FIRST COST AND ANNUAL CHARGES
PROPOSED SABINAL RESERVOIR
SABINAL RIVER

Item	Costs
FIRST COST	
First Cost:	
Lands and damages	$ 1,089,000
Relocations	673,000
Reservoir (clearing)	3,000
Dam	
Embankment	1,573,000
Concrete dam and spillway	6,377,000
Access roads	26,000
Recreation facilities	57,000
Buildings, grounds, and utilities	185,000
Permanent operating equipment	30,000
Engineering and design	810,000
Supervision and administration	590,000
Total estimated first cost	$11,413,000
ANNUAL CHARGES	
(3-1/8% interest rate: 100-year amortization)	
Construction period	3 yr
Investment:	
First cost	$11,413,000
Interest during construction	535,000
Total investment	$11,948,000
Annual Charges:	
Interest on investment	373,400
Amortization charges	18,000
Operation, maintenance, and replacement	49,200
Total annual charges	$ 440,600

Preauthorization cost (not included in first cost) $35,000





AREA-CAPACITY CURVES

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
SABINAL RIVER

RESERVOIR MAP

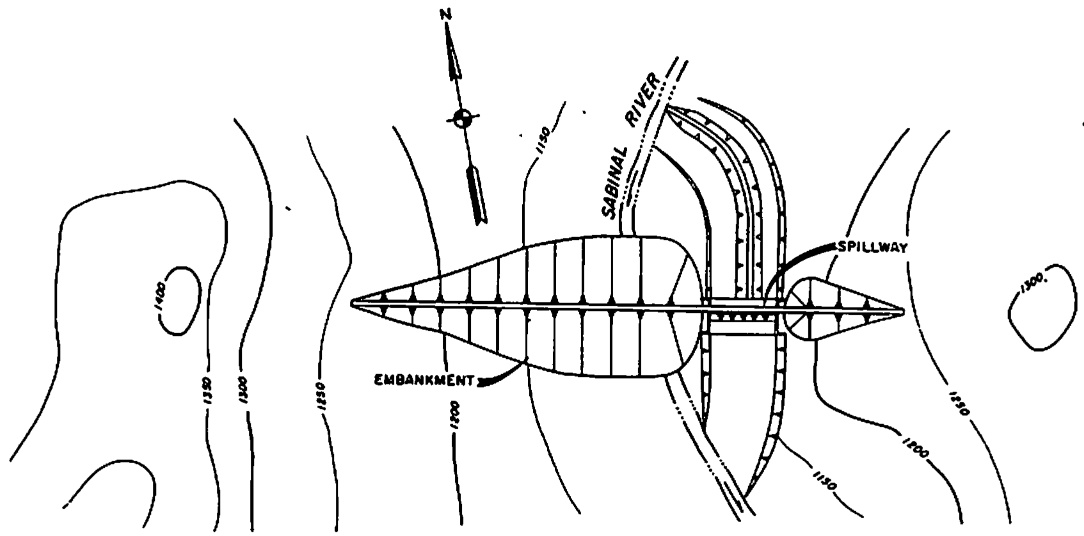
SABINAL-RESERVOIR

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED:	APPROVED:
W. E. Wood (signature) ENGINEER CHIEF, PROJECT PLANNING BRANCH	(signature) ENGINEER CHIEF, ENGINEERING DIVISION	James H. Nash (signature) COL. CORPS OF ENGINEERS DISTRICT ENGINEER

PREPARED		
(signature) ENGINEER CHIEF, GENERAL INVESTIGATIONS BR.	DRAWN BY: V.J.M. CHECKED BY: R.H.G.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR FILE: GUAD. 707-2



PLAN

SCALE OF FEET
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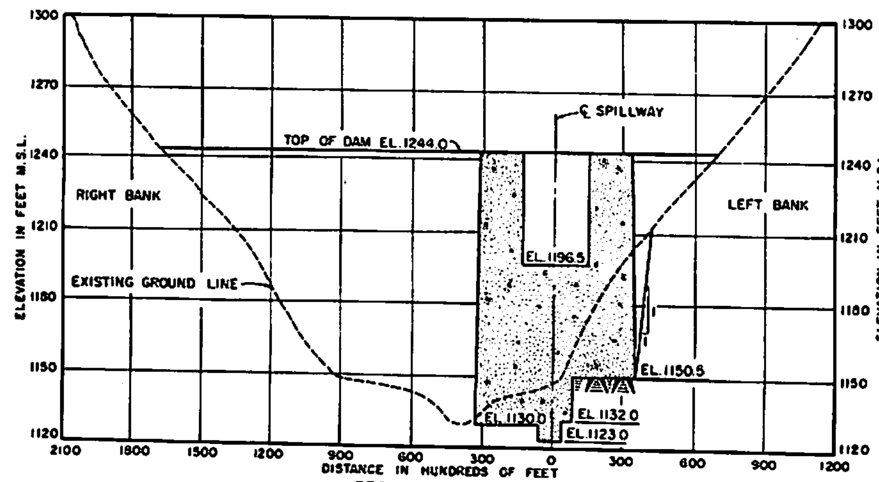
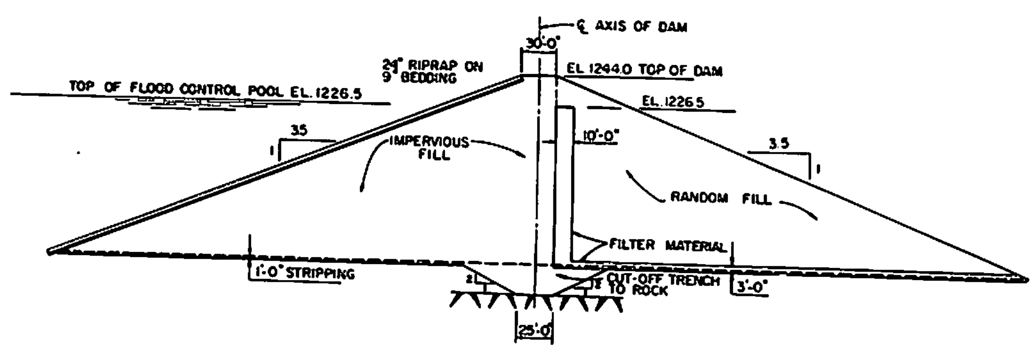
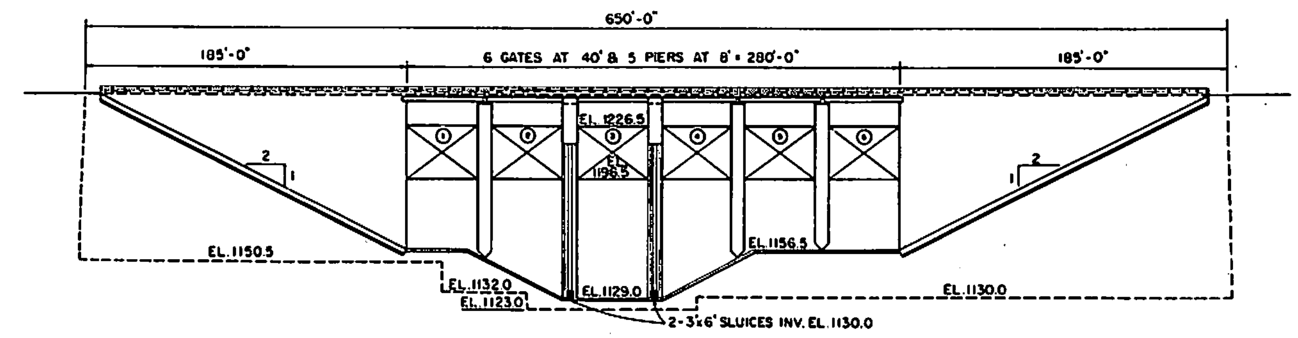


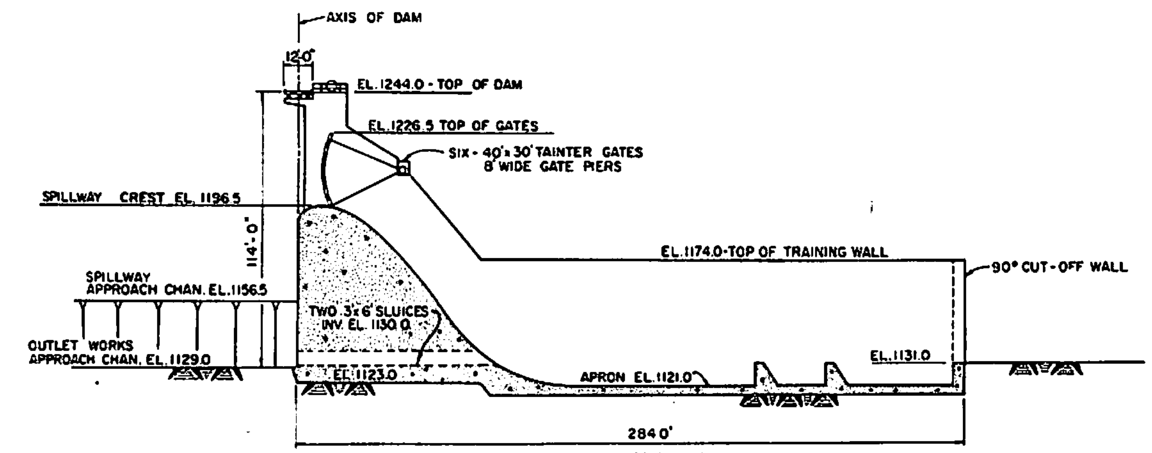
PROFILE OF DAM



SECTION THRU EMBANKMENT
NOT TO SCALE



UPSTREAM ELEVATION OF SPILLWAY
SCALE: 1 INCH = 40FEET



SECTION THRU SPILLWAY
SCALE: 1 INCH = 30FEET

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
SABINAL RIVER

PLAN, PROFILES AND SECTIONS
SABINAL DAM SITE

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED: W. E. Wood, ENGINEER, CHIEF, PLANNING & REPORTS BRANCH
APPROVAL RECOMMENDED: C. B. [signature], ENGINEER, CHIEF, ENGINEERING DIVISION
APPROVED: [signature], COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: [signature], ENGINEER, CHIEF, CIVIL ENGINEERING SECTION
DRAWN BY: A.M.F.
CHECKED BY: W.R.B.
TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
FILE: GUAD. 707-2

79. A summary of the estimated first cost and annual charges for the recommended project is presented in table 14, and a reservoir map and design details of the dam and appurtenant works are shown on plates 12 and 13, respectively. The detailed estimate of first cost is presented as an attachment to this appendix.

80. DAM NO. 7 RESERVOIR.- The Dam No. 7 Reservoir is proposed for construction by local interests at river mile 351.3 on the Guadalupe River, the site proposed by the Guadalupe-Blanco River Authority. The project would operate in conjunction with Canyon Reservoir to develop the resources above Canyon Dam to the fullest extent feasible. The provision of 640,500 acre-feet of conservation storage in Dam No. 7 Reservoir would produce a dependable yield for the Canyon-Dam No. 7 system of 127 million gallons per day (142,700 acre-feet per year). This is an increase of 41 mgd (46,400 acre-feet per year) over that yield determined for the Canyon Reservoir without upstream development. Since the Canyon Dam, 48 miles downstream, has been designed to control all floods of record originating above this project, additional flood storage in Dam No. 7 Reservoir could not be justified.

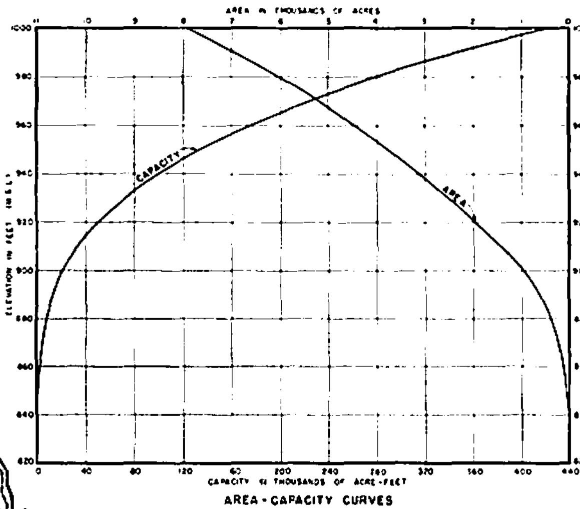
81. The structure investigated for the Dam No. 7 site was an earth and rock-fill embankment with an uncontrolled spillway and an outlet works through the dam. Detailed geologic investigations of the dam site were not conducted by the Corps of Engineers; however, a field reconnaissance of the dam site and reservoir area was made. The following conclusions concerning the geologic conditions to be expected at the Dam No. 7 site are based on the field reconnaissance and the geologic information contained in a preliminary report titled: "Proposed Guadalupe River Dams No. 7 and No. 8," prepared by Forrest and Cotton, Consulting Engineers, for the Guadalupe-Blanco River Authority. The proposed Dam No. 7 Reservoir would be confined in the Lower Glen Rose limestone and Hensell sand formations, and the bedrock is felt to be a suitable foundation for the proposed structure. With provision of a reasonable amount of grouting, the structure foundation and abutment areas could be considered watertight, though some leakage from the reservoir area is expected due to the existing geologic conditions of the area. The Guadalupe River contributes little or no water to the recharge of the Edwards Underground Reservoir, and it is reasonable to expect that the major portion of the reservoir losses from the proposed project would be recovered in the Guadalupe River or its tributary streams upstream from Canyon Reservoir.

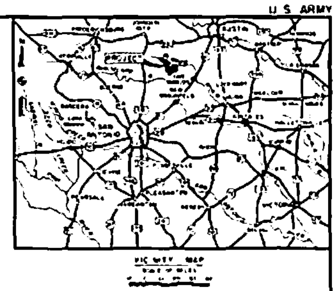
82. The estimated first cost of a reservoir project at the Dam No. 7 site to provide the 640,500 acre-feet of conservation storage and 17,500 acre-feet of sediment storage would be approximately $38,169,000. If recreation lands and facilities were provided at this project, the reservoir would attract approximately 4,800,000 visitors annually.

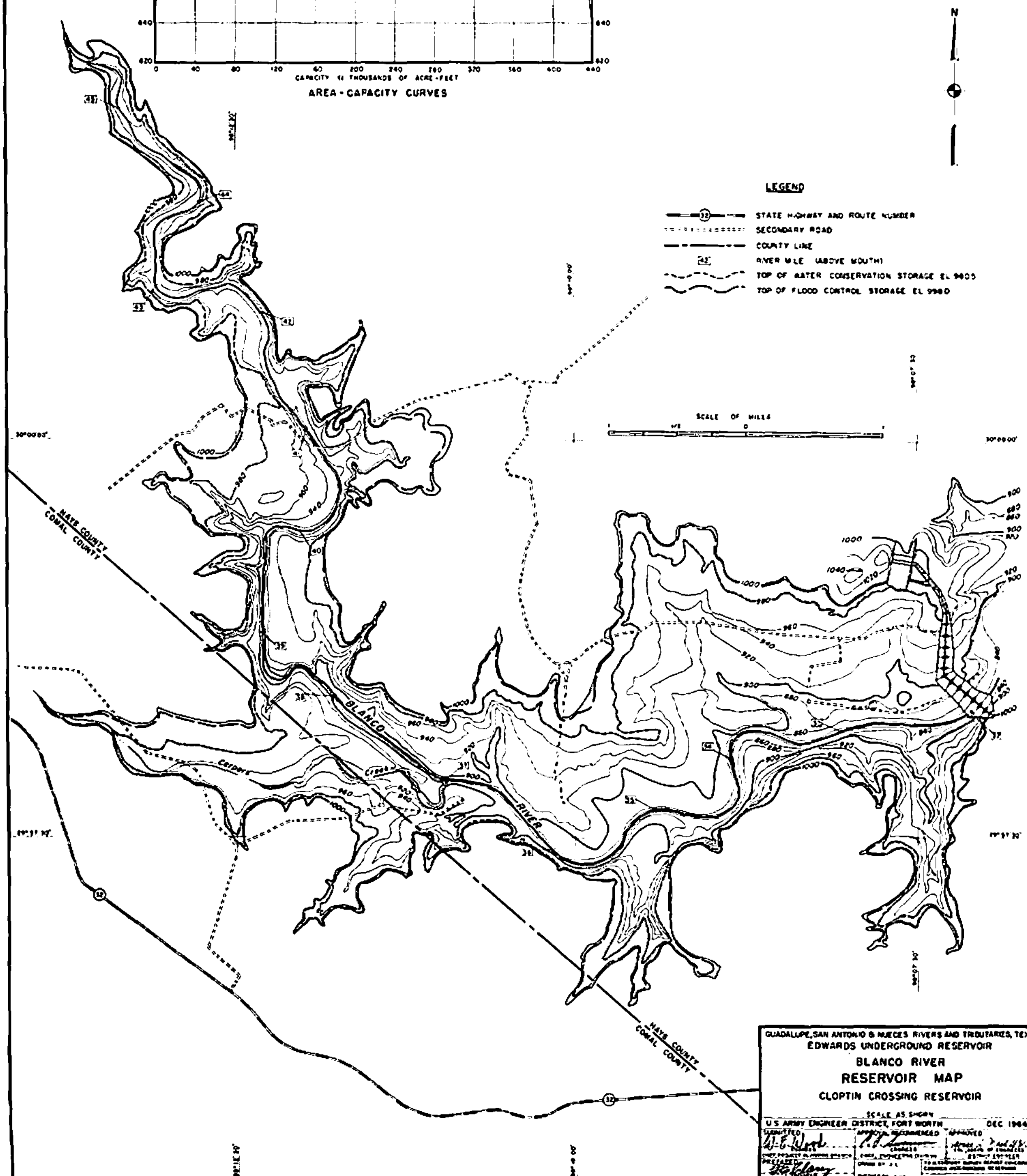
TABLE 14

SUMMARY OF FIRST COST AND ANNUAL CHARGES
PROPOSED CLOPTIN CROSSING RESERVOIR
BLANCO RIVER

Item	Costs
FIRST COST	
First Cost:	
Lands and damages (reservoir and recreation areas)	$ 2,526,000
Relocations	193,000
Reservoir (clearing - reservoir and recreation areas)	327,000
Dam	
Embankment	13,311,000
Spillway	1,220,000
Outlet works	1,937,000
Access roads	13,000
Recreation facilities	2,055,000
Buildings, grounds, and utilities	215,000
Permanent operating equipment	123,000
Engineering and design	1,390,000
Supervision and administration	1,130,000
Total estimated first cost	$24,440,000
ANNUAL CHARGES	
(3-1/8% interest rate - 100-year amortization)	
Construction period	4 yr
Investment:	
First cost	$24,440,000
Interest during construction	1,528,000
Total investment	$25,968,000
Annual Charges:	
Interest on investment	811,500
Amortization charge	39,200
Operation, maintenance, and replacement	185,000
Total annual charges	$ 1,035,700
Preauthorization cost (not included in first cost)	$55,000







GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX
EDWARDS UNDERGROUND RESERVOIR

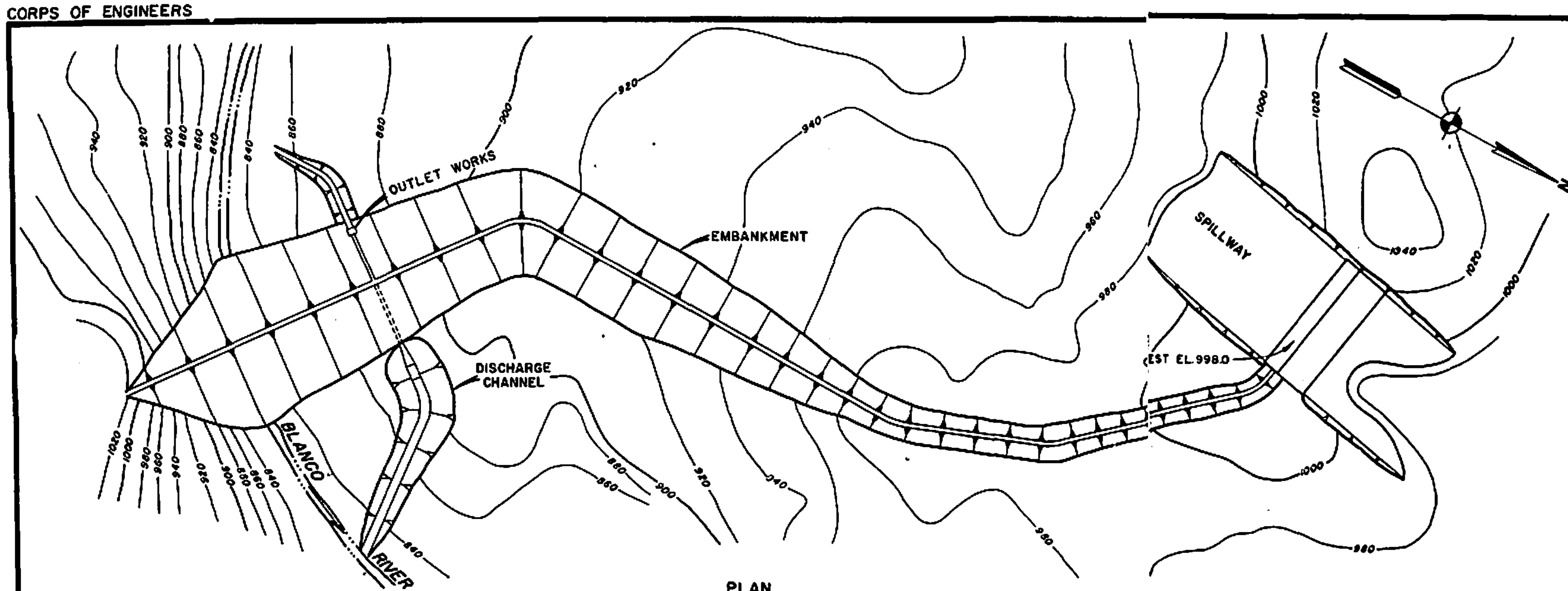
BLANCO RIVER
RESERVOIR MAP
CLOPTIN CROSSING RESERVOIR

SCALE AS SHOWN
U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC 1964

SUBMITTED — APPROVAL RECOMMENDED — APPROVED

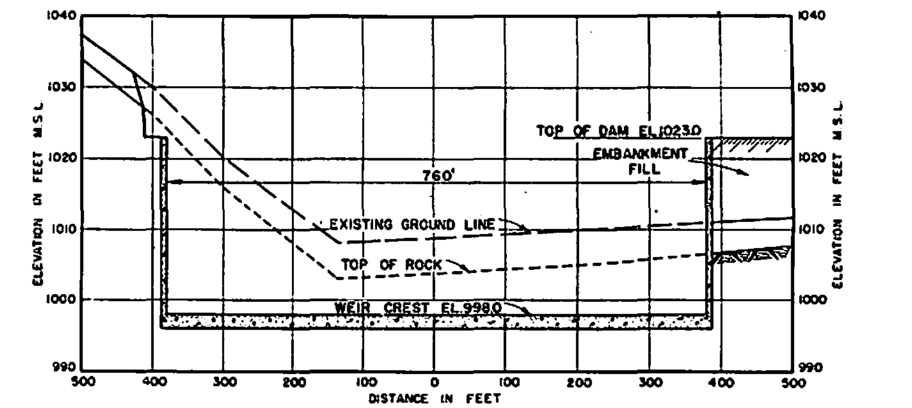
PREPARED

FILE QUAD 707-2

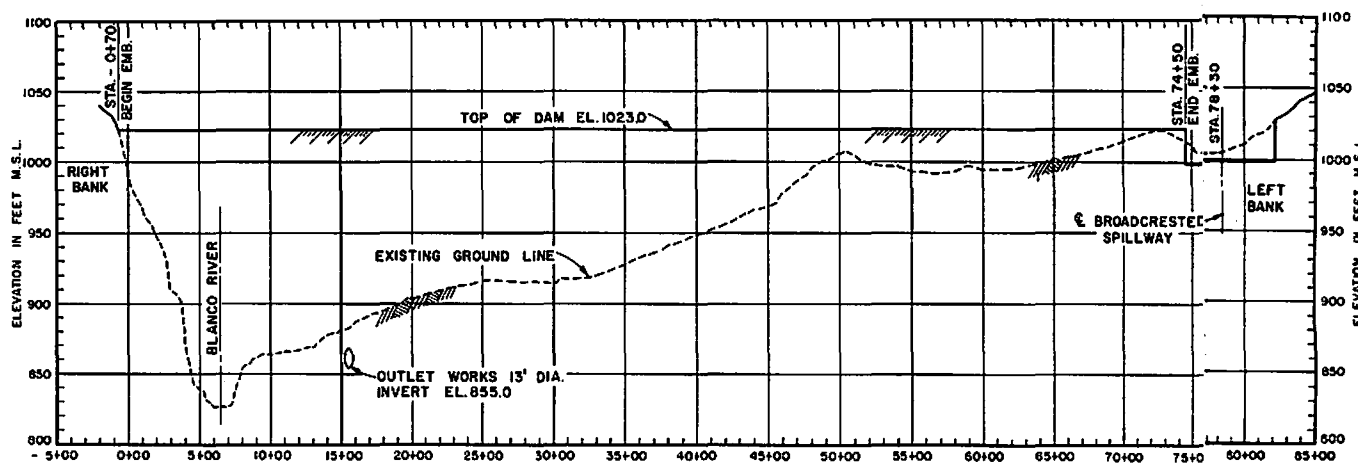


PLAN

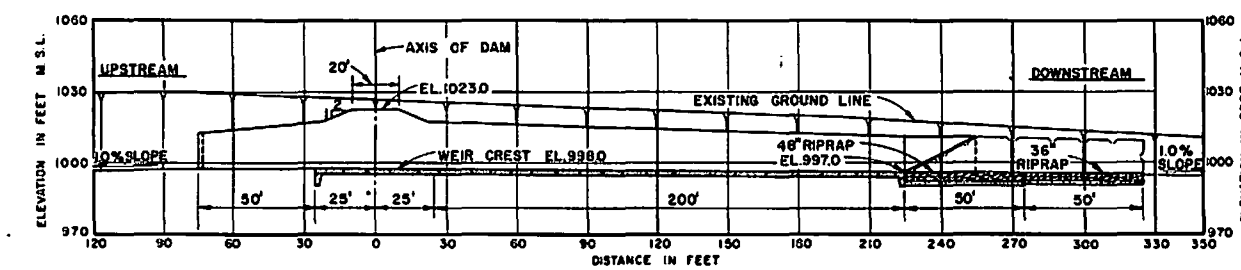
SCALE OF FEET



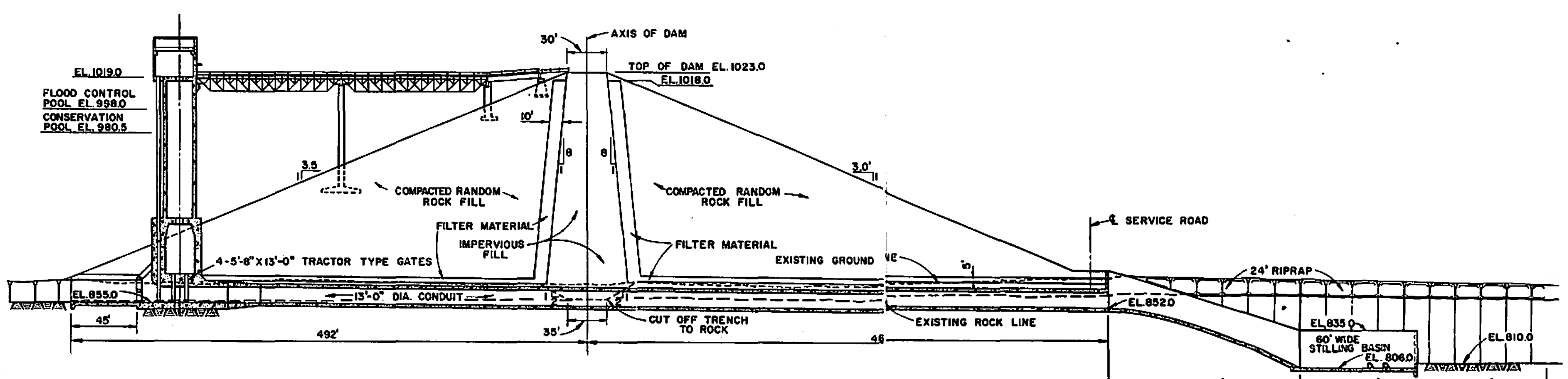
SPILLWAY SECTION AT WEIR



PROFILE OF DAM



SPILLWAY PROFILE



EMBANKMENT SECTION - OUTLET WORKS PROFILE

NOT TO SCALE

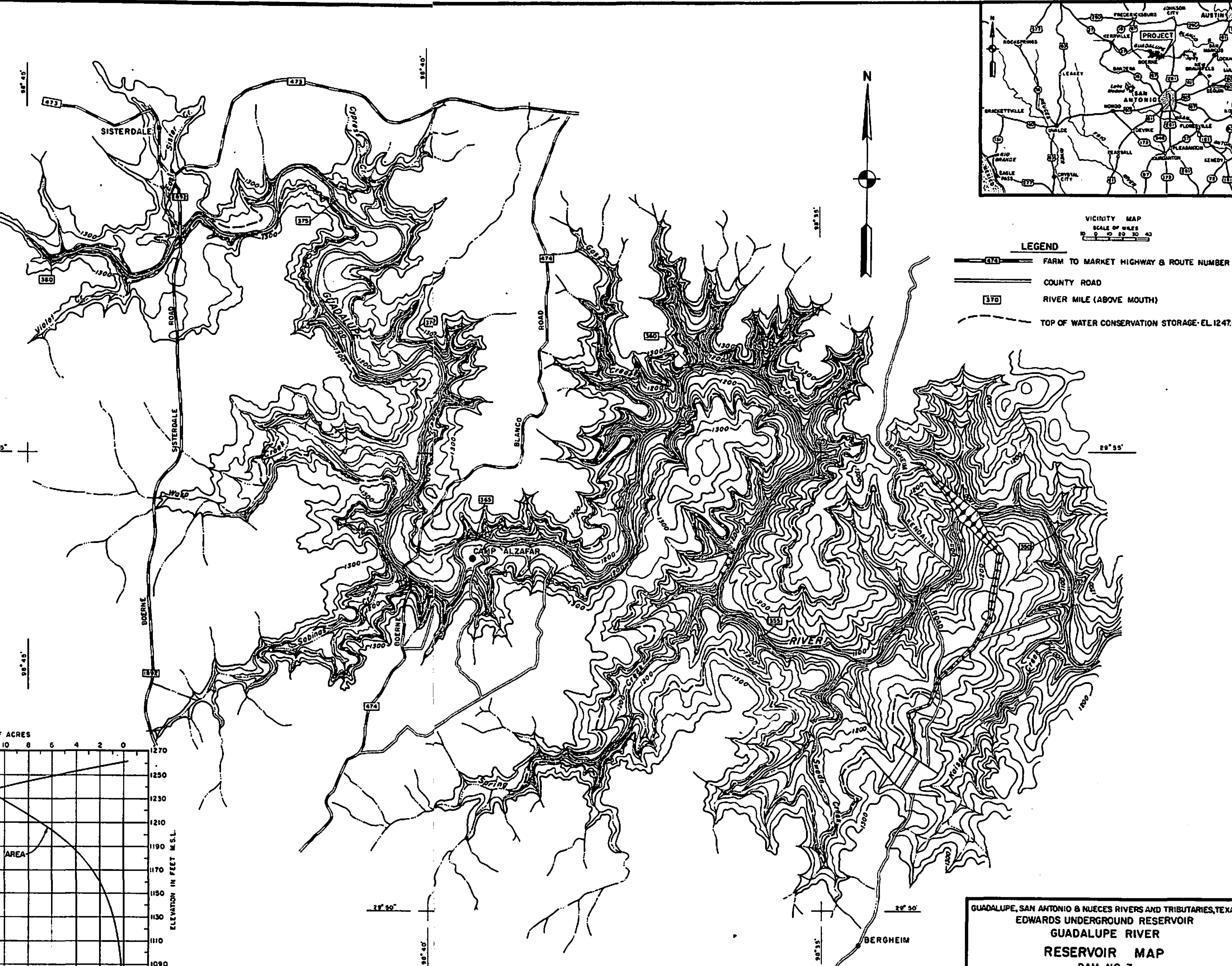
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
BLANCO RIVER

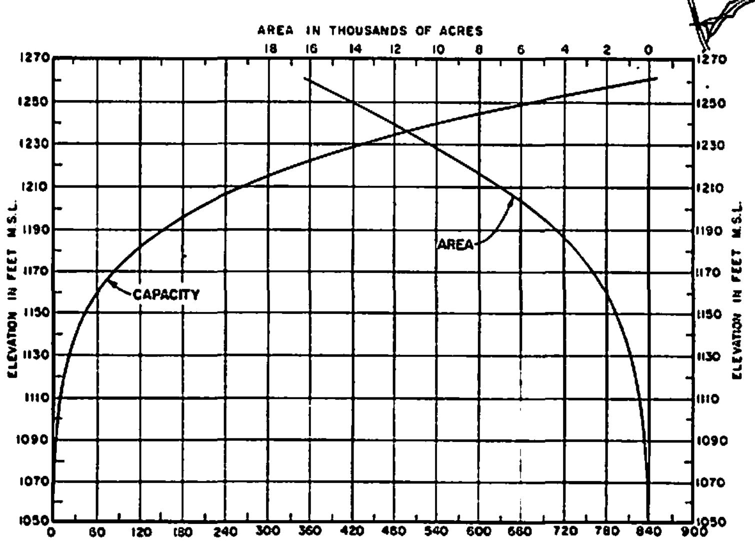
PLAN, PROFILES AND SECTIONS
CLOPTIN CROSSING DAM

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
W. E. Wood, CHIEF, PROJECT PLANNING BRANCH	CHIEF, ENGINEERING DIVISION	DISTRICT ENGINEER
PREPARED: CHIEF, CIVIL ENGINEERING SECTION	DRAWN BY: J.L. / CHECKED BY: W.R.B.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR / FILE: GUAD. 707-2





AREA – CAPACITY CURVES

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE RIVER

RESERVOIR MAP

DAM NO. 7

SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC. 1964

FILE GUAD. 707-2

83. RECHARGE.- Construction of Montell, Concan, and Sabinal Reservoirs in the Nueces River Basin and operation of the projects as previously outlined will result in a net increase in recharge to the Edwards aquifer of 63,900 acre-feet per year (57 million gallons per day). The average annual recharge for the period 1935-56, 423,200 acre-feet, would be increased by the projects to 487,100 acre-feet, as shown in table 15.

84. YIELD OF THE AQUIFER.- The yield of the underground reservoir cannot, over a long period of time, exceed the average annual recharge. Because of the nature of the aquifer, this yield is realized through discharges from both wells and springs. The major springs along the southern limits of the Balcones fault zone are natural outlets for the Edwards Reservoir and are uncontrolled. Flow from these springs is dependent on the water levels in the underground reservoir.

a. Increased pumping.- From hydrologic routings it was determined that the safe yield for pumping may be increased from 234,000 to 263,000 acre-feet per year (235 million gallons per day) without depleting storage in the underground reservoir below elevation 612 feet at San Antonio. This represents an increase of 29,000 acre-feet per year (26 mgd).

(1) The computed safe yield for pumping under modified conditions of recharge, 263,000 acre-feet per year (235 mgd), represents an average during each year of the period 1935-56. If this yearly average is not exceeded this quantity of water would be available during a recurrence of the critical drought as experienced during the period 1947-56, without depleting the reservoir below the historic low. In the absence of an alternative source of water supply this quantity should not be exceeded.

(2) Provision of an alternative surface water supply, sufficient to meet the demands of the area during a critical drought, would enable greater quantities of water to be pumped from the aquifer during wet years and in the early years of a drought period. However, the water level in the underground reservoir would drop to the historic low a number of years prior to the end of the drought, the time depending on the extent of pumping and the existing climatic conditions. For the remaining years of the drought, the dependable yield of the underground reservoir would be only that inflow during the driest year, which in 1956 totaled 44,000 acre-feet. It is believed that if withdrawals exceed the small quantity of inflow expected during the drought that water levels in the aquifer would drop rapidly below the historic low and the danger of contamination of the fresh water source would be significantly increased.

(3) With an alternative source to provide a water supply for the critical drought period it is conceivable that the pumping during wet years could be substantially increased to utilize the full quantity of additional recharge provided by Montell, Concan, and Sabinal Reservoirs, 63,900 acre-feet per year (57 million gallons per day).

b. Increased springflow.- The remainder of the increased recharge, 34,900 acre-feet per year (31 mgd) under this plan of operation would be discharged from the aquifer principally through the major springs. Approximately 4,000 acre-feet per year of this additional springflow would be discharged from Leona Springs in the Nueces River Basin, 13,300 acre-feet from San Antonio and San Pedro Springs in the San Antonio River Basin, and 17,600 acre-feet from Hueco, Comal, and San Marcos Springs in the Guadalupe River Basin. The total average annual springflow for the period 1935-56 was 352,400 acre-feet. Under assumed conditions of constant pumping of 234,000 acre-feet per year during this same period, the average annual springflow would be about 292,900 acre-feet. With the recharge projects in operation this quantity would be increased to 327,800 acre-feet.

c. Water levels in the aquifer.- Water levels in the underground reservoir would be higher over the life of the recharge projects, particularly during periods when large volumes of water are induced into the aquifer. The water levels under modified recharge conditions would range from 1 to 13 feet higher and would average approximately two feet higher over the period of routing 1935-56.

85. DEPENDABLE WATER SUPPLY.- Three reservoir projects are proposed in the plan of improvement to provide conservation storage for purposes other than recharge. The projects are Montell, Cloptin Crossing, and Dam No. 7. Montell Reservoir would contain 1,000 acre-feet of conservation storage to supply 4,300 acre-feet per year to the Nueces River Conservation and Reclamation District. Construction of Cloptin Crossing and Dam No. 7 Reservoirs, as previously described, would provide a total of 915,400 acre-feet of additional conservation storage in the Edwards area. Cloptin Crossing Reservoir would fully develop the upstream resources of the Blanco River and provide a dependable yield of 38 million gallons per day (42,700 acre-feet per year). Dam No. 7 Reservoir would develop to the fullest extent feasible the resources of the Guadalupe River upstream from Canyon Dam. The Canyon-Dam No. 7 Reservoir system would have a dependable yield of 127 mgd (142,700 acre-feet per year). This is an increase of 41 mgd (46,400 acre-feet per year) over the yield determined for the existing Canyon Reservoir without upstream development. Because of the large and rapidly increasing water demands on the Edwards Underground Reservoir, these surface projects could supplement the ground-water supply and prevent its continued depletion if area-wide agreement on development of water resources could be obtained.

TABLE 15

PHYSICAL EFFECTS OF THE PLAN

Stream***	Estimated average annual resources above lower edge of Edwards outcrop (ac-ft)*	Estimated average annual recharge (ac-ft)*: Existing conditions	Modified conditions	Increase due to reservoir projects	Average annual runoff at lower edge of Edwards outcrop*: Existing conditions	Modified conditions	Drainage area** (sq. mi.): Total	Controlled
GUADALUPE RIVER BASIN								
Blanco River and adjacent area	99,500	25,400	25,400	0	74,100	24,200(1)	514	307
Guadalupe River	246,000	0	0	0	246,000	74,100(2)	1,510	1,425
Dry Comal Creek	28,900	20,500	20,500	0	8,400	8,400	98	--
SUBTOTAL - Guadalupe River Basin	374,400	45,900	45,900	0	328,500	106,700		
SAN ANTONIO RIVER BASIN								
Cibolo Creek	58,900	54,100	54,100	0	4,800	4,800	258	--
Salado Creek	24,400	21,400	24,400(3)	3,000(3)	3,000	0	118	118
Leon and San Geronimo Creeks	29,300	27,600	27,600	0	1,700	1,700	152	--
Medina River	94,300	42,700	42,700	0	6,400(4)	6,400(4)	630	613
SUBTOTAL - San Antonio River Basin	206,900	145,800	148,800	3,000(3)	15,900	12,900		
NUECES RIVER BASIN								
Verde Creek	18,700	14,600	14,600	0	4,100	4,100	108	--
Hondo Creek	23,500	18,300	18,300	0	5,200	5,200	136	--
Tributary areas	13,700	10,700	10,700	0	3,000	3,000	79	--
Seco Creek	15,400	12,000	12,000	0	3,400	3,400	89	--
Sabinal River	33,900	17,600	33,400	15,800	16,300	500	214	210
Blanco and Hackberry Creeks	4,100	2,100	2,100	0	2,000	2,000	26	--
Little Blanco Creek	2,500	1,300	1,300	0	1,200	1,200	16	--
Frio River	65,000	40,000	61,500	21,500	25,000	3,500	432	391
Two Tributaries	2,700	1,700	1,700	0	1,000	1,000	18	--
Dry Frio River	27,000	17,100	17,100	0	9,900	9,900	140	--
Leona River	6,800	4,300	4,300	0	2,500	2,500	35	--
Deep Creek	3,500	2,200	2,200	0	1,300	1,300	18	--
Nueces River	98,700	64,400	91,000(5)	26,600(5)	34,300	3,400	784	707
Indian Creek	6,400	4,200	4,200	0	2,200	2,200	51	--
Four Tributaries	7,700	5,000	5,000	0	2,700	2,700	61	--
West Nueces River	29,800	16,000	16,000	0	13,800	13,800	905	--
SUBTOTAL - Nueces River Basin	359,400	231,500	295,400(5)	63,900(5)	127,900	59,700		
TOTAL - Edwards Reservoir Area	940,700	423,200	490,100(3)(5)	66,900(3)(5)	472,300	179,300		

* The annual resources, recharge and runoff (exclusive of springflow) at the lower edge of the Edwards outcrop are averages for the period 1935-56.
** The drainage area at lower edge of the Edwards outcrop, as indicated on plates 2 and 3, appendix II.
*** Location of dam sites shown on plate 4.
(1) Reduced by estimated net inflow of 49,900 ac-ft/yr to Cloptin Crossing.
(2) Reduced by estimated net inflow of 171,900 ac-ft/yr to Dam No. 7 - Canyon Reservoir system.
(3) Using 16 SCS detention structures on Salado Creek (1962 Work Plan), for increase of 3,000 ac-ft/yr.
(4) Does not include approximately 45,200 ac-ft/yr combined loss to evaporation and use for irrigation.
(5) Does not include 4,300 ac-ft/yr (4 mgd) to be delivered to downstream areas.

86. WATER DEMANDS AND SUPPLY.- The projected water demands of the Edwards area are shown in table 16 and figure 11. If only the recharge reservoirs (Montell, Concan, and Sabinal) are provided and the plan to limit the pumping rate from the underground reservoir to 263,000 acre-feet per year (235 mgd) is adopted, then the ground-water and surface-water resources would meet the projected needs of the Edwards area as indicated in the following tabulation:

Need	Sufficient to the year
Municipal and Rural	1996
Municipal, Rural, Industrial, and Thermal Power	1979
Municipal, Rural, Industrial, Thermal Power and Irrigation	(1)
Municipal, Rural, Industrial, Thermal Power, Irrigation, and Water Quality	(1)

(1) Total projected demand cannot be met.

87. If Dam No. 7 and Cloptin Crossing Reservoirs are constructed, in addition to the recharge reservoirs, to supplement the ground-water and surface-water resources of the Edwards Reservoir area, the plan would then meet the projected needs of the area as follows:

Need	Sufficient to the year
Municipal and Rural	2036
Municipal, Rural, Industrial, and Thermal Power	2014
Municipal, Rural, Industrial, Thermal Power, and Irrigation	2001
Municipal, Rural, Industrial, Thermal Power, Irrigation, and Water Quality	1980

TABLE 16

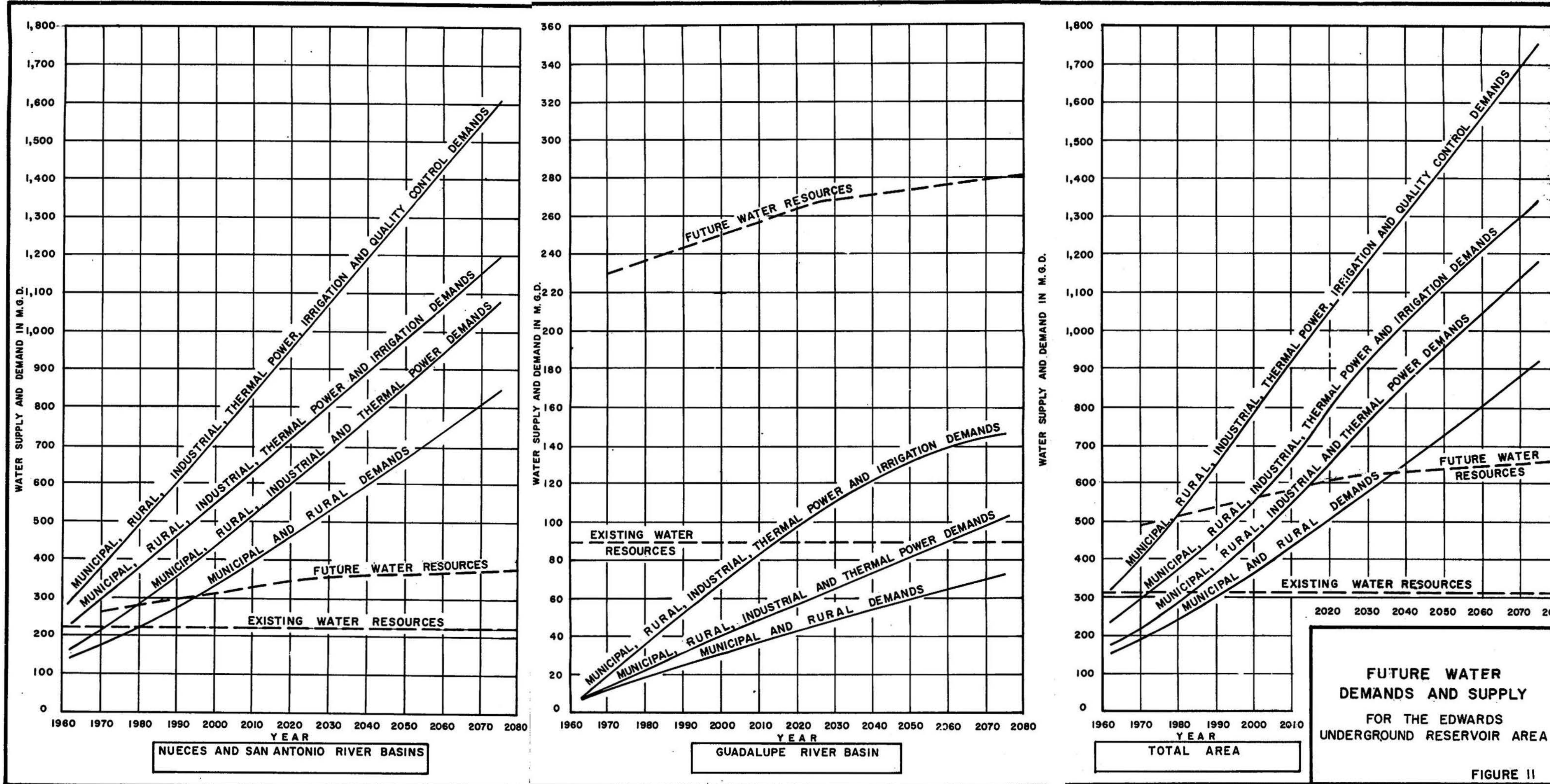
WATER REQUIREMENTS AND RESOURCES

Item	Nueces River Basin	San Antonio River Basin	Guadalupe River Basin	Total Area
Year 1962 Water Use in M.G.D. (1)				
Municipal and Rural	6.1	139.7	6.6	152.4
Industrial and Power	1.6	19.8	0.5	21.9
Irrigation	35.3	29.4	0.3	65.0
TOTAL	43.0	188.9	7.4	239.3
Year 2025 Water Requirements in M.G.D. (2)				
Municipal and Rural	19.9	479.3	46.0	545.2
Industrial and Power	8.7	135.7	15.3	159.7
Irrigation	58.5	60.6	43.8	162.9
Quality Control	-	250.0	-	250.0
TOTAL	87.1	925.6	105.1	1,117.8
Year 2075 Water Requirement in M.G.D. (2)				
Municipal and Rural	29.3	819.9	72.9	922.1
Industrial and Power	13.7	217.9	30.0	261.6
Irrigation	58.5	60.6	43.7	162.8
Quality Control	-	406.0	-	406.0
TOTAL	101.5	1,504.4	146.6	1,752.5

Item			Total Area
Year 2025 Water Resources in M.G.D.			
San Marcos Spring	-	36.0	36.0
Edwards Underground Aquifer	235.0*	-	235.0
Other Ground Water	4.0	18.0	22.0
Montell Reservoir	4.0	-	4.0
Canyon-Dam No. 7 Reservoir System	-	127.0	127.0
Cloptin Crossing Reservoir	-	38.0	38.0
Streamflow	9.0	23.0	32.0
Return Flow	103.0	24.0	127.0
TOTAL	355.0	266.0	621.0
Year 2075 Water Resources in M.G.D.			
San Marcos Spring	-	36.0	36.0
Edwards Underground Aquifer	235.0*	-	235.0
Other Ground Water	5.0	28.0	33.0
Montell Reservoir	4.0	-	4.0
Canyon-Dam No. 7 Reservoir System	-	127.0	127.0
Cloptin Crossing Reservoir	-	38.0	38.0
Streamflow	7.0	10.0	17.0
Return Flow	126.0	40.0	166.0
TOTAL	377.0	279.0	656.0

* Includes recharge from Montell, Concan and Sabinal Reservoirs.

(1) Determined by the Geological Survey; use from the aquifer.
(2) Determined by the Public Health Service; demands of the 14 counties.



FUTURE WATER DEMANDS AND SUPPLY

FOR THE EDWARDS UNDERGROUND RESERVOIR AREA

FIGURE 11

88. As indicated in the above tabulations, development of the water resources of the Edwards Reservoir area, as justified in the plan of improvement, would not meet the anticipated future demands within the area to the year 2075, even with drastic curtailment of use. To meet the anticipated future water demands beyond these dates will require more adequate use of return flows and development of additional water supplies outside the Edwards Reservoir area. Because of the limitations imposed by the authorization for this report, no overall basin water supply plan has been investigated for the three river basins.

89. FLOOD CONTROL.-

a. Nueces River Basin.- The construction of Montell, Concan, and Sabinal Reservoirs to contain 469,600 acre-feet of joint-storage for flood control and recharge purposes would provide flood protection for developments along the Nueces, Frio, and Sabinal Rivers from floods originating on the Edwards Plateau upstream from the dam sites. The largest portion of the benefits would be creditable to Montell Reservoir and would be derived from protection of the urban and extensive agricultural developments along the Nueces River, particularly in the "winter garden" area downstream from the Balcones fault zone in the vicinity of La Pryor, Crystal City, and Cotulla. Additional benefits would also be realized in areas further downstream, including the cities of Tilden and Three Rivers. The prolonged release of floodwaters from the reservoirs at a reduced rate would result in a higher degree of infiltration of these waters into the Edwards Underground Reservoir resulting in benefits to water supply not included above.

b. Guadalupe River Basin.- The provision of 119,900 acre-feet of flood-control storage in Cloptin Crossing Reservoir would provide flood protection to the agricultural lands, transportation and utility facilities and other improvements along the river valley of the Blanco and Guadalupe Rivers downstream from the dam site. It would also provide protection to the cities of San Marcos and Gonzales from floods originating on the Blanco River upstream from the dam site. The flood-control value of the proposed reservoirs is shown in the following tabulation:

	Proposed reservoirs			
	Montell	Concan	Sabinal	Cloptin Crossing
Average annual damages, dollars (1)	716,100	302,600	308,100	1,080,000
Annual damages prevented, dollars (1)	232,000	25,600	19,700	226,000
Annual damages prevented, percent	32.4	8.5	6.4	20.9
Average annual benefits dollars (2)	602,100	59,300	46,300	659,000 (3)
Flood protection frequency	50 yr	50 yr	50 yr	75 yr

(1) Under 1964 conditions of economic development.
(2) Includes benefits allowable for future development.
(3) Includes $163,300 credit for reduction of flood-control storage requirements in Cuero Reservoir.

90. EFFECTS OF PLAN ON YIELD OF DOWNSTREAM RESERVOIRS.-

a. Nueces River Basin.- The plan of development for the Edwards Reservoir area has been formulated in consonance with the improvements proposed in the master plan of the Nueces River Conservation and Reclamation District. Although Montell Reservoir is proposed in lieu of Tom Nunn Hill Reservoir, storage in the Montell project, with the channel dam and pipeline facilities included, would furnish to the Reclamation District the dependable yield of the Tom Nunn Hill project. Based on the cost of a single-purpose water supply reservoir at the Montell site, water could be delivered to the area at an estimated cost of 6.9 cents per 1,000 gallons, some 21.0 cents per 1,000 gallons cheaper than the estimated cost of water from the Tom Nunn Hill project. Substituting Montell Reservoir in the Tom Nunn Hill - Cotulla - Wesley Seale Reservoir system for Tom Nunn Hill Reservoir would not have an adverse effect on the yield of the Cotulla and Wesley Seale Reservoirs.

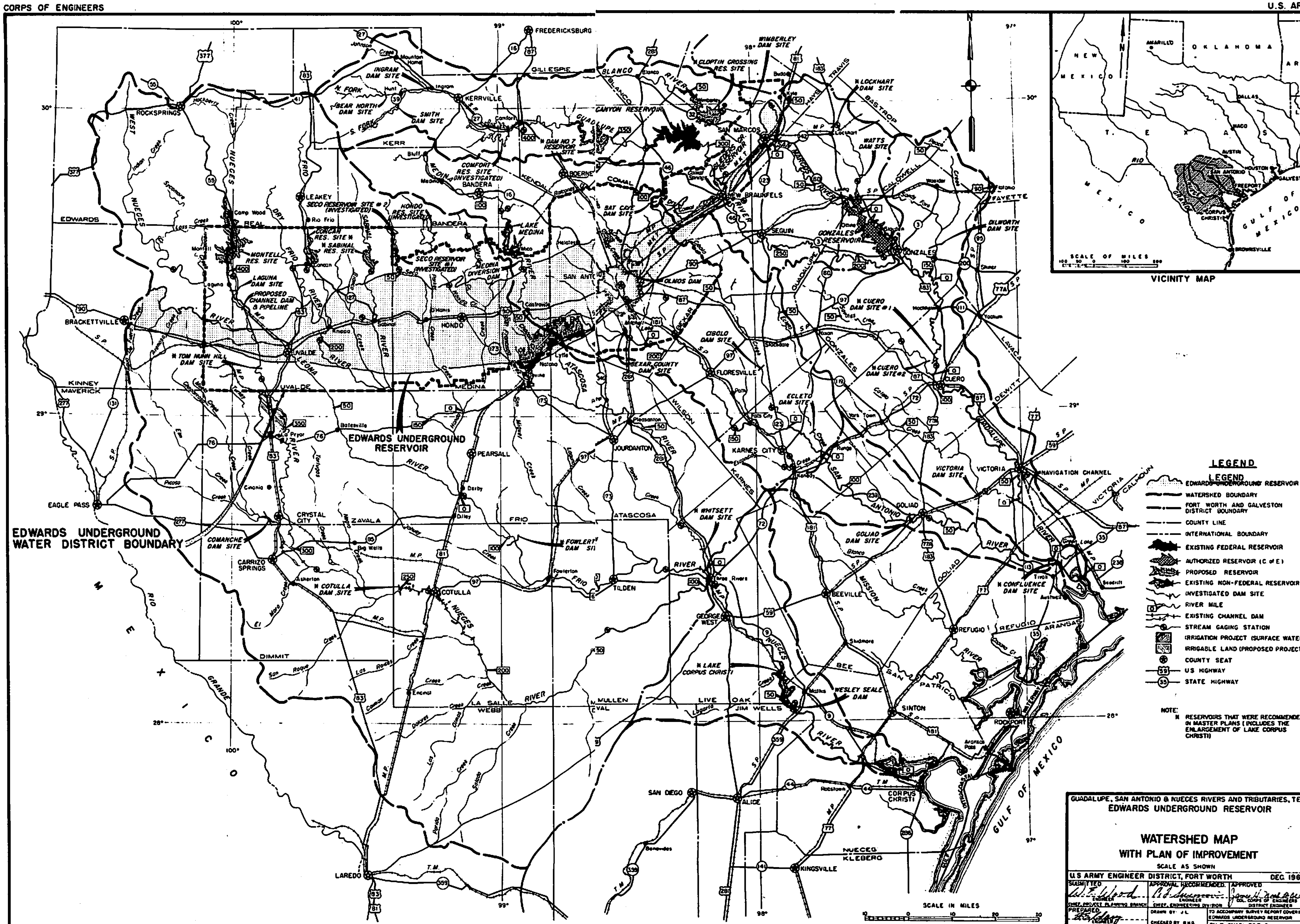
b. Guadalupe River Basin.- The master plan of the Guadalupe-Blanco River Authority provides for the construction of Cloptin Crossing Reservoir, but at a smaller size than that proposed in this report. The master plan also provides for construction of Dam No. 7 Reservoir in case excessive leakage is experienced at Canyon Reservoir; however it would provide less storage than the project proposed in this report. Yield studies made for the two sizes of projects at each of the Cloptin Crossing and Dam No. 7 Reservoir sites and for Canyon and Cuero Reservoirs determined that the critical drought period at each of the above reservoirs was the same and there would be no reservoir spills during this period. For this reason the yield of the Cuero Reservoir as presented in the master plan would not be affected by the increase in the conservation capacity of the Cloptin Crossing and Dam No. 7 Reservoirs as proposed in this report. Also, if the Montell, Concan, and Sabinal Reservoirs in the Nueces River Basin were constructed and operated to recharge the Edwards Underground Reservoir, and if the plan were adopted to limit the pumping from the aquifer to 263,000 acre-feet per year, the additional springflow from the Comal, Hueco, and San Marcos Springs in the Guadalupe River Basin would increase the resources of Cuero Reservoir by 17,600 acre-feet annually. A more detailed discussion of the effect of the proposed projects on the yield of downstream reservoirs is contained in Appendix II, Hydrology and Hydraulic Design.

91. RECREATION - FISH AND WILDLIFE.- To supplement existing recreation developments in the Edwards Reservoir area, it is proposed that land and facilities be provided at the Montell, Concan, Sabinal, and Cloptin Crossing Reservoirs for general recreation and fish and wildlife purposes. The flood control operation of all the projects and the recharge operation of the Montell, Concan, and Sabinal Reservoirs would provide an additional scenic attraction to sightseers. The lowflow of the Nueces River would also be enhanced along a 14-mile reach between the Montell Dam and a channel dam to be constructed immediately upstream from the Edwards outcrop on this stream. The additional recharge water to be provided by the three reservoirs would enhance all the major springs along the Balcones fault zone, as described in paragraph 84b. Of particular significance would be the increase in springflow in the city of San Antonio, estimated to average about 13,300 acre-feet annually. San Antonio and San Pedro Springs have flowed only intermittently in recent years, and the flow of the scenic San Antonio River through the city has been maintained by wells in Brackenridge Park, commercial and industrial wells, and local flood runoff.

92. The recreation lands and facilities proposed in this report would provide recreational opportunities for 2,560,000 visitors annually. Of this total, about 1,700,000 visitors are expected to participate in general recreational activities and about 860,000 visitors in fishing and hunting. The proposed recreational development would complement, but not compete with, those recreational attractions existing in the area. If recreation lands and facilities were provided at the Dam No. 7 Reservoir, this project would attract an estimated additional 4,800,000 visitors annually. A more detailed discussion of the recreation aspects of the proposed reservoir project is contained in Appendix VI, Recreation and Fish and Wildlife.

93. As described by the Bureau of Sport Fisheries and Wildlife in their report attached to appendix VI, inundation of reservoir lands will result in loss of bottomland habitat for big and upland game, particularly deer. Because of the small populations of wild turkey and small fur-bearing animals, they are not expected to be appreciably affected by the proposed projects. The reservoirs with conservation storage will attract

to some degree certain waterfowl during migration, such as mallards, pintails, blue-winged teals, green-winged teals, and coots. Mourning dove populations are expected to continue to be plentiful in the Cloptin Crossing Reservoir area. The Cloptin Crossing and Montell Reservoirs would be clear, attractive impoundments which would provide high quality fish habitat, primarily for largemouth bass, catfish, and white crappie. The fish habitat along the Nueces River between the Montell Dam and the proposed channel dam would also be enhanced by the constant release to be made from the Montell Reservoir.


VICINITY MAP
LEGEND
EDWARDS UNDERGROUND RESERVOIR
WATERSHED BOUNDARY
FORT WORTH AND GALVESTON DISTRICT BOUNDARY
COUNTY LINE
INTERNATIONAL BOUNDARY
EXISTING FEDERAL RESERVOIR
AUTHORIZED RESERVOIR (C of E)
PROPOSED RESERVOIR
EXISTING NON-FEDERAL RESERVOIR
INVESTIGATED DAM SITE
RIVER MILE
EXISTING CHANNEL DAM
STREAM GAGING STATION
IRRIGATION PROJECT (SURFACE WATER)
IRRIGABLE LAND (PROPOSED PROJECT)
COUNTY SEAT
US HIGHWAY
STATE HIGHWAY
NOTE:
✱ RESERVOIRS THAT WERE RECOMMENDED IN MASTER PLANS (INCLUDES THE ENLARGEMENT OF LAKE CORPUS CHRISTI)
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT BOUNDARY
SCALE IN MILES
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
WATERSHED MAP
WITH PLAN OF IMPROVEMENT
SCALE AS SHOWN
U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC 1964
SUBMITTED
APPROVAL RECOMMENDED
APPROVED
CHIEF, PROJECT PLANNING BRANCH
CHIEF, ENGINEERING DIVISION
COL. CORPS OF ENGINEERS DISTRICT ENGINEER
PREPARED
CHIEF, GENERAL INVESTIGATIONS SECT.
TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
FILE GUAD 707-2

COST ALLOCATION AND APPORTIONMENT

94. COST ALLOCATION TO PROJECT PURPOSES.- For the proposed Montell, Concan, Sabinal, and Cloptin Crossing Reservoirs cost allocation studies were made to determine the equitable distribution of the costs to the various project purposes. Allocations were made between the purposes of flood control, water conservation, fish and wildlife and general recreation for the Montell and Cloptin Crossing projects. The costs of the channel dam and pipeline proposed in connection with the Montell Reservoir project are specific costs for water supply purposes and are added to the allocated water supply cost of the reservoir. For the Concan and Sabinal projects, allocations were made between the purposes of flood control, water conservation, and recreation. The total project costs allocated to these purposes for the four reservoir projects are presented in table 17. The allocations were made by the Separable Cost-Remaining Benefits Method. The detailed cost allocations of construction, investment, and annual operation and maintenance costs to various purposes are presented as an attachment to this appendix. Also attached are the summary estimates of first cost and annual charges for single-purpose reservoirs used in the cost allocation studies.

95. APPORTIONMENT OF COSTS AMONG INTERESTS.- A cost apportionment summary is presented in table 18. The apportionment of construction, operation, maintenance, and replacement costs between Federal and non-Federal interests has been made for the four-reservoir projects based on the criteria as described in the following paragraphs.

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

97. The portion of the allocated water supply cost of Montell, Concan, and Sabinal Reservoirs assigned to recharge the Edwards Underground Reservoir has been apportioned both to the Federal Government and to local interests. The largest military complex in the Southwest is located within the Edwards Reservoir area in and around the city of San Antonio. The military installations pumped 13.5 million gallons per day (15,100 acre-feet per year) directly from the underground reservoir in 1962. This quantity represented about 5.5 percent of the total water pumped from the aquifer in 1962. For the period 1955-62 the percentages of water used by the military were virtually the same as those for 1962, and it is assumed that future military water requirements will continue on this same trend. Since the military installations will share with local interests in the benefits to be

derived from the recharge reservoirs, 5.5 percent of the allocated water supply cost of the projects assigned to recharge of the Edwards aquifer have been apportioned to the Federal Government.

98. The cost of Montell and Cloptin Crossing Reservoirs allocated to conventional water supply (including costs for the pipeline and channel dam) is the responsibility of non-Federal interests, in accordance with the provisions of the Water Supply Act of 1958, Public Law 500, 85th Congress, as amended.

99. Recreation is considered to be a project purpose of the Concan and Sabinal Reservoirs, and both general recreation and fish and wildlife recreation are considered to be project purposes of the Montell and Cloptin Crossing Reservoirs. The facilities to be provided have been developed in consonance with Senate Document 97, 87th Congress, 2d Session. Costs for recreation lands and facilities allocated to the Federal Government are within the limits established by H. R. 9032, dated November 6, 1963.

TABLE 17

SUMMARY OF COST ALLOCATIONS
PROPOSED PROJECTS

Project and Purpose	Allocations: First Costs	Allocations: Annual Charges	Annual Benefits	B/C Ratio	Allocated water supply cost per 1,000 gallons
MONTELL RESERVOIR					
Flood Control	$10,873,000	$ 403,200	$ 602,100	1.5	-
Water Conservation:	20,007,000	758,300	1,098,800	1.5	-
Reservoir:	(19,107,000)	(712,300)	(1,052,800)	1.5	-
Recharge	(18,560,000)	(680,100)	(1,010,500)	1.5	0.078
Downstream Supply	(547,000)	(32,200)	(42,300)	1.3	0.023
Pipeline System	(900,000)	(46,000)	(46,000)	1.0	0.056*
Recreation - Fish and Wildlife	1,665,000	76,000	101,500	1.3	-
TOTAL	32,545,000	1,237,500	1,802,400	1.5	
CONCAN RESERVOIR					
Flood Control	1,189,000	55,100	59,300	1.1	-
Water Conservation (Recharge)	14,234,000	531,400	816,800	1.5	0.076
Recreation	227,000	13,000	13,500	1.0	-
TOTAL	15,650,000	599,500	889,600	1.5	
SABINAL RESERVOIR					
Flood Control	898,000	42,800	46,300	1.1	-
Water Conservation (Recharge)	10,288,000	384,900	600,100	1.6	0.075
Recreation	227,000	12,900	13,500	1.0	-
TOTAL	11,413,000	440,600	659,900	1.5	
CLOPTIN CROSSING RESERVOIR					
Flood Control	7,628,000	292,800	659,000	2.2	-
Water Conservation	9,461,000	359,700	653,000	1.8	0.026
Recreation - Fish and Wildlife	7,351,000	383,200	1,285,800	3.4	-
TOTAL	24,440,000	1,035,700	2,597,800	2.5	
TOTAL - PROPOSED PROJECTS	$84,048,000	$3,313,300	$5,949,700	1.8	

*For water conservation storage in the reservoir plus the pipeline system.

TABLE 18

APPORTIONMENT OF COSTS
PROPOSED PROJECTS
(in 1000 dollars)

Project and Purpose	First Cost: Federal	First Cost: Non-Federal	First Cost: Total	Operation, Maintenance and Replacement of Parts Cost: Federal	Operation, Maintenance and Replacement of Parts Cost: Non-Federal	Operation, Maintenance and Replacement of Parts Cost: Total
MONTELL RESERVOIR						
Flood Control	10,873.0	-	10,873.0	19.2	-	19.2
Water Conservation:						
Reservoir:						
Recharge	1,021.0*	17,539.0	18,560.0	1.4*	23.2	24.6
Downstream supply	-	547.0	547.0	-	12.8	12.8
Pipeline System	-	900.0	900.0	-	16.6	16.6
Recreation - Fish and Wildlife	1,665.0	-	1,665.0	17.2	-	17.2
TOTAL	13,559.0	18,986.0	32,545.0	37.8	52.6	90.4
CONCAN RESERVOIR						
Flood Control	1,189.0	-	1,189.0	13.7	-	13.7
Water Conservation (Recharge)	783.0*	13,451.0	14,234.0	2.0*	34.0	36.0
Recreation	227.0	-	227.0	5.1	-	5.1
TOTAL	2,199.0	13,451.0	15,650.0	20.8	34.0	54.8
SABINAL RESERVOIR						
Flood Control	898.0	-	898.0	12.0	-	12.0
Water Conservation (Recharge)	566.0*	9,722.0	10,288.0	1.8*	30.3	32.1
Recreation	227.0	-	227.0	5.1	-	5.1
TOTAL	1,691.0	9,722.0	11,413.0	18.9	30.3	49.2
CLOPTIN CROSSING RESERVOIR						
Flood Control	7,628.0	-	7,628.0	27.3	-	27.3
Water Conservation	-	9,461.0	9,461.0	-	30.4	30.4
Recreation - Fish and Wildlife	7,351.0	-	7,351.0	127.3	-	127.3
TOTAL	14,979.0	9,461.0	24,440.0	154.6	30.4	185.0
TOTAL PROPOSED PROJECTS	32,428.0	51,620.0	84,048.0	232.1	147.3	379.4

*Represents 5.5% of the allocated costs to recharge purposes. All water resources developed by Concan and Sabinal Reservoirs and 86% (26,600 ac.ft./yr) of the water resources developed by Montell Reservoir are indicated for recharge purposes. The remaining 14% (4,300 ac.ft./yr) of water resources developed by Montell Reservoir is indicated for municipal and industrial water supply for downstream areas in the Nueces River Basin.

ATTACHMENT 1

DETAILED AND SUMMARY COST ESTIMATES
AND COST ALLOCATIONS

ATTACHMENT 1

CONTENTS

TABLES

TABLE A1-1

DETAILED ESTIMATE OF FIRST COST
MONTELL DAM AND RESERVOIR
NUECES RIVER
(July 1964 price level)

Item	Unit quantity	Unit cost	Single-purpose 50-year flood control Quantity	Single-purpose 50-year flood control Cost	Multiple-purpose Recharge, W.C., F.C., F.& W. and Recreation Quantity	Multiple-purpose Recharge, W.C., F.C., F.& W. and Recreation Cost
PERTINENT DATA						
Top of dam, elevation			1369.5		1371.0	
Spillway crest, elevation			1328.5		1331.0	
Storage capacity (spillway crest less sediment), acre-feet			225,100		240,300	
A. DETAILED ESTIMATE OF FIRST COST - DAM AND RESERVOIR						
(01.0) Lands and damages						
a. Land costs						
(1) Fee simple lands (including mineral value)	Acre		400	$ 64,000	700	$ 105,000
(2) Flood easement lands	Acre		6,240	545,000	6,440	562,000
(3) Fee severance damage	L.S.			-		-
(4) Easement severance damage	L.S.					
(5) Fee land improvements	L.S.			90,000		90,000
(6) Easement land improvements	L.S.			2,000		2,000
(7) Resettlement reimbursement	L.S.			402,000		408,000
	L.S.			17,000		17,000
Subtotal - land costs				1,120,000		1,184,000
b. Land acquisition expense	L.S.			102,000		103,000
Subtotal - lands and land acquisition				1,222,000		1,287,000
Contingencies, 15% ±				183,000		194,000
TOTAL - LANDS AND DAMAGES				1,405,000		1,481,000
(02.0) Relocations						
a. Roads and bridges						
(1) State Highway 55						
(a) Embankment, borrow	C.Y.	$ 0.60	20,000	12,000	30,000	18,000
(b) Base and surfacing (reservoir crossing)	Mi.	30,000.00	0.2	6,000	0.2	6,000
(c) Riprap	C.Y.	8.00	600	4,800	2,000	16,000
(d) Bedding	C.Y.	6.50	200	1,300	700	4,550
(e) Guard rail	L.F.	2.50	1,800	4,500	2,000	5,000
(f) New road outside reservoir	Mi.	82,000.00	10.3	844,600	10.3	844,600
(g) Connection to existing highway	L.S.			6,900		6,900
(h) Bridge (3 locations)	L.F.	250.00	300	75,000	300	75,000
Subtotal - State Highway 55				955,100		976,050
(2) County roads						
(a) Embankment, borrow	C.Y.	0.60	45,000	27,000	66,000	39,600
(b) Riprap	C.Y.	8.00	2,200	17,600	3,000	24,000
(c) Bedding	C.Y.	6.50	700	4,550	1,000	6,500
(d) Guard rail	L.F.	2.50	1,500	3,750	1,900	4,750
(e) Bridge	L.F.	175.00	150	26,250	150	26,250
(f) Base and surfacing (reservoir crossing)	Mi.	22,000.00	0.2	4,400	0.5	11,000
(g) New road outside reservoir	Mi.	70,000.00	1.417	99,200	1.330	93,100
Subtotal - county roads				182,750		205,200
Subtotal - roads and bridges				1,137,850		1,181,250
b. Cemeteries and utilities						
(1) Electric power lines	L.S.			145,000		145,000
(2) Telephone lines	L.S.			24,000		24,000
(3) Cemeteries	L.S.			51,000		51,000
Subtotal - cemeteries and utilities				220,000		220,000
Subtotal - relocations				1,357,850		1,401,250
Contingencies, 25% ±				339,150		350,750
TOTAL - RELOCATIONS				1,697,000		1,752,000
(03.0) Reservoirs						
a. Clearing	Acre	150.00			260	39,000
Contingencies, 15% ±						6,000
TOTAL - CLEARING						45,000
(04.0) Dams						
a. Embankment						
(1) Care of water	Pump. days	150.00	200	30,000	200	30,000
(2) Clearing and grubbing	Acre	300.00	142	42,600	145	43,500
(3) Excavation, stripping	C.Y.	0.25	101,900	25,475	103,200	25,800
(4) Excavation, common	C.Y.	0.30	76,400	22,920	77,400	23,220
(5) Excavation, cutoff trench	C.Y.	0.80	830,700	664,560	830,700	664,560
(6) Excavation, borrow, impervious	C.Y.	0.50	2,335,000	1,167,500	2,358,000	1,179,000
(7) Excavation, borrow, rock	C.Y.	1.50	-	-	90,000	135,000
(8) Compacted impervious fill	C.Y.	0.10	2,123,000	212,300	2,144,000	214,400
(9) Random rockfill	C.Y.	0.10	10,650,000	1,065,000	10,923,000	1,092,300
(10) Filter material	C.Y.	1.50	1,127,000	1,690,500	1,143,000	1,714,500
(11) Flexible base	C.Y.	7.50	3,630	27,225	3,630	27,225
(12) Aggregate	C.Y.	12.00	290	3,480	290	3,480
(13) Asphalt treatment	Gal.	0.25	15,030	3,758	15,050	3,763
(14) Cofferdam	C.Y.	0.25	223,000	55,750	223,000	55,750
(15) Foundation drilling and grouting	L.S.		-	100,000	-	100,000
(16) Foundation preparation	Sq.	1.00	2,100	2,100	2,100	2,100
Subtotal - embankment				5,113,200		5,314,600
b. Spillway						
(1) Clearing	Acre	150.00	60	9,000	59	8,850
(2) Excavation, rock	C.Y.	1.50	8,938,000	13,407,000	8,979,000	13,468,500
(3) Excavation, structural (rock)	C.Y.	12.00	208	2,496	213	2,556
(4) Concrete (including cement)	C.Y.	35.00	208	7,280	213	7,455
(5) Line drilling	S.F.	1.75	5,610	9,818	5,760	10,080
(6) Reinforcing steel	Lb.	0.15	15,700	2,355	16,100	2,415
(7) Drill and grout anchor holes	L.F.	2.25	935	2,104	960	2,160
(8) Tile gages	L.F.	20.00	82	1,640	80	1,600
Subtotal - spillway				13,441,700		13,503,600
c. Outlet works						
(1) Care of water	Pump. days	150.00	260	39,000	260	39,000
(2) Clearing	Acre	150.00	12	1,800	12	1,800
(3) Excavation, unclassified	C.Y.	1.35	94,000	126,900	94,000	126,900
(4) Backfill, structural	C.Y.	1.00	17,000	17,000	17,000	17,000
(5) Drill and grout anchor holes	L.F.	2.25	3,700	8,325	3,700	8,325
(6) Drill drain holes	L.F.	2.00	2,800	5,600	2,800	5,600
(7) Line drilling	S.F.	1.75	30,900	54,075	31,100	54,425
(8) Operating house	L.S.			20,000		20,000
(9) Concrete, control tower	C.Y.	30.00	655	52,400	665	53,200
(10) Concrete, tower base and transition	C.Y.	35.00	6,740	235,900	6,740	235,900
(11) Concrete, slab	C.Y.	30.00	1,235	37,050	1,235	37,050
(12) Concrete, wall	C.Y.	40.00	1,950	78,000	1,950	78,000
(13) Concrete, conduit	C.Y.	35.00	7,880	275,800	7,980	279,300
(14) Concrete, bridge deck	C.Y.	80.00	112	8,960	114	9,120
(15) Concrete, bridge piers	C.Y.	70.00	430	30,100	440	30,800
(16) Cement	Bbl	5.00	23,750	118,750	23,900	119,500
(17) Steel, reinforcing	Lb.	0.13	2,261,000	293,930	2,274,000	295,620
(18) Steel, structural	Lb.	0.22	137,500	30,250	141,500	31,130
(19) Pipe railing	Lb.	0.35	4,130	1,446	4,200	1,470
(20) Miscellaneous metals	Lb.	0.50	1,000	500	1,000	500
(21) Ladder, grates, grills	Lb.	0.50	3,700	1,850	3,700	1,850
(22) Air vents, steel, 36" ø	L.F.	80.00	300	24,000	300	24,000
(23) Air supply vents, steel, 18" ø	L.F.	60.00	130	7,800	130	7,800
(24) Gage well facilities	L.S.			9,100		9,100
(25) Spiral stairs	L.F.	60.00	130	7,800	130	7,800
(26) Conduit liner	Lb.	0.60	99,600	59,760	99,600	59,760
(27) Rubber water stop	L.F.	3.00	1,980	5,940	2,030	6,090
(28) Water gage, tile	L.F.	20.00	175	3,500	175	3,500
(29) Tractor gates and equipment	L.S.			321,750		321,750
(30) Bulkhead gates and guides	L.S.			35,000		35,000
(31) Ventilation system	L.S.			5,000		5,000
(32) Elevator and inclosure	L.S.			20,000		20,000
(33) Electrical facilities	L.S.			25,000		25,000
(34) Foundation preparation	Sq.	1.00	485	485	490	490
Subtotal - outlet works				1,962,800		1,971,800
Subtotal - dams				20,517,700		20,790,000
Contingencies, 15% ±				3,077,300		3,119,000
TOTAL - DAMS				23,595,000		23,909,000
(08.0) Access road	L.S.			69,500		69,500
Contingencies, 15% ±				10,500		10,500
TOTAL - ACCESS ROAD				80,000		80,000
(19.0) Buildings, grounds, and utilities						
a. Maintenance buildings	L.S.			54,000		54,000
b. Powerline and substation	L.S.			169,000		169,000
c. Water supply	L.S.			10,000		10,000
Subtotal - buildings, grounds, and utilities				233,000		233,000
Contingencies, 15% ±				35,000		35,000
TOTAL - BUILDINGS, GROUNDS AND UTILITIES				268,000		268,000
(20.0) Permanent operating equipment						
a. Stream gages	L.S.			15,000		15,000
b. Radio facilities	L.S.			5,000		5,000
c. Work boat	L.S.			-		10,000
d. Evaporation and rain gages	L.S.			1,000		1,000
e. Sediment and degradation ranges	L.S.			-		51,000
f. Office furniture and equipment	L.S.			5,000		5,000
g. Miscellaneous equipment	L.S.			-		-
Subtotal - permanent operating equipment				26,000		87,000
Contingencies, 15% ±				4,000		13,000
TOTAL - PERMANENT OPERATING EQUIPMENT				30,000		100,000
(30.0) Engineering and design				2,000,000		2,034,000
(31.0) Supervision and administration				1,680,000		1,701,000
TOTAL ESTIMATED FIRST COST - DAM AND RESERVOIR				30,755,000		31,370,000(1)
B. DETAILED ESTIMATE OF FIRST COST - FISH AND WILDLIFE AND RECREATION						
(01.0) Lands and damages (including contingencies)	L.S.					11,500
(03.0) Reservoirs						
a. Clearing (includes contingencies)	Acre	100.00			80	8,000
(14.0) Recreation facilities (includes contingencies)	L.S.					225,500
(30.0) Engineering and design						16,000
(31.0) Supervision and administration						14,000
TOTAL ESTIMATED FIRST COST - FISH, WILDLIFE, AND RECREATION LANDS AND FACILITIES						275,000
TOTAL ESTIMATED FIRST COST - DAM, RESERVOIR, AND RECREATION LANDS AND FACILITIES						31,645,000
C. DETAILED ESTIMATE OF FIRST COST - PIPELINE SYSTEM TO TOM NUNN HILL RESERVOIR SITE						
(04.0) Channel dam (including contingencies)	L.S.					313,000
(09.0) Pipeline (including contingencies)	L.S.					587,000
TOTAL ESTIMATED FIRST COST - PIPELINE SYSTEM TO TOM NUNN HILL RESERVOIR SITE						900,000
D. TOTAL ESTIMATED PROJECT FIRST COST				$30,755,000		$32,545,000

(1) Also single-purpose recharge project or triple-purpose water supply, recharge and flood control project.

TABLE A1-2

DETAILED ESTIMATE OF FIRST COST
CONCAN DAM AND RESERVOIR
FRIO RIVER
(July 1964 price level)

Item	Unit quantity	Unit cost	Single-purpose 50-yr flood control: Quantity	Single-purpose 50-yr flood control: Cost	Joint storage Recharge and 50-yr flood control(1): Quantity	Joint storage Recharge and 50-yr flood control(1): Cost
PERTINENT DATA						
Top of dam, elevation			1399.5		1399.5	
Spillway crest, elevation			1366.5		1366.5	
Storage capacity (spillway crest less sediment), acre-feet			141,200		141,200	
A. DETAILED ESTIMATE OF FIRST COST - DAM AND RESERVOIR						
(01.0) Lands and damages						
a. Land costs						
(1) Fee simple lands	Acre	-	400	$ 145,000	880	$ 319,000
(2) Flood easement lands	Acre	-	3,960	822,200	3,480	723,800
(3) Fee and easement severance damages	L.S.			130,000		130,000
(4) Fee and easement land improvements	L.S.			540,000		540,000
(5) Mineral estate	L.S.			32,700		32,700
(6) Resettlement reimbursement	L.S.			14,700		14,700
Subtotal - land costs				1,684,600		1,760,200
b. Land acquisition	L.S.			112,900		112,900
Subtotal - lands and land acquisition				1,797,500		1,873,100
Contingencies, 15% ±				269,500		280,900
TOTAL - LANDS AND DAMAGES				2,067,000		2,154,000
(02.0) Relocations						
a. Roads and bridges						
(1) U. S. Highway 83 (raise in place)						
(a) Embankment complete (borrow)	C.Y.	$ 0.60	25,000	$ 15,000	25,000	$ 15,000
(b) Base and surfacing	Mi.	30,000.00	0.4	12,000	0.4	12,000
(c) Riprap	C.Y.	8.00	1,500	12,000	1,500	12,000
(d) Bedding	C.Y.	6.50	500	3,250	500	3,250
(e) Guardrail	L.F.	2.50	2,000	5,000	2,000	5,000
(f) Culvert	L.S.			4,000		4,000
(g) Detour	L.S.			3,000		3,000
(2) County roads						
(a) New road	Mi.	56,000.00	6.2875	352,100	6.2875	352,100
(b) Bridge	L.F.	175.00	100	17,500	100	17,500
(3) Park road - Garner State Park	Mi.	26,500.00	0.2	5,300	0.2	5,300
Subtotal - roads				429,150		429,150
b. Utilities						
(1) Rural electric distribution lines	Mi.	2,000.00	5.0	10,000	5.0	10,000
(2) Rural telephone lines	Mi.	1,200.00	5.0	6,000	5.0	6,000
(3) Relocate small structures in Garner State Park	Ea.	2,000.00	5	10,000	5	10,000
Subtotal - utilities				26,000		26,000
Subtotal - relocations				455,150		455,150
Contingencies, 25% ±				113,850		113,850
TOTAL - RELOCATIONS				$ 569,000		$ 569,000
(04.0) Dams						
a. Embankment						
(1) Care of water	Pump days	150.00	150	22,500	150	22,500
(2) Clearing and grubbing	Acre	300.00	65	19,500	65	19,500
(3) Excavation, stripping	C.Y.	0.30	46,300	13,890	46,300	13,890
(4) Excavation, common	C.Y.	0.40	34,800	13,920	34,800	13,920
(5) Excavation, cutoff trench	C.Y.	1.00	80,600	80,600	80,600	80,600
(6) Excavation, impervious, borrow	C.Y.	0.50	781,800	390,900	781,800	390,900
(7) Compacted impervious fill	C.Y.	0.10	710,800	71,080	710,800	71,080
(8) Excavation, rock, borrow	C.Y.	1.25	2,713,000	3,391,250	2,713,000	3,391,250
(9) Random rockfill	C.Y.	0.10	4,984,000	498,400	4,984,000	498,400
(10) Filter material	C.Y.	1.50	507,200	760,800	507,200	760,800
(11) Flexible base	C.Y.	7.50	1,460	10,950	1,460	10,950
(12) Aggregate	C.Y.	12.00	120	1,440	120	1,440
(13) Asphalt treatment	Gal.	0.25	6,040	1,510	6,040	1,510
(14) Cofferdam	C.Y.	0.40	48,000	19,200	48,000	19,200
(15) Foundation preparation	Sq.	1.00	770	770	770	770
(16) Foundation drilling and grouting	L.S.			175,000		175,000
Subtotal - embankment				5,471,700		5,471,700
b. Spillway						
(1) Clearing	Acre	150.00	77	11,550	77	11,550
(2) Excavation, rock	C.Y.	1.50	1,352,000	2,028,000	1,352,000	2,028,000
(3) Excavation, structural (rock)	C.Y.	12.00	660	7,920	660	7,920
(4) Concrete (includes cement)	C.Y.	35.00	860	30,100	860	30,100
(5) Line drilling	S.F.	1.75	6,480	11,340	6,480	11,340
(6) Steel, reinforcing	Lb.	0.15	99,800	14,970	99,800	14,970
(7) Drill and grout anchor holes	L.F.	2.25	1,930	4,343	1,930	4,343
(8) Tile gages	L.F.	20.00	66	1,320	66	1,320
Subtotal - spillway				2,109,500		2,109,500
c. Outlet works						
(1) Care of water	Pump days	150.00	210	31,500	210	31,500
(2) Clearing	Acre	150.00	5	750	5	750
(3) Excavation, unclassified	C.Y.	0.90	265,000	238,500	265,000	238,500
(4) Backfill, structural	C.Y.	1.00	14,000	14,000	14,000	14,000
(5) Drill and grout anchor holes	L.F.	2.25	2,520	5,670	2,520	5,670
(6) Drill drain holes	L.F.	2.00	1,890	3,780	1,890	3,780
(7) Line drilling	S.F.	1.75	25,100	43,925	25,100	43,925
(8) Operating house	L.S.			20,000		20,000
(9) Concrete, control tower	C.Y.	80.00	660	52,800	660	52,800
(10) Concrete, tower base and transition	C.Y.	35.00	5,230	183,050	5,230	183,050
(11) Concrete, slab	C.Y.	30.00	710	21,300	710	21,300
(12) Concrete, wall	C.Y.	40.00	1,255	50,200	1,255	50,200
(13) Concrete, conduit	C.Y.	35.00	7,100	248,500	7,100	248,500
(14) Concrete, bridge deck	C.Y.	80.00	120	9,600	120	9,600
(15) Concrete, bridge piers	C.Y	70.00	450	31,500	450	31,500
(16) Cement	Bbl.	5.00	19,400	97,000	19,400	97,000
(17) Steel, reinforcing	Lb.	0.13	1,820,000	236,600	1,820,000	236,600
(18) Steel, structural	Lb.	0.22	149,000	32,780	149,000	32,780
(19) Pipe railing	Lb.	0.35	4,400	1,540	4,400	1,540
(20) Miscellaneous metal	Lb.	0.50	1,000	500	1,000	500
(21) Ladder, gates, grille	Lb.	0.50	3,700	1,850	3,700	1,850
(22) Air vents, steel, 36"ø	L.F.	80.00	305	24,400	305	24,400
(23) Air supply vent, steel 18"ø	L.F.	60.00	134	8,040	134	8,040
(24) Gage well facilities	L.S.			7,000		7,000
(25) Spiral stairs	L.F.	60.00	134	8,040	134	8,040
(26) Conduit liner	Lb.	0.60	70,190	42,114	70,190	42,114
(27) Rubber water stop	L.F.	3.00	1,885	5,655	1,885	5,655
(28) Water gages, tile	L.F.	20.00	185	3,700	185	3,700
(29) Tractor gates and equipment	L.S.			214,500		214,500
(30) Bulkhead gate and guides	L.S.			25,000		25,000
(31) Ventilation system	L.S.			5,000		5,000
(32) Elevator and inclosure	L.S.			20,000		20,000
(33) Electrical facilities	L.S.			25,000		25,000
Subtotal - outlet works				1,714,800		1,714,800
Subtotal - dams				9,296,000		9,296,000
Contingencies, 15% ±				1,394,000		1,394,000
TOTAL - DAMS				10,690,000		10,690,000
(08.0) Access road	L.S.			82,500		82,500
Contingencies, 15% ±				12,500		12,500
TOTAL - ACCESS ROAD				95,000		95,000
(19.0) Buildings, grounds, and utilities						
a. Maintenance buildings	L.S.			54,000		54,000
b. Water supply	L.S.			10,000		10,000
c. Powerline and substation	L.S.			161,000		161,000
Subtotal - buildings, grounds, and utilities				225,000		225,000
Contingencies, 15% ±				34,000		34,000
TOTAL - BUILDINGS, GROUNDS AND UTILITIES				259,000		259,000
(20.0) Permanent operating equipment						
a. Radio-telephone equipment	L.S.			5,000		5,000
b. Boat	L.S.			-		-
c. Miscellaneous furniture and equipment	L.S.			5,000		5,000
d. Stream gages	L.S.			15,000		15,000
e. Evaporation and rain gages	L.S.			1,000		1,000
f. Sediment and degradation ranges	L.S.			-		-
Subtotal - permanent operating equipment.				26,000		26,000
Contingencies, 15% ±				4,000		4,000
TOTAL - PERMANENT OPERATING EQUIPMENT				30,000		30,000
(30.0) Engineering and design				1,009,000		1,009,000
(31.0) Supervision and administration				772,000		772,000
TOTAL - ESTIMATED FIRST COST - DAM AND RESERVOIR				15,491,000		15,578,000
B. DETAILED ESTIMATE OF FIRST COST - RECREATION						
(01.0) Lands and damages (including contingencies)	Acre	300.00			10	3,000
(03.0) Reservoirs						
a. Clearing (includes contingencies)	Acre	100.00			30	3,000
(14.0) Recreation facilities (includes contingencies)	L.S.					57,000
(30.0) Engineering and design						6,000
(31.0) Supervision and administration						3,000
TOTAL - ESTIMATED FIRST COST - RECREATION						72,000
C. TOTAL - ESTIMATED PROJECT COST				$15,491,000		$15,650,000

(1) Also single-purpose recharge reservoir project and multiple-purpose recharge, flood control, and recreation project.

TABLE A1-3

DETAILED ESTIMATE OF FIRST COST
SABINAL DAM AND RESERVOIR
SABINAL RIVER
(July 1964 price level)

Item	Unit quantity	Unit cost	Single-purpose 50-year flood control		Joint-storage Recharge and 50-yr flood control (1)	
			Quantity	Cost	Quantity	Cost
PERTINENT DATA						
Top of dam, elevation			1241.0		1244.0	
Top of gates, elevation			1223.5		1226.5	
Spillway crest, elevation			1193.5		1196.5	
Storage capacity (top of gates less sediment), acre-feet			80,400		89,100	
A. DETAILED ESTIMATE OF FIRST COST - DAM AND RESERVOIR						
(01.0) Lands and damages						
a. Land costs						
(1) Fee simple land	Acre		400	$ 70,800	400	$ 70,800
(2) Flood easement lands	Acre		2,810	421,500	3,000	450,000
(3) Fee severance damage	L.S.			80,000		80,000
(4) Fee land improvements	L.S.			252,000		267,000
(5) Mineral value	L.S.			19,400		20,600
(6) Resettlement reimbursement	L.S.			6,000		6,000
Subtotal - land costs				849,700		894,400
b. Land acquisition expense	L.S.			50,000		50,000
Subtotal - lands and land acquisition				899,700		944,400
Contingencies, 15% ±				135,300		141,600
TOTAL - LANDS AND DAMAGES				1,035,000		1,086,000
(02.0) Relocations						
a. Roads and bridges						
(1) Farm to Market Highway 187						
(a) New road complete	Mi.	$75,000.00	6	450,000	6	450,000
(b) Bridge	L.F.	200.00	250	50,000	250	50,000
(c) Connections to existing highways	L.S.			10,700		10,700
Subtotal - roads and bridges				510,700		510,700
b. Utilities						
(1) Rural electric distribution lines	Mi.	2,000.00	8.7	17,400	8.7	17,400
(2) Rural telephone lines	Mi.	1,200.00	8.7	10,440	8.7	10,440
Subtotal - utilities				27,840		27,840
Subtotal - relocations				538,540		538,540
Contingencies, 25% ±				134,460		134,460
TOTAL - RELOCATIONS				673,000		673,000
(04.0) Dams						
a. Embankment						
(1) Care of water	Pump days	150.00	160	24,000	160	24,000
(2) Clearing and grubbing	Acre	300.00	22	6,600	21	6,300
(3) Excavation, stripping	C.Y.	0.25	13,900	3,475	14,600	3,650
(4) Excavation, common	C.Y.	0.35	10,400	3,640	11,000	3,850
(5) Excavation, cutoff trench	C.Y.	1.00	30,600	30,600	30,600	30,600
(6) Excavation, random, borrow	C.Y.	0.30	521,000	156,300	542,000	162,600
(7) Excavation, impervious, borrow	C.Y.	0.50	706,100	353,050	755,400	377,700
(8) Compacted impervious fill	C.Y.	0.10	641,900	64,190	686,800	68,680
(9) Filter material	C.Y.	3.00	61,800	185,400	66,100	198,300
(10) Random fill	C.Y.	0.10	479,700	47,970	516,500	51,650
(11) Riprap	C.Y.	8.00	30,000	240,000	31,500	252,000
(12) Bedding	C.Y.	6.00	11,200	67,200	11,800	70,800
(13) Flexible base	C.Y.	8.00	720	5,760	740	5,920
(14) Aggregate	C.Y.	12.00	55	660	60	720
(15) Asphalt treatment	Gal.	0.25	2,950	738	3,070	768
(16) Cofferdam	C.Y.	0.50	12,000	6,000	12,000	6,000
(17) Slope protection	Acre	500.00	8	4,000	9	4,500
(18) Foundation preparation	Sq.	1.00	250	250	250	250
(19) Foundation drilling and grouting	L.S.			100,000		100,000
Subtotal - embankment				1,299,800		1,368,300
b. Concrete dam and spillway						
(1) Care of water	Pump days	150.00	300	45,000	300	45,000
(2) Cofferdam	C.Y.	0.35	62,000	21,700	62,000	21,700
(3) Clearing	Acre	150.00	34	[illegible]	[illegible]	[illegible]
(4) Drill and grout anchor holes	L.F.	2.25	9,300	20,925	9,600	21,600
(5) Drill drain holes	L.F.	2.00	7,000	14,000	7,200	14,400
(6) Line drilling	S.F.	1.75	23,500	41,125	24,000	42,000
(7) Concrete, weir	C.Y.	25.00	45,610	1,140,250	48,680	1,217,000
(8) Concrete, non-overflow	C.Y.	25.00	53,200	1,330,000	57,950	1,448,750
(9) Concrete, pier	C.Y.	40.00	5,020	200,800	5,020	200,800
(10) Concrete, slab	C.Y.	25.00	4,110	102,750	4,210	105,250
(11) Concrete, wall	C.Y.	35.00	9,080	317,800	9,270	324,450
(12) Concrete, bridge deck	C.Y.	75.00	80	6,000	80	6,000
(13) Cement	Bbl	5.00	146,380	731,900	156,520	782,600
(14) Steel, reinforcing	Lb.	0.13	4,144,000	538,720	4,344,000	564,720
(15) Steel, structural	Lb.	0.22	78,000	17,160	78,000	17,160
(16) Pipe railing, 2" ϕ aluminum	Lb.	1.50	4,000	6,000	4,000	6,000
(17) Bridge railing, 2-1/2" ϕ aluminum	Lb.	1.50	7,400	11,100	7,400	11,100
(18) Miscellaneous metals	Lb.	0.50	10,000	5,000	10,000	5,000
(19) Ladders, grates, and grills	Lb.	0.50	8,000	4,000	8,000	4,000
(20) Walkways	Lb.	0.50	5,600	2,800	5,600	2,800
(21) Waterstops, rubber	L.F.	3.00	2,570	7,710	2,650	7,950
(22) Tile gages	L.F.	20.00	155	3,100	158	3,160
(23) Tainter gates	Lb.	0.40	512,000	204,800	512,000	204,800
(24) Gate hoists, shafts, hangers	Lb.	1.25	123,000	153,750	123,000	153,750
(25) Trunion anchorage and seals	Lb.	0.40	156,000	62,400	156,000	62,400
(26) Sluice gates and operating equipment	Ea.	32,500.00	4	130,000	4	130,000
(27) Trash racks and guides	Lb.	0.40	7,100	2,840	7,400	2,960
(28) Emergency bulkheads	Lb.	0.50	52,800	26,400	52,800	26,400
(29) Precast bridge girders	Ea.	720.00	18	12,960	18	12,960
(30) Crane	L.S.			34,000		34,000
(31) Electrical facilities	L.S.			50,000		50,000
(32) Standby power unit	L.S.			10,000		10,000
(33) Foundation preparation	Sq.	1.00	1,040	1,040	1,060	1,060
Subtotal - concrete dam and spillway				5,261,100		5,544,900
Subtotal - dams				6,560,900		6,913,200
Contingencies, 15% ±				984,100		1,036,800
TOTAL - DAMS				7,545,000		7,950,000
(08.0) Access road	L.S.			23,000		23,000
Contingencies, 15%				3,000		3,000
TOTAL - ACCESS ROA.				26,000		26,000
(19.0) Buildings, grounds and utilities						
(1) Maintenance buildings	L.S.			54,000		54,000
(2) Water supply	L.S.			10,000		10,000
(3) Power line and substation	L.S.			97,000		97,000
Subtotal - buildings, grounds and utilities				161,000		161,000
Contingencies, 15% ±				24,000		24,000
TOTAL - BUILDINGS, GROUNDS AND UTILITIES				185,000		185,000
(20.0) Permanent operating equipment						
(1) Radio - telephone equipment	L.S.			5,000		5,000
(2) Miscellaneous furniture and equipment	L.S.			5,000		5,000
(3) Stream gages	L.S.			15,000		15,000
(4) Evaporation and rain gages	L.S.			1,000		1,000
Subtotal - permanent operating equipment				26,000		26,000
Contingencies - 15% ±				4,000		4,000
TOTAL - PERMANENT OPERATING EQUIPMENT				30,000		30,000
(30.0) Engineering and design				800,000		805,000
(31.0) Supervision and administration				565,000		586,000
TOTAL - ESTIMATED FIRST COST - DAM AND RESERVOIR				10,859,000		11,341,000
B. DETAILED ESTIMATE OF FIRST COST - RECREATION						
(01.0) Lands and damages (includes contingencies)	Acre	300.00			10	3,000
(03.0) Reservoirs						
a. Clearing (includes contingencies)	Acre	100.00			30	3,000
(14.0) Recreation facilities (includes contingencies)	L.S.					57,000
(30.0) Engineering and design						5,000
(31.0) Supervision and administration						4,000
TOTAL - ESTIMATED FIRST COST - RECREATION						72,000
C. TOTAL ESTIMATED PROJECT FIRST COST				$10,859,000		$11,413,000

(1) Also single-purpose recharge reservoir project and multiple-purpose recharge, flood control and recreation project.

TABLE A1-4

DETAILED ESTIMATE OF FIRST COST
CLOPTIN CROSSING DAM AND RESERVOIR
BLANCO RIVER
(July 1964 price level)

Item	Unit quantity	Unit cost	Single-purpose 75-Yr flood control Quantity	Single-purpose 75-Yr flood control Cost	Single-purpose maximum water conservation Quantity	Single-purpose maximum water conservation Cost	Multiple-purpose FC, WC, FW, & R Quantity	Multiple-purpose FC, WC, FW, & R Cost
PERTINENT DATA								
Top of dam, elevation			973.0		1005.0		1023.0	
Spillway crest, elevation			947.0		980.0		998.0	
Storage capacity (spillway crest less sediment), acre-feet			114,700		271,200		394,800	
A. DETAILED ESTIMATE OF FIRST COST - DAM AND RESERVOIR								
(01.0) Lands and damages								
a. Land costs								
(1) Fee simple lands (including minerals)	Acre		500	$ 70,000	6,580	$ 590,600	9,700	$ 1,043,000
(2) Flood easement lands and improvements	Acre		3,700	211,600		-		-
(3) Fee severance damage	L.S.			55,000		75,000		100,000
(4) Fee land improvements	L.S.			70,000		660,000		775,000
(5) Easement land improvements	L.S.			475,000		-		-
(6) Resettlement reimbursement	L.S.			20,000		24,000		26,000
Subtotal - land costs				901,600		1,349,600		1,944,000
b. Land acquisition expense	L.S.			56,000		70,400		70,400
Subtotal - lands and land acquisition				957,600		1,420,000		2,014,400
Contingencies, 15% ±				143,400		213,000		301,600
TOTAL - LANDS AND DAMAGES				1,101,000		1,633,000		2,316,000
(02.0) Relocations								
a. Roads and bridges								
(1) County road - Bendigo crossing								
(a) New road	Mi.	$60,000.00	1.3	78,000	1.3	78,000	1.3	78,000
(b) Bridge	L.F.	175.00	200	35,000	320	56,000	400	70,000
Subtotal - roads and bridges				113,000		134,000		148,000
b. Utilities								
(1) Electric power lines	Mi.	2,000.00	2	4,000	2	4,000	2	4,000
(2) Rural telephone lines	Mi.	1,200.00	2	2,400	2	2,400	2	2,400
Subtotal - utilities				6,400		6,400		6,400
Subtotal - relocations				119,400		140,400		154,400
Contingencies, 25% ±				29,600		34,600		38,600
TOTAL - RELOCATIONS				149,000		175,000		193,000
(03.0) Reservoirs								
a. Clearing	Acre	50.00		-	3,720	186,000	3,750	187,500
Contingencies, 15% ±				-		28,000		28,500
TOTAL - RESERVOIRS						214,000		216,000
(04.0) Dams								
a. Embankment								
(1) Care of water	Pump. days	150.00	75	11,250	120	18,000	160	24,000
(2) Clearing and grubbing	Acre	350.00	57	19,950	88	30,800	110	38,500
(3) Excavation, stripping	C.Y.	0.30	37,800	11,340	58,900	17,670	74,700	22,410
(4) Excavation, common	C.Y.	0.40	28,300	11,320	44,200	17,680	56,000	22,400
(5) Excavation, borrow, rock	C.Y.	1.25	-	-	4,530,000	5,662,500	6,610,000	8,262,500
(6) Excavation, borrow, impervious	C.Y.	0.50	524,200	262,100	846,600	423,300	1,098,000	549,000
(7) Excavation, cutoff trench	C.Y.	1.00	32,500	32,500	32,500	32,500	32,500	32,500
(8) Compacted impervious fill	C.Y.	0.10	476,600	47,660	769,600	76,960	998,200	99,820
(9) Filter material	C.Y.	1.50	524,200	786,300	822,700	1,234,050	1,057,100	1,585,650
(10) Random rockfill	C.Y.	0.10	2,458,000	245,800	4,939,000	493,900	6,905,000	690,500
(11) Flexible base	C.Y.	6.50	2,230	14,495	3,320	21,580	3,720	24,180
(12) Aggregate	C.Y.	12.00	180	2,160	270	3,240	300	3,600
(13) Asphalt treatment	Gal.	0.25	9,200	2,300	13,740	3,435	15,380	3,845
(14) Cofferdam	C.Y.	0.20	80,000	16,000	80,000	16,000	80,000	16,000
(15) Foundation preparation	Sq.	1.00	315	315	315	315	315	315
(16) Foundation drilling and grouting	L.S.			100,000		150,000		200,000
Subtotal - embankment				1,563,500		8,201,900		11,575,200
b. Spillway								
(1) Clearing	Acre	200.00	84	16,800	21	4,200	35	7,000
(2) Excavation, common	C.Y.	0.40	663,000	265,200	170,000	68,000	223,000	89,200
(3) Excavation, rock	C.Y.	1.25	3,285,000	4,106,250	200,000	250,000	110,000	137,500
(4) Concrete, slab	C.Y.	25.00	23,680	592,000	18,440	461,000	14,750	368,750
(5) Concrete, wall	C.Y.	35.00	980	34,300	980	34,300	980	34,300
(6) Cement	Bbl.	5.00	30,830	154,150	24,280	121,400	19,660	98,300
(7) Reinforcing steel	Lb.	0.13	1,870,000	243,100	1,470,000	191,100	1,200,000	156,000
(8) Riprap	C.Y.	6.00	16,540	99,240	13,040	78,240	10,580	63,480
(9) Bedding	C.Y.	5.00	7,100	35,500	5,600	28,000	4,540	22,700
(10) Drill and grout anchor holes	L.F.	2.25	32,000	72,000	25,250	56,813	20,500	46,125
(11) Line drilling	S.F.	1.75	26,800	46,900	23,500	41,125	21,200	37,100
Subtotal - spillway				5,665,400		1,334,200		1,060,500
c. Outlet works								
(1) Care of water	Pump. days	150.00	230	34,500	200	30,000	200	30,000
(2) Clearing	Acre	200.00	9	1,800	9	1,800	9	1,800
(3) Excavation, unclassified	C.Y.	1.50	214,000	321,000	181,000	271,500	184,000	276,000
(4) Backfilling, structural	C.Y.	1.00	4,000	4,000	6,700	6,700	7,700	7,700
(5) Drill and grout anchor holes	L.F.	2.25	5,120	11,520	5,300	11,925	5,300	11,925
(6) Drill drain holes	L.F.	2.00	3,120	6,240	3,250	6,500	3,250	6,500
(7) Line drilling	S.F.	1.75	22,200	38,850	24,900	43,575	26,400	46,200
(8) Operating house	L.S.			20,000		20,000		20,000
(9) Concrete, control tower	C.Y.	75.00	380	28,500	620	46,500	740	55,500
(10) Concrete, tower base and transition	C.Y.	30.00	6,740	202,200	5,230	156,900	5,230	156,900
(11) Concrete, conduit	C.Y.	30.00	4,170	125,100	5,240	157,200	6,550	196,500
(12) Concrete, slab	C.Y.	25.00	1,130	28,250	1,130	28,250	1,130	28,250
(13) Concrete, wall	C.Y.	35.00	1,070	37,450	1,150	40,250	1,150	40,250
(14) Concrete, bridge deck	C.Y.	75.00	70	5,250	100	7,500	120	9,000
(15) Cement	Bbl.	5.00	17,100	85,500	17,310	86,550	19,210	96,050
(16) Steel, reinforcing	Lb.	0.13	1,653,000	214,890	1,652,000	214,760	1,811,000	235,430
(17) Steel, structural	Lb.	0.20	76,000	15,200	121,000	24,200	158,000	31,600
(18) Pipe railing	Lb.	0.35	2,500	875	3,840	1,344	4,600	1,610
(19) Metals, miscellaneous	Lb.	0.50	1,000	500	1,000	500	1,000	500
(20) Ladders, grates, grills	Lb.	0.50	3,600	1,800	3,200	1,600	3,200	1,600
(21) Spiral stairs	L.F.	55.00	62	3,410	99	5,445	117	6,435
(22) Conduit liner	Lb.	0.55	99,600	54,780	70,200	38,610	70,200	38,610
(23) Rubber water stop	L.F.	3.00	1,250	3,750	1,830	5,490	1,970	5,910
(24) Water gages, tile	L.F.	20.00	143	2,860	175	3,500	193	3,860
(25) Tractor gates and equipment	L.S.			297,000		214,500		214,500
(26) Bulkhead gates, guides, etc.	L.S.			30,000		25,000		25,000
(27) Gage well facilities	L.S.			3,700		5,250		6,150
(28) Electrical facilities	L.S.			22,000		22,000		22,000
(29) Riprap	C.Y.	6.00	2,780	16,680	2,780	16,680	2,780	16,680
(30) Bedding	C.Y.	5.00	1,110	5,550	1,110	5,550	1,110	5,550
(31) Concrete, bridge piers	C.Y.	65.00	120	7,800	380	24,700	450	29,250
(32) Air vents, 18" ø	L.F.	60.00	55	3,300	90	5,400	110	6,600
(33) Air vents, 36" ø	L.F.	80.00	320	25,600	280	22,400	310	24,800
(34) Ventilation system	L.S.			5,000		5,000		5,000
(35) Elevator, inclosure, etc.	L.S.			20,000		20,000		20,000
(36) Foundation preparation	Sq.	1.00	595	595	600	600	650	650
Subtotal - outlet works				1,685,500		1,577,700		1,684,300
Subtotal - dams				8,914,400		11,113,800		14,320,000
Contingencies, 15% ±				1,337,600		1,667,200		2,148,000
TOTAL - DAMS				10,252,000		12,781,000		16,468,000
(08.0) Access road	L.S.			11,600		11,600		11,600
Contingencies, 15% ±				1,400		1,400		1,400
TOTAL - ACCESS ROAD				13,000		13,000		13,000
(19.0) Buildings, grounds and utilities								
a. Maintenance facilities	L.S.			54,000		54,000		54,000
b. Water supply	L.S.			12,000		12,000		12,000
c. Powerline and substation	L.S.			121,000		121,000		121,000
Subtotal - buildings, grounds and utilities				187,000		187,000		187,000
Contingencies, 15% ±				28,000		28,000		28,000
TOTAL - BUILDINGS, GROUNDS AND UTILITIES				215,000		215,000		215,000
(20.0) Permanent operating equipment								
(1) Radio-telephone equipment	L.S.			4,000		4,000		4,000
(2) Boat	L.S.			-		8,000		8,000
(3) Miscellaneous furniture and equipment	L.S.			5,000		10,800		10,800
(4) Stream gages	L.S.			15,000		15,000		15,000
(5) Evaporation and rain gages	L.S.			1,000		1,000		1,000
(6) Sedimentation and degradation ranges	L.S.			-		68,300		68,300
Subtotal - permanent operating equipment				25,000		107,100		107,100
Contingencies, 15% ±				4,000		15,900		15,900
TOTAL - PERMANENT OPERATING EQUIPMENT				29,000		123,000		123,000
(30.0) Engineering and design				970,000		1,160,000		1,252,000
(31.0) Supervision and administration				710,000		895,000		999,000
TOTAL - ESTIMATED PROJECT FIRST COST - DAM AND RESERVOIR (Single- and dual-purpose projects)				13,439,000		17,209,000		21,795,000
B. DETAILED ESTIMATE OF FIRST COST - FISH AND WILDLIFE AND RECREATION								
(01.0) Lands and damages								
a. Land costs								
(1) Fee simple lands	Acre						900	168,100
(2) Fee severance damage	L.S.							10,000
Subtotal - land costs								178,100
Contingencies, 15% ±								26,700
TOTAL - LAND COSTS								204,800
b. Land acquisition expense	L.S.							5,200
TOTAL - LANDS AND DAMAGES								210,000
(03.0) Reservoirs								
a. Clearing	Acre						2,420	96,800
Contingencies, 15% ±								14,200
TOTAL - RESERVOIRS								111,000
(14.0) Recreation facilities								
a. Access roads and park roads	L.S.							795,600
b. Parking areas	L.S.							185,000
c. Picnic facilities	L.S.							407,000
d. Water supply	L.S.							185,000
e. Sanitary facilities	L.S.							166,500
f. Boat launching ramps	L.S.							55,500
g. Vegetative improvements	L.S.							37,000
h. Signs	L.S.							37,000
Subtotal - recreation facilities								1,868,600
Contingencies, 10% ±								186,400
TOTAL - RECREATION FACILITIES								2,055,000
(30.0) Engineering and design								138,000
(31.0) Supervision and administration								131,000
TOTAL - ESTIMATED FIRST COSTS - FISH AND WILDLIFE AND RECREATION								2,645,000
C. TOTAL - ESTIMATED PROJECT FIRST COST				$13,439,000		$17,209,000		$24,440,000

TABLE A1-5

SUMMARY OF FIRST COSTS
PROPOSED ALTERNATE WATER CONSERVATION
ONLY PROJECT TO YIELD 4 MGD
NUECES RIVER
(July 1, 1964, price level)

A. First cost dam and reservoir:

(01.0) Lands and damages	$81,000
(02.0) Relocations	2,000
(03.0) Reservoirs (clearing)	46,600
(04.0) Dam, concrete	1,012,400
(20.0) Permanent operating equipment	10,000
(30.0) Engineering and design	215,600
(31.0) Supervision and administration	90,400
Total estimated first cost (dam and reservoir)	$1,458,000
First cost of channel dam	313,000
First cost of pipeline	587,000
Total estimated first cost of project	$2,358,000

(Interest rate: 3-1/8%; amortization: 100 years)

Construction period: 1 year

B. Investment cost:

1. First cost	$2,358,000
2. Interest during construction	0
Total investment cost	$2,358,000

C. Annual charges:

1. Interest on investment	$73,700
2. Amortization	3,600
3. Operations, maintenance, and replacements	20,000
Total annual charges	$97,300

TABLE A1-6

SUMMARY OF FIRST COSTS AND ANNUAL CHARGES
PROPOSED RESERVOIR FOR RECREATION AND FISH-WILDLIFE ENHANCEMENT
BLANCO RIVER
(July 1964 price level)

A. First cost:

(01.0) Lands and damages (reservoir and recreation areas)	$1,676,000
(02.0) Relocations	175,000
(03.0) Reservoir clearing (reservoir and recreation areas)	251,000
(04.0) Dam	
(a) Embankment	3,233,000
(b) Spillway	4,945,000
(c) Outlet works	1,685,000
(08.0) Access roads	13,000
(14.0) Recreation facilities	2,055,000
(19.0) Buildings, grounds, and utilities	215,000
(20.0) Permanent operating equipment	123,000
(30.0) Engineering and design	1,138,000
(31.0) Supervision and administration	871,000
Total estimated first cost of project	$16,380,000

(Interest rate: 3-1/8%; amortization: 100 years)

Construction period: 4 years

B. Investment cost:

1. First cost	$16,380,000
2. Interest during construction	1,024,000
Total investment cost	$17,404,000

C. Annual charges:

1. Interest on investment	$543,900
2. Amortization	26,300
3. Operations, maintenance and replacements	140,000
Total annual charges	$710,200

TABLE A1-7

ALLOCATION OF COSTS
(SEPARABLE COSTS-REMAINING BENEFITS METHOD)
MONTELL RESERVOIR
(July 1964 price level)

	Single-purpose: 50-Yr. Flood Control	Single-purpose: Water Conservation	Single-purpose: Recharge	Single-purpose: Fish & Wildlife and Recreation	Multiple-purpose	Triple-purpose: Flood Control, Water Conservation, and Recharge	Triple-purpose: Flood Control, Recharge, and Recreation	Triple-purpose: Flood Control, Water Conservation, and Recreation	Triple-purpose: Water Conservation, Recharge and Recreation
PERTINENT INFORMATION									
Construction period, years	5	-	5	-	5	5	5	5	5
First costs, dollars	30,755,000	1,458,00	31,370,000		31,645,000	31,370,000	31,645,000	31,130,000	31,645,000
Investment costs, dollars	33,158,000	1,458,00	33,821,000		34,117,000	33,821,000	34,117,000	33,562,000	34,117,000
Annual charges, dollars	1,130,300	51,00	1,153,000	(1)	1,191,500	1,165,500	1,179,000	1,159,900	1,179,000
Annual maintenance and operation, dollars	44,100	3,00	45,000		73,800	57,500	61,300	60,400	61,300
Increased recharge, acre-feet annually	-	-	26,600		26,600				
Dependable yield, acre-feet annually	-	4,00	-		4,300				
Dependable yield, million gallons daily	-	4	-		4				
Dependable yield, thousand gallons annually	-	1,401,65	-		1,401,065				
Increased recharge, thousand gallons annually	-	-	8,667,051(2)		8,667,051				
Total annual benefits, dollars	602,100	42,00	1,010,500	101,500	1,756,400				
Flood control storage, acre-feet	225,100	-	-		239,300(3)				
Recharge storage, acre-feet	-	-	239,300						
Water conservation storage, acre-feet	-	1,00	-		1,000				
Sediment storage, acre-feet	12,000	1,50	12,000		12,000				
Total storage, acre-feet	237,100	2,50	251,300		252,300				
COST ALLOCATIONS									
Allocation of annual charges, dollars									
1. Benefits	602,100	42,00	1,010,500	101,500	1,756,400				
2. Alternate cost	1,130,300	51,00	1,153,000	(1)	-				
3. Benefits limited by alternate cost	602,100	42,00	1,010,500	101,500	-				
4. Separable costs	12,500	12,00	31,600	26,000	82,600				
5. Remaining benefits	589,600	29,00	978,900	75,500	1,673,800				
6. Percent distribution of item 5	35.23	178	58.48	4.51	100				
7. Allocated joint cost	390,700	19,00	648,500	50,000	1,108,900				
8. Total allocation	403,200	32,00	680,100	76,000	1,191,500				
9. Percent distribution of item 8	33.84	270	57.08	6.38	100				
Allocation of operation and maintenance costs, dollars									
10. Separable costs	12,500	12,00	13,400	16,300	54,700				
11. Percent joint costs, item 6	35.23	178	58.48	4.51	100				
12. Allocated joint costs	6,700	00	11,200	900	19,100				
13. Total allocation	19,200	12,00	24,600	17,200	73,800				
14. Percent distribution of item 13	26.02	1734	33.33	23.31	100				
Allocation of initial investment, dollars									
15. Allocated annual charges	403,200	32,00	680,100	76,000	1,191,500				
16. Allocated O&M costs	19,200	12,00	24,600	17,200	73,800				
17. Remainder	384,000	19,00	655,500	58,800	1,117,700				
18. Percent distribution of item 17	34.36	173	58.65	5.26	100				
19. Allocated investment	11,723,000	590,00	20,010,000	1,794,000	34,117,000				
20. Allocated first costs	10,873,000	547,00	18,560,000	1,665,000	31,645,000				
Ratio of annual benefits to allocated annual charges	1.5	.3	1.5	1.3	1.5				
Allocated costs of water									
Increased recharge cost per thousand gallons, dollars					0.078				
Downstream water supply cost per thousand gallons, dollars (less pipeline)					0.023				
Downstream water supply cost per thousand gallons, dollars (including pipeline)					0.056				
Excess benefits over annual charges, dollars					564,900				

SPECIFIC COSTS

Purpose	Amount (dollars)
Recreation, Fish & Wildlife	
First cost	275,000
Operation, maintenance & replacements	16,300
Annual charges	26,000
Pipeline	
First cost	900,000
Operation, maintenance & replacements	16,600
Annual charges (4)	46,000

NOTE:
(1) Annual charges for single-purpose recreation project assumed to excd annual benefits.
(2) Net increase in average annual recharge.
(3) Joint storage for flood control and recharge.
(4) Pipeline costs and benefits amounting to $46,000 omitted from allocion.

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'ABLE A1-8

INVESTMENT C STS AND ANNUAL CHARGES

MON ELL RESERVOIR

(Interest rate: 3-1 8% - Amortization: 100 years)
(July 964 price level)
(In 1,000 dollars)

Item	Single-purpose: 50-yr Flood Control	Single-purpose: Water Conservation	Single-purpose: Recharge	Single-purpose: Recreation	Triple-purpose: F.C., W.C., Recharge	Triple-purpose: F.C., Recharge, & Recreation	Triple-purpose: F.C., W.C., & Recreation	Triple-purpose: W.C., Recharge & Recreation	Multiple-purpose: F.C., W.C., Recharge & Recreation	Specific costs: Recreation	Specific costs: Water Conservation**
Construction period (years)	5	-	5	-	5	5	5	5	5	5	-
INVESTMENT COSTS											
Estimated first cost	30,755.0	1,458.0	31,370.0	*	31,370.0	31,645.0	31,130.0	31,645.0	31,645.0	275.0	900.0
Interest during construction	2,403.0	-	2,451.0		2,451.0	2,472.0	2,432.0	2,472.0	2,472.0	21.0	-
Total investment	33,158.0	1,458.0	33,821.0		33,821.0	34,117.0	33,562.0	34,117.0	34,117.0	296.0	900.0
ANNUAL CHARGES											
Interest on investment	1,036.2	45.6	1,056.9		1,056.9	1,066.2	1,048.8	1,066.2	1,066.2	9.3	28.1
Amortization	50.0	2.2	51.1		51.1	51.5	50.7	51.5	51.5	0.4	1.3
Operation, maintenance and replacement	44.1	3.4	45.0		57.5	61.3	60.4	61.3	73.8	16.3	16.6
Total annual charges	1,130.3	51.2	1,153.0	*	1,165.5	1,179.0	1,159.9	1,179.0	1,191.5	26.0	46.0

* Annual charges for alternate recreation project assumed to exceed annual benefits.
** Channel dam and pipeline for downstream water supply.

TABLE A1-9

ALLOCATION OF COSTS
(SEPARABLE COSTS-REMAINING BENEFITS METHOD)
CONCAN RESERVOIR
(July 1964 price level)

	Single-purpose			Multiple-purpose	Dual-purpose		
	50-Year Flood Control	Recharge	Recreation		50-Year Flood Control and Recreation	50-Year Flood Control and Recharge	Recharge and Recreation
PERTINENT INFORMATION							
Construction period, years	4	4	-	4	4	4	4
First costs, dollars	15,491,000	15,578,000		15,650,000	15,563,000	15,578,000	15,650,000
Investment costs, dollars	16,459,000	16,552,000		16,628,000	16,536,000	16,552,000	16,628,000
Annual charges, dollars	577,500	580,500	*	599,500	584,800	592,200	587,800
Annual maintenance and operation, dollars	38,300	38,300		54,800	43,100	50,000	43,100
Increased recharge, acre-feet annually	-	21,500		21,500			
Increased recharge, thousand gallons annually	-	7,005,324		7,005,324			
Total annual benefits, dollars	59,300	816,800	13,500	889,600			
Flood control storage, acre-feet	141,200	-		141,200**			
Recharge storage, acre-feet	-	141,200					
Sediment storage, acre-feet	7,800	7,800		7,800			
Total storage, acre-feet	149,000	149,000		149,000			
COST ALLOCATIONS							
Allocation of annual charges, dollars							
1. Benefits	59,300	816,800	13,500	889,600			
2. Alternate cost	577,500	580,500	*	-			
3. Benefits limited by alternate cost	59,300	580,500	13,500	-			
4. Separable costs	11,700	14,700	7,300	33,700			
5. Remaining benefits	47,600	565,800	6,200	619,600			
6. Percent distribution of item 5	7.68	91.32	1.00	100			
7. Allocated joint cost	43,400	516,700	5,700	565,800			
8. Total allocation	55,100	531,400	13,000	599,500			
9. Percent distribution of item 8	9.19	88.64	2.17	100			
Allocation of operation and maintenance costs, dollars							
10. Separable costs	11,700	11,700	4,800	28,200			
11. Percent joint costs, item 6	7.68	91.32	1.00	100			
12. Allocated joint costs	2,000	24,300	300	26,600			
13. Total allocation	13,700	36,000	5,100	54,800			
14. Percent distribution of item 13	25.00	65.69	9.31	100			
Allocation of initial investment, dollars							
15. Allocated annual charges	55,100	531,400	13,000	599,500			
16. Allocated O&M costs	13,700	36,000	5,100	54,800			
17. Remainder	41,400	495,400	7,900	544,700			
18. Percent distribution of item 17	7.60	90.95	1.45	100			
19. Allocated investment	1,264,000	15,123,000	241,000	16,628,000			
20. Allocated first costs	1,189,000	14,234,000	227,000	15,650,000			
Ratio of annual benefits to allocated annual charges	1.1	1.5	1.0	1.5			
Allocated increased recharge cost per 1000 gallons, dollars				0.076			
Excess benefits over annual charges, dollars				290,100			

SPECIFIC COSTS

Purpose	Amount (dollars)
Recreation	
First cost	72,000
Operation, maintenance, and replacements	4,800
Annual charges	7,300

* Annual charges for single-purpose recreation project assumed to be greater than annual benefits.
** Joint storage for flood control and recharge.

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TABLE A1-10

INVESTMENT COSTS AND ANNUAL CHARGES

CONCAN RESERVOIR

(Interest rate: 3-1/8% - Amortization: 100 years)
(July 1964 price levels)
(In 1,000 dollars)

Item	Single-purpose			Dual-purpose			Multiple-purpose	
	50-yr Flood Control	Recharge	Recreation	50-yr F.C. & Recharge	Recharge & Recreation	50-yr F.C. & Recreation	50-yr F.C., Rechg and Recreation	Specific costs for Recreation
Construction period (years)	4	4	-	4	4	4	4	4
INVESTMENT COSTS								
Estimated first cost	15,491.0	15,578.0	*	15,578.0	15,650.0	15,563.0	15,650.0	72.0
Interest during construction	968.0	974.0		974.0	978.0	973.0	978.0	4.0
Total investment	16,459.0	16,552.0		16,552.0	16,628.0	16,536.0	16,628.0	76.0
ANNUAL CHARGES								
Interest on investment	514.3	517.2		517.2	519.6	516.7	519.6	2.4
Amortization	24.9	25.0		25.0	25.1	25.0	25.1	0.1
Operation, maintenance and replacements	38.3	38.3		50.0	43.1	43.1	54.8	4.8
Total annual charges	577.5	580.5	*	592.2	587.8	584.8	599.5	7.3

*Annual charges for alternate recreation project assumed to exceed annual benefits.

TABLE A1-11

ALLOCATION OF COSTS
(SEPARABLE COSTS-REMAINING BENEFITS METHOD)
SABINAL RESERVOIR
(July 1964 price level)

	Single-purpose			Multiple-purpose	Dual-purpose		
	50-Year Flood Control	Recharge	Recreation		50-Year Flood Control and Recharge	50-Year Flood Control and Recreation	Recharge and Recreation
PERTINENT INFORMATION							
Construction period, years	3	3		3	3	3	3
First costs, dollars	10,859,000	11,341,00		11,413,000	11,341,000	10,931,000	11,413,000
Investment costs, dollars	11,368,000	11,873,00		11,948,000	11,873,000	11,443,000	11,948,000
Annual charges, dollars	405,800	423,40	*	440,600	433,300	413,100	430,600
Annual maintenance and operation, dollars	33,400	34,40		49,200	44,400	38,200	39,200
Increased recharge, acre-feet annually	-	15,80		15,800			
Increased recharge, thousand gallons annually		5,148,09		5,148,098			
Total annual benefits, dollars	46,300	600,10	13,500	659,900			
Flood control storage, acre-feet	80,400	-		89,100**			
Recharge storage, acre-feet	-	89,10					
Sediment storage, acre-feet	4,200	4,20		4,200			
Total storage, acre-feet	84,600	93,30		93,300			
COST ALLOCATIONS							
Allocation of annual charges, dollars							
1. Benefits	46,300	600,10	13,500	659,900			
2. Alternate cost	405,800	423,40	*	-			
3. Benefits limited by alternate cost	46,300	423,40	13,500	-			
4. Separable costs	10,000	27,50	7,300	44,800			
5. Remaining benefits	36,300	395,90	6,200	438,400			
6. Percent distribution of item 5	8.28	90.3	1.41	100			
7. Allocated joint cost	32,800	357,40	5,600	395,800			
8. Total allocation	42,800	384,90	12,900	440,600			
9. Percent distribution of item 8	9.71	87.3	2.93	100			
Allocation of operation and maintenance costs, dollars							
10. Separable costs	10,000	11,00	4,800	25,800			
11. Percent joint costs, item 6	8.28	90.3	1.41	100			
12. Allocated joint costs	2,000	21,10	300	23,400			
13. Total allocation	12,000	32,10	5,100	49,200			
14. Percent distribution of item 13	24.39	65.2	10.37	100			
Allocation of initial investment, dollars							
15. Allocated annual charges	42,800	384,90	12,900	440,600			
16. Allocated O&M costs	12,000	32,10	5,100	49,200			
17. Remainder	30,800	352,80	7,800	391,400			
18. Percent distribution of item 17	7.87	90.1	1.99	100			
19. Allocated investment	940,000	10,770,00	238,000	11,948,000			
20. Allocated first costs	898,000	10,288,00	227,000	11,413,000			
Ratio of annual benefits to allocated annual charges	1.1	1.	1.0	1.5			
Allocated increased recharge cost per 1000 gallons, dollars				0.075			
Excess benefits over annual charges, dollars				219,300			

SPECIFIC COSTS

Purpose	Amount (dollars)
Recreation	
First cost	72,000
Operation, maintenance and replacements	4,800
Annual charges	7,300

*Annual charges for single-purpose recreation project assumed to be greater than annual benefits.
**Joint storage for flood control and recharge.

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TABLE A1-12

INVESTMENT COSTS AND ANNUAL CHARGES

SABINAL RESERVOIR

(Interest rate: 3-1/8% - Amortization: 100 years)
(July 1964 price levels)
(In 1,000 dollars)

Item	Single-purpose: 50-yr Flood Control	Single-purpose: Recharge	Single-purpose: Recreation	Dual-purpose: 50-yr F.C. & Recharge	Dual-purpose: Recharge and Rec.	Dual-purpose: 50-yr F.C. and Recreation	Multiple-purpose 50-yr F.C. Recharge and Recreation	Specific costs for Recreation
Construction period (years)	3	3		3	3	3	3	3
INVESTMENT COSTS								
Estimated first cost	10,859.0	11,341.0	*	11,341.0	11,413.0	10,931.0	11,413.0	72.0
Interest during construction	509.0	532.0		532.0	535.0	512.0	535.0	4.0
Total investment	11,368.0	11,873.0		11,873.0	11,948.0	11,443.0	11,948.0	76.0
ANNUAL CHARGES								
Interest on investment	355.2	371.1		371.0	373.4	357.6	373.4	2.4
Amortization	17.2	17.9		17.9	18.0	17.3	18.0	0.1
Operation, maintenance and replacements	33.4	34.4		44.4	39.2	38.2	49.2	4.8
Total annual charges	405.8	423.4	*	433.3	430.6	413.1	440.6	7.3

*Annual charges for alternate recreation project assumed to exceed annual benefits.

TABLE A1-13

ALLOCATION OF COSTS
(SEPARABLE COSTS-REMAINING BENEFITS METHOD)
CLOPTIN CROSSING RESERVOIR
(July 1964 price level)

	Single-purpose				Dual-purpose		
	75-Yr Flood Control	Maximum Water Conservation	Recreation - Fish & Wildlife	Multiple-purpose	Flood Control & Recreation - Fish & Wildlife	Water Conservation & Recreation - Fish & Wildlife	Flood Control & Water Conservation
PERTINENT INFORMATION							
Construction period, years	4	4	4	4	4	4	4
First costs, dollars	13,439,000	17,209,000	16,380,000	24,440,000	19,090,000	19,854,000	21,795,000
Investment costs, dollars	14,279,000	18,285,000	17,404,000	25,968,000	20,283,000	21,095,000	23,157,000
Annual charges, dollars	504,800	645,000	710,200	1,035,700	825,400	853,500	823,600
Annual maintenance and operation, dollars	37,000	46,000	140,000	185,000	161,000	162,400	65,000
Dependable yield, acre-feet annually	-	42,700	-	42,700			
Dependable yield, million gallons daily	-	38	-	38			
Dependable yield, thousand gallons annually	-	13,912,898	-	13,912,898			
Total annual benefits, dollars	659,000	653,000	1,285,800	2,597,800			
Flood control storage, acre-feet	114,700	-	-	119,900			
Water conservation storage, acre-feet	-	271,200	133,400	274,900			
Sediment storage, acre-feet	9,200	9,200	9,200	9,200			
Total storage, acre-feet	123,900	280,400	142,600	404,000			
COST ALLOCATIONS							
Allocation of annual charges, dollars							
1. Benefits	659,000	653,000	1,285,800	2,597,800			
2. Alternate cost	504,800	645,000	710,200	-			
3. Benefits limited by alternate cost	504,800	645,000	710,200	-			
4. Separable costs	182,200	210,300	212,100	604,600			
5. Remaining benefits	322,600	434,700	498,100	1,255,400			
6. Percent distribution of item 5	25.65	34.65	39.70	100			
7. Allocated joint cost	110,600	149,400	171,100	431,100			
8. Total allocation	292,800	359,700	383,200	1,035,700			
9. Percent distribution of item 8	28.27	34.73	37.00	100			
Allocation of operation and maintenance costs, dollars							
10. Separable costs	22,600	24,000	120,000	166,600			
11. Percent joint costs, item 6	25.65	34.65	39.70	100			
12. Allocated joint costs	4,700	6,400	7,300	18,400			
13. Total allocation	27,300	30,400	127,300	185,000			
14. Percent distribution of item 13	14.76	16.43	68.81	100			
Allocation of initial investment, dollars							
15. Allocated annual charges	292,800	359,700	383,200	1,035,700			
16. Allocated O&M costs	27,300	30,400	127,300	185,000			
17. Remainder	265,500	329,300	255,900	850,700			
18. Percent distribution of item 17	31.21	38.71	30.08	100			
19. Allocated investment	8,105,000	10,052,000	7,811,000	25,968,000			
20. Allocated first costs	7,628,000	9,461,000	7,351,000	24,440,000			
Ratio of annual benefits to allocated annual charges	2.2	1.8	3.4	2.5			
Allocated unit construction cost (cost/acre-feet exclusive of O&M), dollars							
Flood control storage				63.62			
Water conservation storage				34.42			
Allocated water supply cost per 1000 gallons, dollars				0.026			
Excess benefits over annual charges, dollars				1,562,100			

SPECIFIC COSTS

Purpose	Amount (dollars)
Recreation, Fish and Wildlife	
First cost	2,645,000
Operation, maintenance, and replacements	120,000
Annual charges	212,100

TABLE A1-14

INVESTMENT COSTS AND ANNUAL CHARGES
CLOPTIN CROSSING RESERVOIR
(Interest rate: 3-1/8% - Amortization: 100 years)
(July 1964 price levels)
(In 1000 dollars)

Item	Single-purpose			Dual-purpose			Multiple-purpose	Specific costs (Rec., F&W)
	75-yr. F.C.	Max. W.C.	Rec., F&W	75-yr. F.C. & Max. W.C.	75-yr. F.C. & Rec., F&W	Max. W.C. & Rec., F&W	75-yr. F.C., Max. W.C. & Rec., F&W	
Construction period (years)	4	4	4	4	4	4	4	4
INVESTMENT COSTS								
Estimated first cost	13,439.0	17,209.0	16,380.0	21,795.0	19,090.0	19,854.0	24,440.0	2,645.0
Interest during construction	840.0	1,076.0	1,024.0	1,362.0	1,193.0	1,241.0	1,528.0	165.0
Total investment	14,279.0	18,285.0	17,404.0	23,157.0	20,283.0	21,095.0	25,968.0	2,810.0
ANNUAL CHARGES								
Interest on investment	446.2	571.4	543.9	723.7	633.8	659.2	811.5	87.8
Amortization	21.6	27.6	26.3	34.9	30.6	31.9	39.2	4.3
Oper., Maint., & Replacements	37.0	46.0	140.0	65.0	161.0	162.4	185.0	120.0
Total annual charges	504.8	645.0	710.2	823.6	825.4	853.5	1,035.7	212.1

TABLE A1-15

COST SHARING FOR RECREATION AND FISH AND WILDLIFE

Item	Montell 50-yr Flood Control, Recharge, and Water Conservation	Concan Joint-Use Flood Control and Recharge	Sabinal Joint-Use Flood Control and Recharge	Cloptin Crossing 75-yr Flood Control Water Conservation
1. COST-SHARING FOR RECREATION AND FISH AND WILDLIFE UNDER H.R. 9032				
a. Joint-Use Costs (Lands and Facilities)				
(1) Total initial construction costs	$31,645,000	$15,650,000	$11,413,000	$24,440,000
(2) Total specific land and facilities	275,000	72,000	72,000	2,645,000
(3) Total joint-use lands and facilities	31,370,000	15,578,000	11,341,000	21,795,000
b. Allocated Construction Costs for Recreation and Fish and Wildlife				
(1) Specific costs	275,000	72,000	72,000	2,645,000
(2) Joint costs	929,000	17,000	14,000	1,257,000
(3) Other costs (Separable less specific)	461,000	138,000	141,000	3,449,000
(4) Total	1,665,000	227,000	227,000	7,351,000
c. Cost-Sharing Under H.R. 9032				
(1) Non-Reimbursables (Federal)				
(a) Specific costs	275,000	72,000	72,000	2,645,000
(b) Joint costs	929,000	17,000	14,000	1,257,000
(c) Limit on joint costs under H.R. 9032	5,705,000	3,337,000	2,701,000	4,269,000
(d) Other costs	461,000	138,000	141,000	3,449,000
(e) Limit on other costs under H.R. 9032	5,000,000	3,894,000	2,835,000	5,000,000
(f) Federal costs (Non-reimbursable)	1,665,000	227,000	227,000	7,351,000
(2) Reimbursables (Non-Federal)				
(a) Excess of joint costs over limit	-	-	-	-
(b) Excess of other costs	-	-	-	-
(c) Non-Federal costs (Reimbursable)	-	-	-	-

ATTACHMENT 2

REPORT BY PUBLIC HEALTH SERVICE

WATER SUPPLY
AND
WATER QUALITY CONTROL STUDY
EDWARDS UNDERGROUND RESERVOIR
TEXAS

Study of Needs and Value of Storage
For Municipal and Industrial Water Supply
and Water Quality Control

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

FEBRUARY 1965

WATER SUPPLY

AND

WATER QUALITY CONTROL STUDY

EDWARDS UNDERGROUND RESERVOIR

TEXAS

Abstract

An investigation has been carried out which discloses the need for and value of storage for municipal and industrial water supply in the proposed Cloptin Crossing, Montell, Concan, and Sabinal Reservoirs. The latter three reservoirs are to be used to recharge the Edwards limestone fault zone aquifer which provides municipal and industrial water supply. A portion of the immediate and future needs for water in the study area can be satisfied from storage in these projects. The investigation further found need for water quality control in the San Antonio River downstream from San Antonio. Economic and demographic studies revealed a potential for increased industrial development and population growth, and serve as the foundation for the projected needs.

Prepared for

DEPARTMENT OF THE ARMY

U.S. Army Engineer District

Fort Worth, Texas

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

JANUARY 1965

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I. INTRODUCTION

Request and Authority

In a letter dated November 30, 1962, the U.S. Army Engineer District, Fort Worth, Texas, requested that the Department of Health, Education, and Welfare make necessary studies ". . . to determine the estimated water needs and value of the water for the area included in the authorized study (the Edwards Underground Reservoir area of Texas). . . ." This study is in accordance with provisions of (1) the Federal Water Pollution Control Act, as amended (33 U.S.C. 466 et seq.), and (2) a Memorandum of Agreement between the Department of the Army and the Department of Health, Education, and Welfare dated November 4, 1958.

Purpose and Scope

The purpose of the study is to estimate the water requirements for municipal and industrial and water quality control purposes in the Edwards Underground Reservoir area of Texas and the surrounding study area to the year 2075. Estimates are also made of the value of benefits attributable to the Federal reservoir projects which will provide storage of water for these purposes.

In addition to determining requirements, an area-wide plan for supplying these needs is developed, which provides for orderly and efficient utilization of potential water resources within the area, and gives full recognition to all permits, commitments, and agreements executed by local interests.

Acknowledgments

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

Bureau of Business Research, University of Texas, Austin, Texas
Texas State Department of Health, Austin, Texas
Texas Water Commission, Austin, Texas
U.S. Army Engineer District, Fort Worth, Texas
U.S. Department of Agriculture, San Marcos, Texas

II. SUMMARY OF FINDINGS AND CONCLUSIONS

Summary of Findings

1. The study area comprises 14 counties in south Texas, 7 of which are in part underlain by the Edwards Underground Reservoir. It is generally coincident with the upper portions of three river basins: the Guadalupe, the San Antonio, and the Nueces.

2. The Edwards and associated limestones rank with some of the best aquifers in the country. The exceptionally high transmissibility of the fault zone aquifer permits the movement of ground water from one river basin to another.

3. The economy of the study area is highly diversified. Agriculture and manufacturing together accounted for 15.4 percent of the labor force in 1960.

4. The San Antonio Standard Metropolitan Statistical Area (SMSA) accounts for over 80 percent of the water use in the study area.

5. The water quality of the existing and firmly planned sources is acceptable for municipal, industrial, and agricultural uses.

6. The project design incorporates the following base streamflows in the system: (a) Most severe drought of record for reservoir (surface and ground) yields as determined by the Corps of Engineers, and (b) monthly low flows with an exceedence of 95 percent for calculating water quality control needs.

Conclusions

1. To insure continued growth, careful planning for efficient development of all of the study area's water resources is essential. Realization of the full potential of these resources for municipal, industrial, agricultural, and recreational purposes will be possible only if present and future pollution in the area is controlled. Since presently known methods of waste treatment cannot accomplish this control, some means of maintaining minimum quality conditions in the area's waters must be made a part of the water supply plan.

2. The study area's population is expected to grow to 2,950,000 by the year 2025, and 4,620,000 by the year 2075, from a base of 846,000 in 1960.

3. Estimated future municipal and industrial water supply needs for the study area are 689 million gallons per day (mgd) in the year 2025 and 1,167 mgd in 2075.

4. With the water supply plan as presented herein, the potential water resources located within the study area are sufficient to satisfy all estimated area municipal and industrial water requirements until the year 2000. The addition of the tentative quantity of 180,000 acre-feet per year (161 mgd) from the proposed Cuero Reservoir (Guadalupe River, mile 110.8) will provide sufficient water to supply all municipal and industrial needs until the year 2018, at which time the area would become deficient. The projected irrigation needs to this time will be satisfied from direct use of municipal and industrial return flows.

5. To maintain water quality in the San Antonio River downstream from the study area will require a draft-on-storage of 123,000 acre-feet per year in the year 1970; 280,000 acre-feet per year in the year 2025; and 454,700 acre-feet per year in the year 2075, assuming 85 percent removal of biochemical oxygen demand (BOD) and a low streamflow with a recurrence interval of 20 years. No source of water to meet this requirement was found in the study area ; therefore, maintenance of good water quality in the San Antonio River will be contingent on development of highly efficient advanced waste treatment and water reuse techniques.

6. The three proposed recharge reservoirs will have no effect on the quality of the Edwards Underground water, since the waters to be impounded to recharge the aquifer are from the same source streams as the present uncontrolled recharge water.

7. Minimum annual project water supply benefits based on alternative costs (See Appendix) are as follows:

Reservoir	Water Supply Benefits
Cloptin Crossing	$ 653,000
Montell	1,098,800
Concan	816,800
Sabinal	600,100

Since need for the project reservoirs is immediate, the above values have not been discounted. The value of benefits was determined as being equal to the cost of the most likely alternate source of water supply that would be used in the absence of the project.

III. PROJECT DESCRIPTION

Location and Purpose

The project consists of four reservoirs located in two river basins as shown in figure III-1 located at the back of this report. One of the proposed reservoirs, Cloptin Crossing, is a conventional multiple-purpose project located in the Guadalupe River basin. The remaining three, Montell, Concan, and Sabinal, all in the Nueces River basin, are designed to increase the yield of the Edwards limestone fault-zone aquifer through recharge. This recharge is to be accomplished by releasing waters from the joint storage pools for flood control and recharge purposes. These surface releases would be absorbed by the aquifer as they flow downstream through a zone where the streambeds and the Edwards limestone aquifer are hydraulically connected.

Pertinent Data

Pertinent data for the four project reservoirs are shown below in table III-1. Also included is the pertinent data for Dam Number 7 Reservoir which is recommended for local interest construction.

In addition, Canyon Reservoir at mile 303.0 of the Guadalupe River has been constructed by the Corps of Engineers. Deliberate impoundment began on June 16, 1964. This project has a conservation pool capacity of 366,400 acre-feet and a yield of 86.0 mgd. Other study area reservoirs with conservation pool capacities in excess of 5,000 acre-feet are Dunlap, McQueeney, and H-4, all power projects in the Guadalupe River basin, and Medina Lake, an irrigation project in the San Antonio River basin. Although it is located outside the study area, the proposed Cuero Reservoir (Guadalupe River, mile 110.8) is expected to provide an additional water supply of 161 mgd or 180,000 acre-feet per year to the study area.

Table III-1

Pertinent Data

Reservoir	River Mile	Stream	Basin	Conservation Storage (1,000 ac./ft.)	Joint-Storage FC & Recharge (1,000 ac./ft.)	Increased Resources for Recharge (mgd)	Dependable Yield (mgd)
Montell	401.6	Nueces	Nueces	1.0	239.3	23.7	4.0 a/
Concan	226.2	Frio	Nueces	-	141.2	19.2	-
Sabinal	42.3	Sabinal	Nueces	-	89.1	14.1	-
Cloptin Crossing	32.5	Blanco	Guadalupe	274.9	-	-	38.0
Dam No. 7 b/	351.3	Guadalupe	Guadalupe	640.5	-	-	41.0 c/

a/ Used to satisfy existing downstream appropriated water rights by passing the yield around the recharge zone via a pipeline.

b/ Recommended for local interest construction.

c/ Net increase of Canyon-Dam No. 7 Reservoir system over that yield determined for Canyon Reservoir without upstream development.

Source: Corps of Engineers 1/

Recharge Data

The Corps of Engineers, in making routings for determining the yield of the Edwards fault-zone aquifer, used a control elevation of 612 feet mean sea level (m.s.l.) in Bexar County Well H-26 (Beverly Lodges). See figure III-1 for the location of this observation well. This is considered the lowest safe water level in the aquifer and was previously reached in the year 1956, when the underground reservoir was dewatered to its lowest historical level. Chances are that lowering of the water level below this control elevation would increase the possibility of intrusion of highly mineralized water which is found to the south of the highly pumped zone in the San Antonio area.

These routings indicate a recharge of 423,200 acre-feet per year through the routing period of 1935-1956 under existing conditions of recharge. With the recharge reservoirs in operation, the period recharge would be 487,100 acre-feet per year, which represents an increase of 63,900 acre-feet per year. This increase is divided between spring flow and pumping as shown in table III-2.

The proposed recharge reservoirs should have no effect on ground water quality in the Edwards limestone aquifer, since natural recharge to the aquifer is from the same streams and in the same places.

Table III-2

Average Annual Discharge of Edwards Fault Zone Aquifer Through Period of Routing, 1935-1956

Mode of Discharge	Existing Conditions	With Recharge Reservoirs	Increase
Pumping	234,000	263,000	29,000
Spring Flow*	285,900**	320,800	34,900***
Total	519,900	583,800	63,900

*For purposes of this report, spring flow is assumed to consist of Comal, San Marcos, and Hueco Springs in the Guadalupe River basin; San Antonio and San Pedro Springs in the San Antonio River basin; and Leona Springs in the Nueces River basin.

**Under assumed conditions of constant pumping of 234,000 acre-feet per year during period of routing. The total average annual spring flow for the period 1935-1956 was 352,400 acre-feet.

***The increase of 34,900 acre-feet per year is divided among the springs as follows: (1) Comal, San Marcos, and Hueco Springs, 17,600 acre-feet per year; (2) San Antonio and San Pedro Springs, 13,300 acre-feet per year; and (3) Leona River Springs, 4,000 acre-feet per year.

Source: Corps of Engineers 1/

IV. STUDY AREA DESCRIPTION

General

The study area comprises 14 counties, 7 of which are in part underlain by the Edwards Underground Reservoir of Texas. Also, the area is generally coincident with the upper portions of three river basins: the Guadalupe, the San Antonio, and the Nueces. (See figure III-1.) The study area, which comprises over 5 percent of the land area of the State of Texas, is located between 97° and 101° west longitude, and 29° and 30° north latitude, and includes the San Antonio SMSA.

Geography

Blanco, Comal, Kendall, Kerr, Edwards, Real, Bandera, and Hays Counties are located on the Edwards Plateau, which is a limestone highlands with deeply eroded valleys. The soils of the plateau are thin and stony, generally limiting agriculture to ranching. Caldwell and Guadalupe Counties are in the blackland prairie region, a gently rolling area which was originally a grasslands but now supports cotton, corn, sorghums, small grains, and forages. Northern Bexar, Medina, Uvalde, and Kinney Counties are on the Edwards Plateau and their southern portions lie within the Gulf Coastal Plain region, which has deep sandy soil generally covered by mesquite and dwarf oak. This latter area is used primarily for raising livestock.

The climate of the study area can best be described as varying from semiarid to subhumid. The mean annual rainfall ranges from 22 to 39 inches. Average annual temperatures vary from 64° to 69° and the average length of the growing season is 221 to 279 days.

Runoff within the area is characterized by large variations annually as well as seasonally. Due to the interchange between surface and ground waters, however, exact measurements of surface runoff are difficult to determine. In most streams, with the exception of those whose base flows are spring-fed, periods of zero flow have been experienced.

Characteristics of the Subareas

The study area was divided into three subareas for the purpose of providing suitable size base areas for study, at the same time maintaining a reasonable degree of homogeneity of economic, water resource, and geographic factors.

The principal characteristics of each of the subareas are shown in table IV-1.

Table IV-1

Characteristics of the Subareas

Item	Sub-area I	Sub-area II	Sub-area III
Counties	Blanco Caldwell Comal Guadalupe Hays Kendall Kerr	Bandera Bexar	Edwards Kinney Medina Real Uvalde
Principal Cities	Johnson City Lockhart New Braunfels Seguin San Marcos Boerne Kerrville	San Antonio Bandera	Rock Springs Brackettville Uvalde Sabinal Leakey Hondo Castroville
1960 Population	112,363	691,043	42,566
Economy	Ranching Farming Oil Tourist	Manufacturing Ranching Farming Tourist	Ranching Tourist
Topography	Mountainous to level rolling	Hilly to undulating	Rugged to rolling plains
Altitude (ft. m.s.l.)	600 to 1,850	500 to 2,400	600 to 2,500
Annual Rainfall (inches)	30.1 to 38.8	27.9 to 29.0	22.0 to 28.6
Mean Annual Temperature (deg. F.)	64 to 68	65 to 67	65 to 69
Growing Season (days)	221 to 269	250 to 279	222 to 274

Source: A. H. Belo Corporation [2/]

V. WATER RESOURCES OF THE STUDY AREA

Ground Water [3-11]

Ground water conditions in the study area are of primary importance, since three of the project reservoirs are to be used for ground water recharge.

The geologic units in order of importance as aquifers in the study area are the Edwards and associated limestones, the Glenrose limestone, the Travis Peak formation of the Trinity group, and the Leona formation, the Austin Chalk, Hosston and Sligo formations, rocks of the Taylor and Navarro groups, the Carizzo sand, and the rocks of the Wilcox group.

The Edwards is a dense, hard limestone, but on weathering the rock is extensively honeycombed and cavernous. Where it is exposed, conditions are favorable for a direct infiltration of rainwater and streamflow. Wells that penetrate fractures obtain large yields, but others may yield little or no water. Wells in the so-called Edwards limestone fault-zone aquifer yield 1,500 gallons per minute on the average. The exceptionally high transmissibility of the fault-zone aquifer permits the movement of ground water from one river basin to another. The Edwards limestone-Trinity sands aquifer supplies the base flow in many of the perennial streams which in turn supply much of the recharge of the fault zone. The Edwards limestone-Trinity sands under the Edwards Plateau, north and west of the fault zone, yield an average of 400 gallons per minute per well.

The Glen Rose limestone crops out north of the Balcones fault zone and its yields are small to moderate.

The Leona formation consists of alluvium and terrace deposits in the valleys of the major streams. Its importance as an aquifer is restricted to Leona River valley southeast of the city of Uvalde, where some wells yield enough water for irrigation. Evidently there is a hydraulic connection between Leona and Edwards formations in this area, and production from the Leona is dependent on the artesian head in the Edwards.

The Cow Creek limestone of the Travis Peak formation yields moderate quantities of water in Comal and Kendall Counties. Near Uvalde, and locally near San Antonio, the Austin Chalk yields moderate quantities of water similar in chemical quality to the water in the Edwards limestone, suggesting a hydraulic connection (probably through faults).

The Carrizo-Wilcox sands underlie the blackland south and east of the fault zone, and have available moderate quantities of water.

The average yield per well in the Carrizo-Wilcox sands is 500 gallons per minute.

Principal springs in the area are the Leona River Springs near Uvalde, San Antonio and San Pedro Springs at San Antonio, Hueco and Comal Springs at New Braunfels, and San Marcos Springs at San Marcos. During the 1955 to 1957 period, all of the springs except San Marcos ceased flowing during part of the time.

Surface Water

Records of the streamflow in the study area vary in length, from 47 years for the Frio River near Derby, Texas, to 1 year for Salado Creek at San Antonio. Discharge frequency analyses were made at various points along the several streams in the study area. The results of these analyses are shown in table V-1.

Water Quality

A resume of surface water mineral quality for the study area is presented in table V-2. The mineral quality of study area surface waters can be generally described as good.

Ground water quality may also be generally described as good, except for high total dissolved solids in the Carrizo-Wilcox sands and high natural fluorides in some of the wells. Chemical characteristics of ground water are shown in table V-3. [12/] The recharge reservoirs should have no effect on ground water quality in the Edwards limestone aquifer, since the zones of recharge and sources of recharge water will not be changed.

Table V-1

Discharge Frequency Analyses

Location	Drainage Area sq. mi.	River Mile	Years of Record	Annual Average Flow at Various Exceedence Intervals (cfs) 50%	80%	90%	95%	98%
Guadalupe River at Comfort	836	397	22	98	58	36	23	10
Guadalupe River near Spring Branch	1,282	334	39	192	94	64	47	33
Guadalupe River above Comal River at New Braunfels	1,516	281	33	320	116	63	44	26
Comal River at New Braunfels	117	1.1	29	320	220	141	88	45
Plum Creek near Luling	356	--	31	85	27	15	9	5
Medina River near Pipe Creek	457	--	20	85	26	24	8	5
Medina River near San Antonio	1,225	5.2	22	100	41	20	15	12
Hondo Creek near Hondo	132	--	9	12	4	1	0	0
Sabinal River near Sabinal	206	--	19	15	5	2	1	0
Frio River at Concan	405	--	36	69	32	21	15	10
Frio River near Derby	3,493	--	46	63	22	13	7	3
West Nueces River near Bracketville	700	--	16	15	1	0	0	0
Nueces River near Laguna	764	395	38	108	57	41	31	23
Nueces River below Uvalde Creek	947	366	22	38	14	6	4	2
Cibolo Crk. near Falls City	831	9	31	82	39	25	16	10
San Antonio River below confluence with Medina River	--	--	36	76	38	27	21	16

Source: Geological Survey 13 14/

Table V-2

Surface Water Mineral Quality

Location	River Mile	Number of Samples	Average Values in mg/l: Total Dissolved Solids*	Chlorides	Sulfates
Guadalupe River near Comfort	397	126	302	24	22
Guadalupe River near New Braunfels	279	120	297	22	22
Guadalupe River near Seguin	256	90	325	30	27
N. Fork of Guadalupe River near Kerrville	425	110	261	20	12
Comal Creek near New Braunfels	1	113	305	19	24
San Marcos River near Luling		96	423	65	42
San Marcos River near San Marcos		103	307	22	24
Blanco River near Wimberly		102	263	21	25
Cibolo Creek near Schertz	60	119	399	45	42
San Antonio River near San Antonio	220	120	494	74	72
San Antonio River between San Antonio and Falls City	181	127	496	76	83
Medina River near Castroville	45	109	312	24	52
Medina River near San Antonio	8	119	481	68	98
Nueces River near Laguna	395	111	252	21	14
Nueces River near Tom Nunn Hill	366	114	264	24	24
Frio River near Concan	224	109	302	20	16
Frio River near Leon River	128	82	381	71	49

* Residue at 105°C.

Source: Texas State Department of Health 15/

Table V-3

Ground Water Quality (mg/l)

Item	City: County:	Blanco Blanco	Kyle Hays	San Marcos Hays	Luling Caldwell	Lockhart Caldwell	New Braunfels Comal	Marion Guadalupe	San Antonio Bexar
Total Dissolved Solids (Residue at 105°C.)		570	490	357	1,240	415	284	588	296
Hardness as $CACO_3$		491	367	305	8	209	250	400	244
Calcium		93	78	38	2	59	70	120	69
Magnesium		63	42	20	1	15	18	24	18
Sodium		22	21	12	470	71	9	64	16
Iron		.003	.4	.05	.08	.95	.10	.02	.13
Sulfate		115	131	26	135	50	23	8	32
Chloride		24	28	24	178	85	21	79	19
Fluoride		3.2	3.2	0.1	0.5	0.2	0.2	1.1	0.3
Nitrate		---	---	8.0	.04	0.4	3.7	27.0	3.7
Date		1/50	10/49	4/60	4/57	4/55	7/56	1/60	---
Class of Analysis		Typical	Typical		Typical	Typical	Typical	Typical	Average

Source: Texas State Department of Health [17]

VI. THE ECONOMY

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

Present

Extractive Industries

Mining

The principal minerals in the study area are petroleum, natural gas, stone, sand and gravel, lime, and clays. A total of 302,023,811 barrels of crude oil has been produced in the study area since petroleum was first discovered in 1889. The 1958 production of crude oil in the study area was 7,907,891 barrels, which was 0.86 percent of the State's production. [16/] The value of mineral production between the years 1952 and 1961 is shown in table VI-1.

Table VI-1

Value of Mineral Production in the Study Area, 1952-1961 (1,000's of 1960 dollars)

Year	Total Study Area	Sub-area I	Sub-area II	Sub-area III
1952	32,085	18,845[1/]	9,228	4,012[1/]
1953	31,351	21,093	9,135	1,123
1954	39,602	23,966	13,265	2,371
1955	43,373	25,072	15,663	2,638
1956	44,095	25,492	15,840	2,763
1957	37,816	23,813[1/]	13,392	611[1/]
1958	41,248	24,270[1/]	16,462	516[1/]
1959	49,780	25,644[1/]	20,081	4,055
1960	42,746	25,076[1/]	16,932	738[1/]
1961	40,211	21,037[2/]	18,235	939[1/]

1/ To avoid disclosure of individual company operations, one county is not included.

2/ To avoid disclosure of individual company operations, three counties are not included.

Source: Bureau of Mines [16/]

Agriculture

In terms of income and employment, agriculture is the leading extractive industry in the study area. Although agricultural employment decreased 31 percent between 1950 and 1960, the value of agricultural output increased 32 percent. The value of farm products sold per agricultural employee has risen 91 percent in the decade between 1950 and 1960. As shown in table VI-2, agricultural output was valued at 69,674,063, 1960 dollars in 1959. 17/ The sale of livestock and livestock products accounted for over 77 percent of this value. Most of the income from livestock and livestock products resulted from the sale of wool, mohair, beef, and poultry. An appreciable increase in cattle feeding in the study area has occurred in recent years.

Major crops grown in the area include cotton, corn, grain sorghums, and vegetables. A shift of some cropland to pasture in order to accommodate a more diversified livestock program has occurred in recent years. Total irrigated land increased from 21,331 acres in 1949 to 42,529 acres in 1959. Over 86 percent of the land was irrigated from ground water sources in 1959.

Table VI-2

Agricultural Statistics for the Study Area
1944, 1949, 1954, and 1959

Item	1944	1949	1954	1959
Number of Farms	15,397	13,930	13,026	10,281
Land in Farms (1,000 acres)	8,319	8,340	3,299	7,511
Cropland Harvested (1,000 acres)	725	728	498	578
Pastureland (1,000 acres)	7,448	7,303	7,492	7,354
Value of Livestock and Livestock Products Sold*	33,872	37,705	38,038	53,847
Value of Crops Sold*	9,285	15,193	9,384	15,743
Value of Forest Products Sold*	99	72	50	84
Total Value of Farm Products Sold*	43,256	52,970	47,472	69,674
Number of Farms Irrigated	668	404	499	497
Land in Irrigated Farms (1,000 acres)	--	272	735	663
Irrigated Cropland Harvested (1,000 acres)	--	14	23	32
Other Irrigated Land (1,000 acres)	--	7	18	11

*All values in 1,000's of 1960 dollars.

Source: Bureau of the Census 17/

Manufacturing

Manufacturing employment in the study area increased 104 percent or 14,300 in the two decades from 1940 to 1960. This compares with a statewide increase of 154 percent for the same two decades. Although the study area exhibits a diversified manufacturing base, the bulk of the industries at present are engaged in the manufacture of textiles, food and kindred products, and fabricated metals. These industries accounted for about 65 percent of the manufacturing employment in 1960. Other manufacturing industries worthy of mention include stone and clay, printing and publishing, furniture, and some nondurable goods. Data on manufacturing activities for the study area are shown in table VI-3.

Table VI-3

Manufacturing Activity in the Study Area
1939, 1947, 1954, and 1958

Item	1939	1947	1954	1958
Number of Establishments	400	553	680	696
Number of Employees	--	17,927	21,196	23,859
Value Added by Manufacturing (1,000's of 1960 dollars)	59,520	96,880	138,840	182,346

Source: Bureau of the Census 18/

Generally an increase in employment, coupled with increased value added per employee, reflects favorably on the prospect for continued growth in the manufacturing industries.

Service Industries

Service industries constitute a large segment of the economic activity of the study area. They employed 63 percent and 79 percent of the total labor force in 1940 and 1960, respectively. The high 1960 percentage in the study area can be attributed to relatively more employees in government and the large numbers of armed forces personnel based in the area.

Labor Force and Employment

Changes in the study area labor force between 1940 and 1960 can be readily seen in table VI-4. The most notable changes in employment which occurred are: (1) An increase of manufacturing employment which is below the rate of increase for the State of Texas. Between 1940 and 1960, manufacturing employment increased 104 percent. Manufacturing employment accounted for 10.2 percent of the study area labor force in 1960. (2) A decrease of workers in agriculture. The study area showed a decrease of 50 percent in agricultural employment between 1940 and 1960, while Texas agricultural employment decreased 64 percent. (3) Unemployment has decreased from 13.6 percent of the labor force in 1940 to 4.7 percent of the labor force in 1960. During the same period, total labor force has increased from 190,587 to 273,671.

Table VI-4

Labor Force and Employment Summary for the Study Area, 1940, 1950, and 1960

Item	Labor Force 1940 Percent	Labor Force 1940 Number (1,000's)	Labor Force 1950 Percent	Labor Force 1950 Number (1,000's)	Labor Force 1960 Percent	Labor Force 1960 Number (1,000's)
Agriculture and Forestry	14.9	28.4	9.5	20.7	5.2	14.2
Mining	1.1	2.1	1.0	2.2	0.9	2.5
Manufacturing	7.2	13.7	10.0	21.8	10.2	28.0
Resource Oriented	4.7	8.9	5.7	12.4	5.4	14.9
Furniture, Lumber and Wood Products	0.5	1.0	0.7	1.5	0.6	1.9
Primary Metals	0.5	1.0	0.2	.4	0.2	.5
Food & Kindred Products	2.3	4.3	2.9	6.4	2.9	8.0
Chemical & Allied Products	0.2	.4	0.2	.4	0.2	.5
Stone, Clay & Glass	0.5	1.0	1.0	2.2	0.9	2.4
Other Nondurables	0.7	1.2	0.7	1.5	0.6	1.6
Nonresource Oriented	2.5	4.8	4.3	9.4	4.8	13.1
Fabricated Metals, Transportation & Other Durable Goods	0.6	1.1	1.2	2.6	1.8	4.9
Textiles & Apparel	1.0	2.0	1.9	4.2	1.8	4.9
Printing, Publishing & not Elsewhere Classified	0.9	1.7	1.2	2.6	1.2	3.3
All Other Employment (Services)	63.2	120.5	75.5	164.6	79.0	216.1
Unemployed	13.6	25.9	4.0	8.7	4.7	12.9
Total Labor Force (1,000's Workers)		190.6		218.0		273.7

Source: Bureau of the Census 19/

Tourism and Recreation

The considerable income that the study area derives from tourism and recreational activities is worthy of note in this discussion of the economy of the study area. Resources which promote these activities include spring-fed, perennially flowing streams, scenic mountainous woods, numerous caves and caverns, and State parks. Game (deer, wild turkey, quail, dove, and sport fish) is also plentiful in most of the study area. These factors have attracted dude ranches, hunting and fishing resorts, and generally have favored the growth of the tourist industry. Aside from attracting outside visitors, the location of these excellent tourist and recreational facilities is convenient for the residents of San Antonio, Austin, and other large Texas cities.

Population

Study area population increased from 328,342 in 1920 to 845,972 in 1960 as shown in table VI-5. 20/ This represents an annual growth rate of approximately 2 3/8 percent, compared to an annual rate of 1 13/16 percent for the State of Texas during the same period. The urban component of the population with a growth rate of 3½ percent is also presented in table VI-5. 20/

Table VI-5

Historic Population for the Study Area
1920-1960

Year	Total Population	Urban Population
1920	328,342	180,743
1930	438,376	274,894
1940	480,801	303,901
1950	648,117	511,867
1960	845,972	721,812

Source: Bureau of the Census 20/

The Future

Mining activity is expected to continue to increase at approximately the same growth rate experienced between 1940 and 1960. This level of output can be sustained by presently known reserves using new methods of secondary recovery of petroleum.

Agriculture is expected to continue increasing its output although the labor force utilized in this endeavor can be expected to decrease. This greater output will be the result of improved technology and increased productivity in agriculture. As the result, higher agricultural incomes are expected. It is anticipated that an expanding population, higher income, a higher standard of living, and changing tastes of consumers will provide for continued growth in the livestock industry.

The segment of the economy dedicated to manufacturing is expected to expand primarily in the nonresource-oriented industries. Manufacturing employment is expected to represent 13.8 percent of the labor force by the year 2025.

The service industries, which include sales, insurance, finance, personal services, and transportation, employed 79 percent of the labor force or 216,096 workers in 1960. Based on past trends, modified by relative growth and income in the area, comparable employment in the year 2025 will be about 768,000, or 81 percent of the labor force.

A summary of the present and future employment is shown in table VI-6.

Table VI-6

Labor Force and Employment for the Study Area
1960, 2025, and 2075

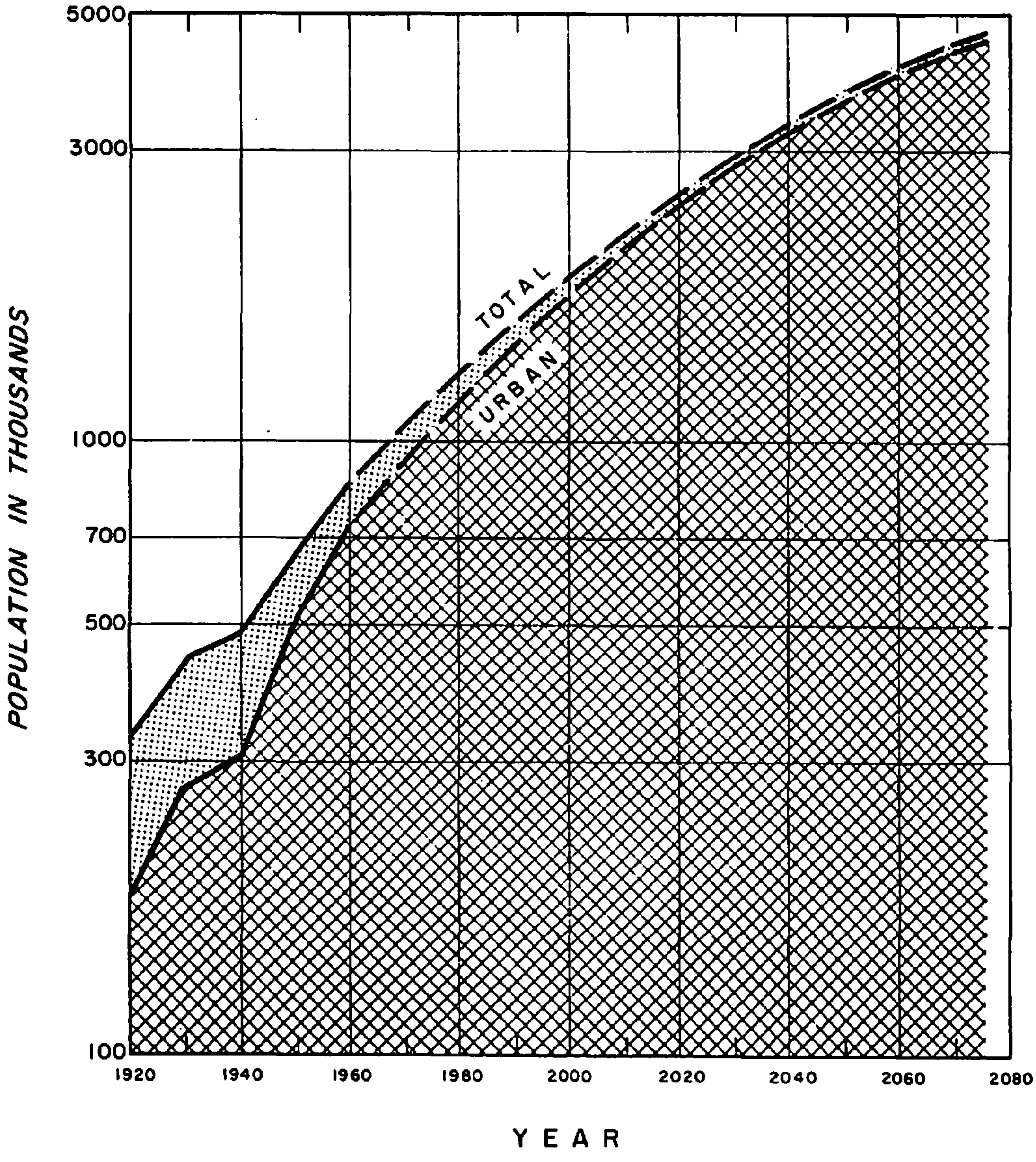
Item	Percent of Labor Force 1960	2025	2075
Agriculture & Forestry	5.2	1.2	0.8
Mining	0.9	0.4	0.3
Manufacturing	10.2	13.8	13.5
Resource Oriented	5.4	5.0	4.9
Furn., Lumber & Wood	0.5	0.4	0.4
Primary Metals	0.2	0.3	0.2
Food & Kindred Products	3.0	2.8	2.8
Chemicals & Allied Products	0.2	0.4	0.4
Stone, Clay & Glass	0.9	0.6	0.7
Other Nondurables	0.6	0.5	0.4
Nonresource Oriented	4.8	8.8	8.6
Fabricated Metals, Machinery, Transportation, and other Durable Goods	1.8	5.6	5.4
Textiles & Apparel	1.8	2.7	2.6
Printing, Publishing & not Elsewhere Classified	1.2	0.5	0.6
All Other Employment (Services)	79.0	80.6	81.4
Unemployed	4.7	4.0	4.0
Total Labor Force (1,000's of Workers)	273.7	952.9	1,660.0

Total population for the study area is expected to reach 2,949,700 by 2025 and 4,620,000 by 2075, as shown in figure VI-1 and table VI-7. Similarly, urban population is expected to reach 2,852,100 by 2025 and 4,521,000 by 2075. Many factors are considered in formulating the population projections. These include: (1) Resources and employment analysis; (2) the trend toward urbanization; (3) growth comparisons with cities that were of similar size to the cities of the study area in the recent past; and (4) the ratio of growth between study area cities and the State's urban population.

Table VI-7

Population for United States, Texas, and the Study Area, 1960, 2025, and 2075
(1,000's)

Year	United States	Texas	Study Area	
			Total	Urban
1960	179,977	9,580	846	722
2025	546,000	30,000	2,950	2,852
2075	790,000	54,000	4,620	4,521



WATER SUPPLY & WATER QUALITY CONTROL STUDY
EDWARDS UNDERGROUND RESERVOIR – TEXAS

POPULATION TRENDS & PROJECTIONS

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

FIGURE VI-1

VII. WATER REQUIREMENTS

General

The term water requirements encompasses a multiplicity of uses which are dependent upon a large number of variables. Although primarily concerned with water for municipal, industrial, and water quality control purposes, this study examines other water uses that affect the supply and demand for water within the study area. The probable future water requirements of the study area are based on economic projections, coupled with analyses of unit water requirements.

Types of Water Use

Municipal

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

Industrial

The definition of industrial water use in this study refers to all water except that supplied from municipal systems which is used by the manufacturing industries (Standard Industrial Classification Categories 13, 14, and 20 through 39). 21/ The total industrial requirements are determined by combining the projected number of employees with the projected unit employee water use for each of the several industrial categories. The base data were obtained from a published survey of the study area, and adjustments have been made to reflect anticipated recirculation practices. 22/

Power Generation

Consumptive use of water for thermal power generation is a part of the industrial requirement that has been determined separately. Information on future water use was developed from estimates of area power companies, the Federal Power Commission, and the Edison Electric Institute for the Senate Select Committee on National Water Resources. Consideration was given to the general location of future power generation installations, and the projected needs were apportioned throughout the study area according to assumed service areas of the several facilities.

Rural

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

Irrigation

The projected use of water for irrigation was adapted from estimates of the United States Study Commission-Texas.*

Water Quality Control

Water quality control is defined as any measure employed to enhance the utility, value, and attractiveness of waters used for purposes which are affected by changes in water quality. Waters in nature are never PURE in the strict chemical sense of the word. More often than not, however, natural waters are fit for use by man in his pursuit of normal endeavors. This use and the subsequent return of waste almost always cause some degradation of water quality downstream, even after provision of highly sophisticated waste treatment. As population and the demand for water increase, this degradation of natural waters becomes increasingly worse and must be arrested before the damage becomes irreparable. Until economically feasible methods of complete waste treatment become a reality, the quality of waters can best be controlled by provision of additional water to dilute the treated wastes generated by the population. This, then is the method of water quality control with which this report is concerned, as treatment alone is not sufficient to maintain desirable stream conditions in the San Antonio River.

Of the indicators presently available for the evaluation of water quality, dissolved oxygen and total dissolved solids were chosen for use in this study. The principal causes of manmade pollution in the study area are: (a) Domestic sewage; (b) industrial wastes from food processing; (c) various other industrial wastes; and (d) irrigation return flows. All of the above contribute biochemical oxygen demand (BOD) and a variety of chemical constituents that can best be estimated as total dissolved solids. Water quality control

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*The projected values for irrigation do not represent a decision of the Public Health Service. However, they are included because (1) return flows from this source affect the quality of the study area's waters, and (2) a fully integrated water supply plan must include irrigation, especially in an area where the use represents a considerable portion of the demand on the potential water resource.

requirements are based on the assumption that sufficient waste treatment will be provided to remove 85 percent of the BOD, but none of the total dissolved solids.*

Water to regulate quality is assumed to be needed when the dissolved oxygen content of the stream drops below 4 milligrams per liter (mg/l)** and/or when the total dissolved solids reach 500 mg/l.

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

The quantity of municipal and industrial return flows is estimated as a percentage of water use. The municipal return flow percentage used was 62.0 percent, 23/ while industrial return flow percentages vary from 23 percent to 90 percent. 24/

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

The contribution of total dissolved solids resulting from industrial use varies from 12.2 tons per million gallons to 1.2 tons per million gallons of return flow. 24/ For the BOD contribution from industry, it was assumed that final industrial effluents which discharge wastes containing BOD would have the same concentration as a municipal sewage that has been treated to remove 85 percent of the BOD. This concentration is 56 mg/l ultimate BOD, assuming a typical municipal sewage has an untreated concentration of 370 mg/l ultimate first stage BOD.

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

Irrigation return flows were assumed to be one-third of the water applied for that purpose, and it was further assumed that all of the dissolved solids in the irrigation source water would be returned to the stream. 25/

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

**The lower limit of 4 mg/l of dissolved oxygen was chosen because, (1) it is sufficient to sustain most species of fish native to this area, and (2) it provides a buffer zone to keep the streams waters from becoming anaerobic in the event that unforeseen shock loads of organic pollutants are accidently discharged to the watercourse.

In determining the amount of water from storage required to preserve the quality of the stream, it is necessary to make allowances for natural flows that can be expected to occur in the stream. Discharge frequency analyses of the streams in the basin were made from published streamflow data, which included adjustment to reflect future conditions in the basin. Calculations were then performed to determine the amount of regulation water from storage needed to maintain stream quality for hydrologic conditions that can be expected to recur in the basin streams every 20 years.

Two analyses ot the basin waters, one of organic pollution (BOD), and one of chemical pollution (total dissolved solids), were made utilizing electronic computational methods where applicable.

Computations indicated that concentration of the stable pollutants (total dissolved solids) will not reach undesirable levels within the time horizon of this study.

On the other hand, organic pollution (BOD) computations revealed that waters of the San Antonio River downstream from the city of San Antonio are now and will continue to be deficient in dissolved oxygen.

Based on the previously described assumptions of organic loading, waste treatment, and hydrologic conditions; the amounts of supplemental water that will be required to maintain a minimum of 4.0 mg/l of dissolved oxygen in the waters of the San Antonio River are as shown in table VII-1 and in figure VII-1

Table VII-1

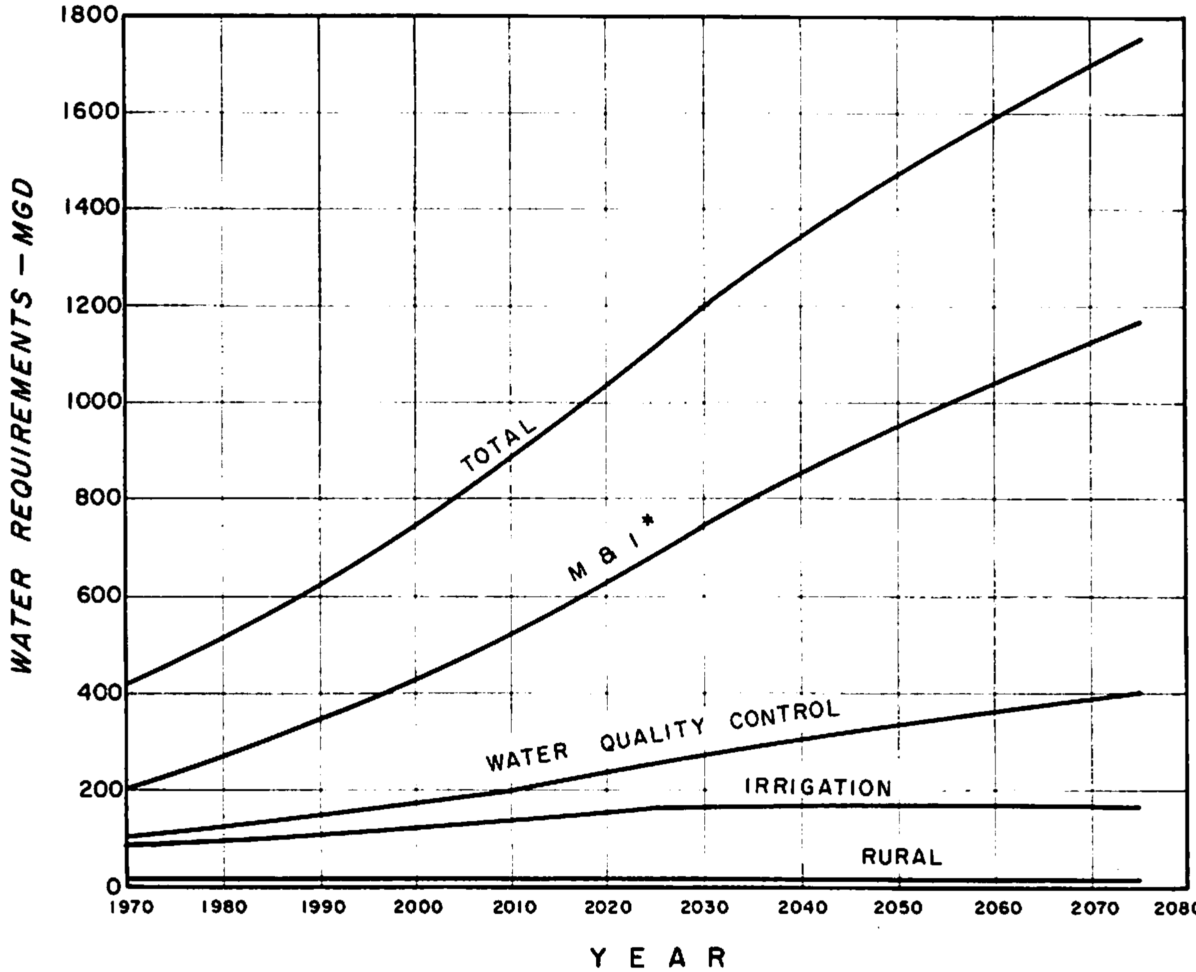
Water Quality Control Requirements

Year	Annual Draft-on-Storage in Acre-Feet/Yr. x 1,000
1970	123.0
2025	280.0
2075	454.7

No water quality problems were found in any of the other study area streams.

Base Year Water Use

The year 1958 was selected as the base for the study because it was the most recent year for which reliable data from several sources were available. The 1958 study area water use by type is shown in table VII-2.



*INCLUDES CONSUMPTIVE REQUIREMENT FOR THERMAL POWER GENERATION.

WATER SUPPLY & WATER QUALITY CONTROL STUDY

EDWARDS UNDERGROUND RESERVOIR – TEXAS

STUDY AREA WATER REQUIREMENTS

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE

Public Health Service

REGION VII DALLAS, TEXAS

FIGURE VII-1

Table VII-2

Base Year Water Use

Subarea	Municipal	Industrial	Thermal Power Generation	Rural	Irrigation	Total
	1958 Water Use (mgd)					
1	11.0	2.3	--	7.5	6.0	26.8
2	86.1	22.7	4.5	7.4	35.0	155.7
3	7.1	0.2	--	3.7	39.7	50.7
Study Area Total	104.2	25.2	4.5	18.6	80.7	233.2

Source: The University of Texas 22/, Public Health Service 26 30/, and Texas Board of Water Engineers 27-29/

Future Water Requirements

Estimates of future water requirements for the several types of water use in the study area were made using the technique of combining projected unit uses with economic and population projections. Irrigation water use estimates, however, are those of the U.S. Study Commission-Texas converted to suit the study area boundaries. Table VII-3 summarizes the study area water needs for the years 2025 and 2075.

Table VII-3

Projected Water Requirements

Sub-area	Municipal	Industrial	Thermal Power Generation	Rural	Irrigation	Water Quality Control	Total
	Water Requirements in mgd*						
			For the Year 2025				
1	36.4	14.0	1.4	9.3	43.9	--	105.0
2	478.8	92.3	43.3	0.5	60.6	250.0	925.5
3	14.2	8.7	--	6.0	58.4	--	87.3
TOTAL	529.4	115.0	44.7	15.8	162.9	250.0	1,117.8
			For the Year 2075				
1	63.6	27.9	2.1	9.3	43.8	--	146.7
2	819.4	151.8	66.1	0.6	60.5	406.0	1,504.4
3	22.4	13.7	--	6.8	58.5	--	101.4
TOTAL	905.4	193.4	68.2	16.7	162.8	406.0	1,752.5

*The expression of these estimates to tenths of an mgd is not intended to imply precision. Since this table is the resultant addition of many individual values, several of which are less than one mgd, the use of tenths eliminates rounding and the loss of identity of the several smaller water uses.

A graphical presentation of water requirements in the study area is shown in figure VII-1.

VIII. WATER SUPPLY AND WATER QUALITY CONTROL PLAN

General

In order to supply the water needs shown in the previous section, a plan is presented utilizing all available water resources in the Edwards Underground Reservoir area of Texas, including the tentative import of water from Cuero Reservoir.

Water Availability

With the project features in operation, the water resources of the study area in the year 2025 are as follows:

	Yield (mgd)
Surface:	
Cloptin Crossing Reservoir	38.0
Dam 7 Reservoir	41.0
Canyon Reservoir	86.0
Run of Stream Sources a/	32
Montell Reservoir b/	4.0
Cuero Reservoir c/	161.0
Ground:	
Edwards Underground Reservoir pumpage d/	235
San Marcos Spring e/	36
Other ground water resources f/	22
Municipal and Industrial Return Flow directly utilized (varying quantity 1960-2025) g/	13 - 127
	782

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a/Used primarily for irrigation; yield based on 98 percent exceedence interval of annual flows.

b/Used to satisfy future downstream municipal and industrial requirements.

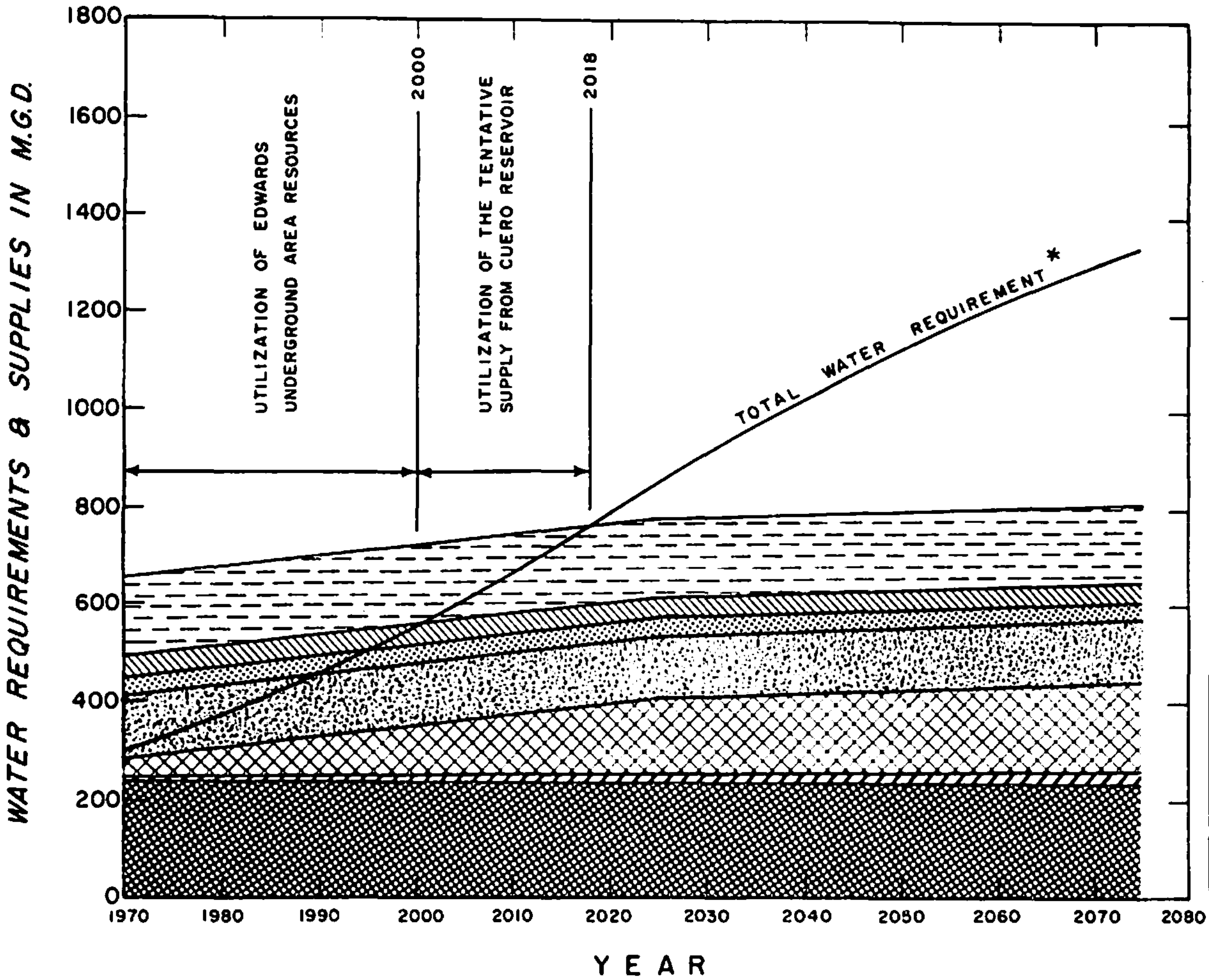
c/Total dependable yield of 300 mgd based on Bureau of Reclamation routing.

d/Based on Corps of Engineers' routing.

e/Dependable flow from San Marcos Spring based on Corps of Engineers' routing.

f/Estimated development in Carrizo-Wilcox sands, Edwards limestone-Trinity sands aquifer and use of Las Moras Spring.

g/Used to satisfy requirements for irrigation and thermal power generation.



EDWARDS LIMESTONE FAULT ZONE AQUIFER (WITH RECHARGE RESERVOIRS)

OTHER GROUND WATER SOURCES a/

RUN OF STREAM SUPPLIES AND DIRECT USE OF M. & I. RETURN FLOWS b/

CANYON & DAM No. 7 RESERVOIRS

CLOPTIN CROSSING RESERVOIR

SAN MARCOS SPRING

CUERO RESERVOIR IMPORT (161 M.G.D. TENTATIVE)

*Total water requirement includes municipal, industrial, thermal power generation, rural, and irrigation uses. Water quality control requirements are not included.

a/ Estimated development in Carrizo Wilcox sands, Edwards Limestone–Trinity sands aquifers and use of Las Moras Spring

b/ Used primarily for irrigation and thermal power generation.

WATER SUPPLY & WATER QUALITY CONTROL STUDY
EDWARDS UNDERGROUND RESERVOIR – TEXAS

STUDY AREA WATER AVAILABILITY (INCLUDING THE TENTATIVELY AGREED IMPORT FROM CUERO RESERVOIR)

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

FIGURE VIII-1

As discussed in Section VII, the draft-on-storage required for the San Antonio River downstream from San Antonio varies from 123,000 acre-feet/year in 1970; to 280,000 acre-feet/year in 2025; to 454,700 acre-feet/year in 2075. Due to the nature of or locations of the resources listed above their use for water quality control purposes is doubtful. Of the four Federal projects, three (Montell, Concan, and Sabinal Reservoirs) are for ground water recharge located far from the point of need for water quality control. The nature of their design rules out use of these reservoirs for water quality control. Cloptin Crossing, the remaining Federal reservoir is dropped from further consideration for water quality control in the foreseeable future, since its entire dependable yield (38 mgd) is proposed for municipal and industrial uses by the Guadalupe-Blanco River Authority and its location is also far from the point of need. Even if it were available, this reservoir could provide only about one-third of the 1970 water quality control requirement.

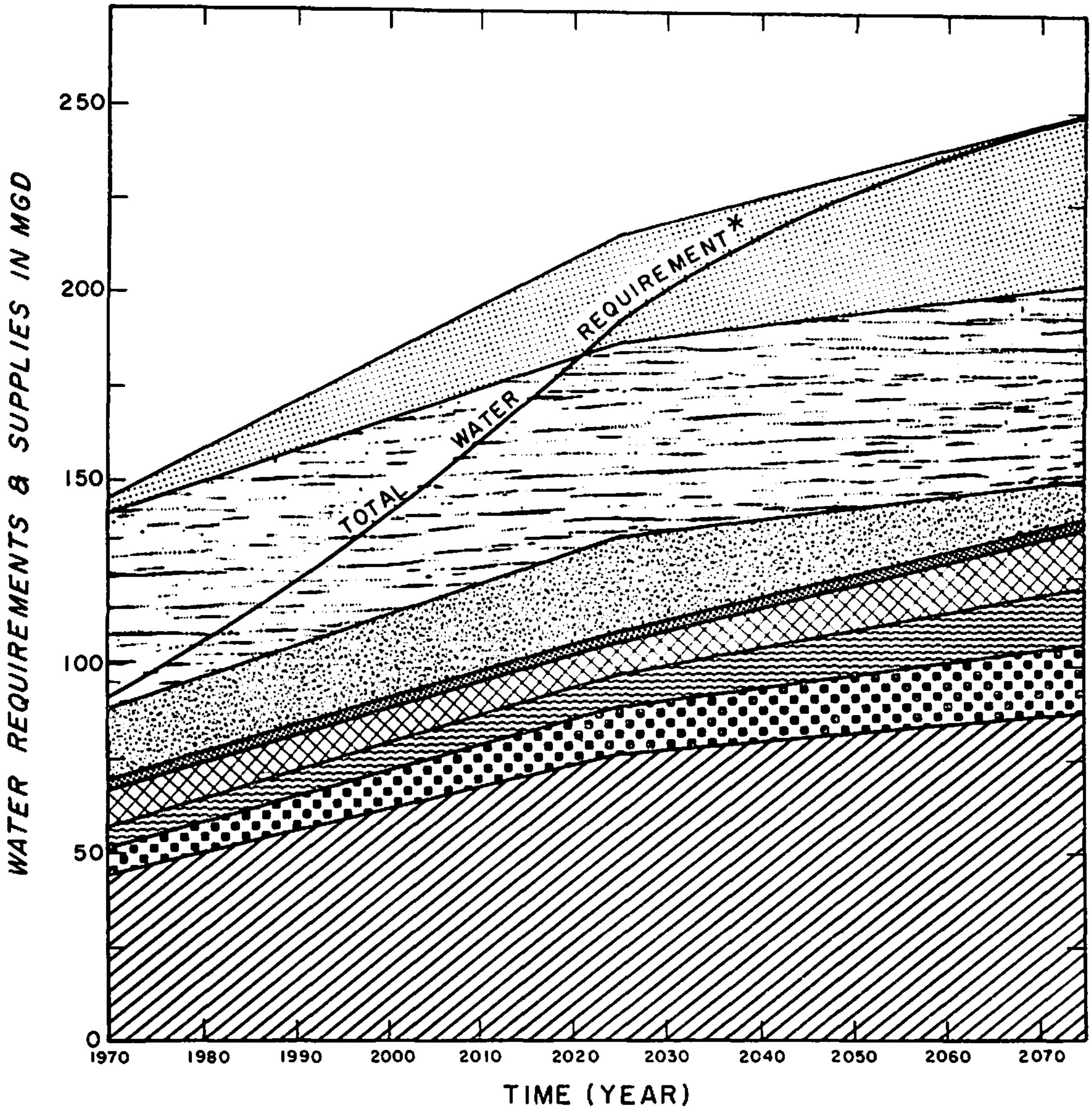
It is concluded, therefore, that under the stated assumptions of waste treatment and hydrologic conditions, the San Antonio River will be practically devoid of oxygen for about 110 miles downstream from the city of San Antonio by the year 2025. This situation may be ameliorated by the future development of highly efficient advanced waste treatment and water reuse techniques. If left unchecked, however, such conditions would create a public health hazard and nuisance and severely curtail the utility of these waters, resulting in damages to fish and wildlife, loss or downgrading of recreational opportunities, and restrictions of probable economic activities.

An over-plot of these resources on the total requirement curve of figure VII-1 (excluding water quality control) shows that the area's resources will satisfy the total water requirements until approximately the year 2000. (See figure VIII-1.)

Addition of the tentative quantity of 161 mgd from Cuero Reservoir on the Guadalupe River [31/] will make it possible to meet all area water needs excluding water quality control until the year 2018.

A closer examination of the future water requirements shows that it is the San Antonio SMSA (Bexar County) which will suffer the shortages. A graph of needs and resources versus time for the area excluding Bexar County indicates that its water requirements can be satisfied for the entire length of the projection period. (See figure VIII-2.)

If the San Antonio area is to grow and prosper beyond the year 2018, it is imperative that additional sources of water be made available. The location of such sources, however, is beyond the scope of this report.



LEGEND

- EDWARDS LIMESTONE
- EDWARDS-TRINITY LIMESTONE
- CARRIZO-WILCOX SANDS
- SAN MARCOS SPRING
- LAS MORAS SPRING
- RUN OF STREAM SUPPLIES
- CANYON & DAM No. 7 RESERVOIRS
- REUSE OF M & I RETURN FLOWS

*TOTAL WATER REQUIREMENT INCLUDES MUNICIPAL, INDUSTRIAL, THERMAL POWER GENERATION, RURAL, AND IRRIGATION USES. THERE IS NO WATER QUALITY CONTROL REQUIREMENT IN THIS CASE.

WATER SUPPLY & WATER QUALITY CONTROL STUDY

EDWARDS UNDERGROUND RESERVOIR - TEXAS

STUDY AREA WATER AVAILABILITY EXCLUDING SAN ANTONIO S.M.S.A.

U.S. DEPARTMENT OF HEALTH, EDUCATION, & WELFARE

Public Health Service

REGION VII DALLAS, TEXAS

FIGURE VIII-2

IX. BENEFITS

Senate Document No. 97 (87th Congress, 2nd sess.) makes the following statement concerning evaluation of benefits of municipal and industrial water supply storage in Federal reservoirs:

> "The amount water users should be willing to pay for such improvements in lieu of foregoing them affords an appropriate measure of this value. In practice, however, the measure of the benefit will be approximated by the cost of achieving the same results by the most likely alternative means that would be utilized in the absence of the project."

This alternative cost method was used to evaluate storage for municipal and industrial use in the three recharge reservoirs as well as the conventional multiple-purpose reservoirs. The values determined in this way are considered to be the minimum annual values of the benefits.

Alternative Plans Considered

Although the study area is underlain by an excellent aquifer, it is relatively short of water as shown in the previous discussion. Three of the four project reservoirs are designed to increase the yield of the Edwards Underground Reservoir. The remaining reservoir, Cloptin Crossing, plus local interest development represent all of the area's surface water resources which can be economically developed at the present time. A tentative local plan provides for the importation of water from the proposed Cuero Reservoir on the Guadalupe River; however, additional importation from surrounding basins, although remotely possible, seems infeasible at this time due to area politics.

After investigation of various possibilities, a single-purpose reservoir at the site of Cloptin Crossing Reservoir was adopted as the most reasonable alternative to this project. This single-purpose project was assumed to have a yield equal to the yield expected from the storage to be provided for municipal and industrial water supply purposes in the proposed multipurpose reservoir.

For the three recharge reservoirs, the most reasonable alternative adopted was water from the proposed Cuero Reservoir on the Guadalupe River. The benefits for these reservoirs were evaluated as being equal to the cost of delivered water from the alternative source (Cuero Reservoir) taking into account the differential costs of pumping and treatment. 31/ Benefits are calculated only for the increase in water available for pumping and the increased spring flow from the fault zone aquifer which results from these recharge reservoirs.

A summary of the annual project benefits is shown in table IX-1. The methods of calculation used for the benefit evaluation are shown in the Appendix. Since all of the reservoirs are needed as soon as possible, no discounting of the benefits is made. Values shown represent present worth in the year 1970.

Table IX-1

Summary of Value of Water Supply Benefits

Reservoir	Dependable Yield (mgd)	Value: Annual (1970 $)	Value: Equivalent Cents per 1,000 gal.
Cloptin Crossing	38.0	$ 653,000	4.7
Montell: Downstream	4.0*	$ 88,300	6.0*
Montell: Recharge	-0-	$1,010,500	11.7**
Concan	-0-	$ 816,800	11.7**
Sabinal	-0-	$ 600,100	11.7**

* The dependable yield of Montell Reservoir is used to satisfy future downstream municipal and industrial water requirements. The benefit for this function of the reservoir is based on the most reasonable alternative. (See Appendix)

** Based on prorated increase in resource of Edwards Underground Reservoir. (See Appendix)

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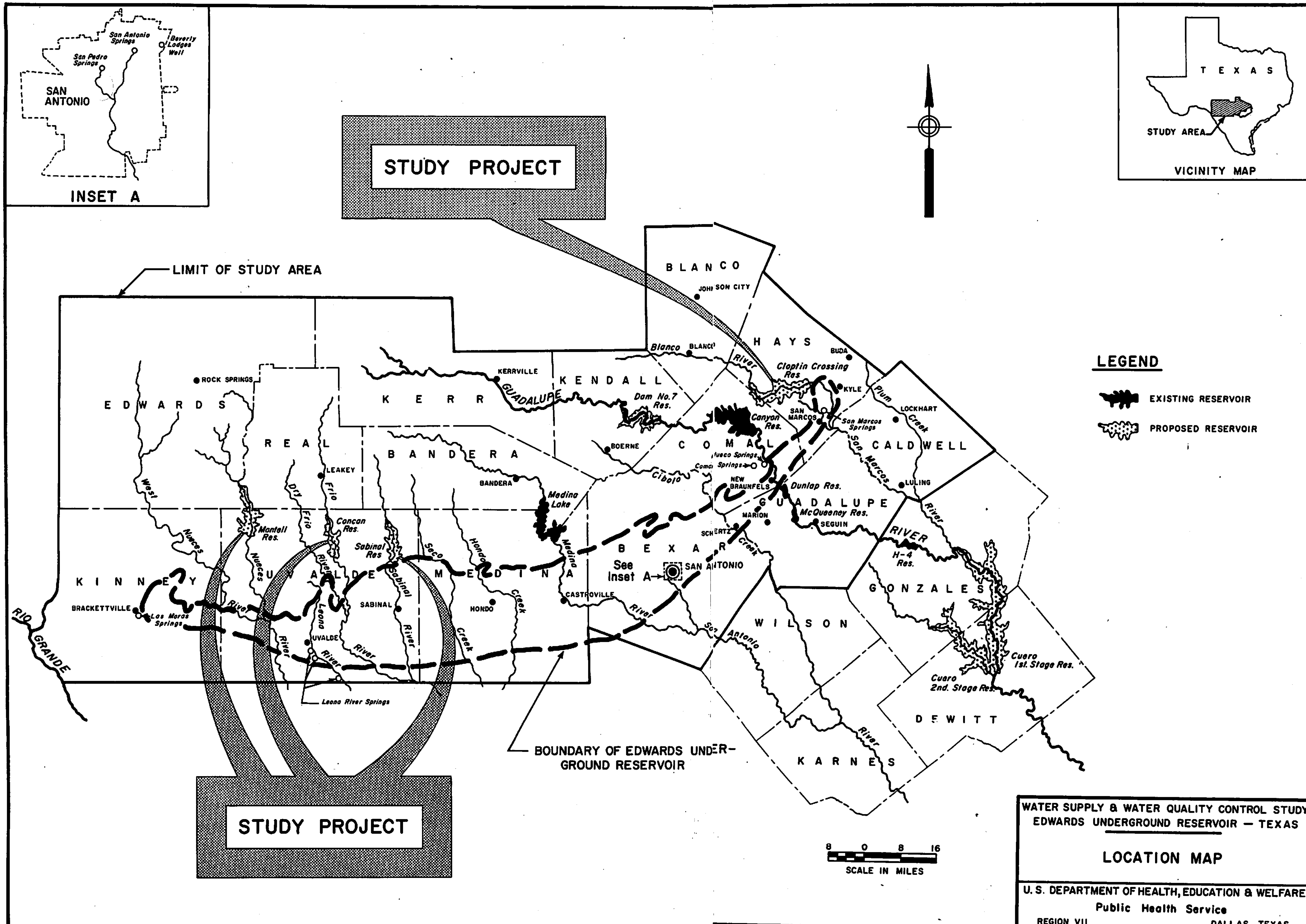


WATER SUPPLY & WATER QUALITY CONTROL STUDY
EDWARDS UNDERGROUND RESERVOIR — TEXAS
LOCATION MAP
U. S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
Public Health Service
REGION VII
DALLAS, TEXAS
INSET A
San Antonio Springs
Beverly Lodges Well
San Pedro Springs
SAN ANTONIO
STUDY PROJECT
VICINITY MAP
TEXAS
STUDY AREA
LEGEND
EXISTING RESERVOIR
PROPOSED RESERVOIR
LIMIT OF STUDY AREA
BOUNDARY OF EDWARDS UNDERGROUND RESERVOIR
SCALE IN MILES
8 0 8 16
EDWARDS
REAL
KERR
KENDALL
BLANCO
HAYS
COMAL
CALDWELL
BANDERA
GUADALUPE
BEXAR
KINNEY
UVALDE
MEDINA
WILSON
GONZALES
KARNES
DEWITT
ROCK SPRINGS
KERRVILLE
JOHNSON CITY
BLANCO
BUDA
KYLE
SAN MARCOS
LOCKHART
LULING
BOERNE
NEW BRAUNFELS
MARION
SEGUIN
SCHERTZ
SAN ANTONIO
CASTROVILLE
BANDERA
LEAKEY
SABINAL
HONDO
UVALDE
BRACKETTVILLE
Los Moras Springs
Leona River Springs
San Marcos Springs
Comal Springs
Canyon Res.
Medina Lake
Dam No. 7 Res.
Cloptin Crossing Res.
Dunlap Res.
McQueeney Res.
H-4 Res.
Cuero 1st. Stage Res.
Cuero 2nd. Stage Res.
Montell Res.
Concan Res.
Sabinal Res.
See Inset A
RIO GRANDE
GUADALUPE RIVER
Blanco River
Cibolo Creek
San Antonio River
Medina River
Hondo Creek
Seco Creek
Sabinal River
Frio River
Dry Frio
Leona River
Nueces River
West Nueces
Plum Creek
San Marcos River

FIGURE III-1

APPENDIX

APPENDIX

Benefit Calculations

CLOPTIN CROSSING RESERVOIR PROJECT

Most reasonable alternative: Single-purpose reservoir with a yield from storage of 38.0 mgd.

Estimated first cost	$15,670,000
Estimated interest during construction	1,175,000
Estimated total investment	$16,845,000

Amortize private investment for 25 years at 4 percent
(16,845,000)(0.06401) = $1,078,248 per year

Convert to equivalent Federal investment to provide for same annual payment.

Present worth of 1 per period @ 3 1/8 percent = 17.17308

Then equivalent Federal investment =
(1,078,248)(17.17308) = 18,516,839

Amortize Federal investment for 100 years at 3 1/8 percent

Annual Cost = (18,516,839)(0.03276)	=	$606,612
Estimated annual operation and maintenance	=	46,000
Annual benefit	=	$652,612
Say		$653,000

MONTELL RESERVOIR, SABINAL RESERVOIR, AND CONCAN RESERVOIR PROJECTS

Most reasonable alternative to increase in pumping potential = Cost of delivered water from another source (Cuero Reservoir) + Cost of pumping ground water + Treatment differential (Cuero less ground)

Increase in yield of Edwards limestone aquifer for pumping = 29,000 acre-feet per year or 25.9 mgd. 1/

Estimated treatment plant cost for 25.9 mgd = $2,976,100

Amortize private investment for 25 years @ 4 percent
(2,976,100)(0.06401) = $190,500

Convert to equivalent Federal investment to provide for same annual payment

Present worth of 1 per period @ 3 1/8 percent = 17.17308

Then equivalent Federal investment =
(190,500)(17.17308) = $3,272,300

Amortize Federal investment for 100 years @ 3 1/8 percent

Annual Cost = (3,272,300)(0.03276) =	$107,200
Estimated Annual Operation & Maintenance =	261,500
Annual Cost	$368,700

or on a unit basis = 3.9¢ per 1,000 gallons

Estimated ground water pumping cost = 2.4¢ per 1,000 gallons

Estimated ground water chlorination cost = 0.2¢ per 1,000 gal.

Cuero Reservoir water delivered cost 31/ = 12.3¢ per 1,000 gal.

Therefore: Unit benefit for pumping =

12.3 - 2.4 + (3.9 - 0.2) = 13.6¢ per 1,000 gallons

Increase in Spring flow from San Antonio and San Pedro Springs

Value of most reasonable alternative to increase in spring flow from San Antonio and San Pedro Springs is the same as that for pumping in the San Antonio area plus the cost of pumping ground water (no delivery cost is involved; therefore, the 2.4¢/1,000 gallons cost of pumping must be re-added.)

Therefore: Unit benefit for San Antonio & San Pedro Springs =
13.6 + 2.4 = 16.0¢/1,000 gallons

Increase in Spring flow from San Marcos, Comal, and Hueco Springs

Value of most reasonable alternative to increased spring flow from San Marcos, Comal, and Hueco Springs = Delivered cost of Cuero water 31/ - Cost of transmission from springs to San Antonio.

From curve of cost vs. capacity for transmission from Comal and San Marcos Springs to San Antonio: 1/ for 17,600 AF/yr or 15.7 mgd cost = 5.0¢ per 1,000 gal.

Unit benefit for increased spring flow = 12.3 - 5.0 = 7.3¢ per 1,000 gal.

Increase in Spring flow from Leona River Springs

The discharge of the Leona River Springs percolates into the Leona formation, a shallow aquifer overlying the Edwards limestone. The value of this increase in spring flow is based on obtaining an equal amount of water from the deeper Edwards limestone formation. The quality of both waters is approximately the same.

Increased spring flow = 4,000 acre-feet per year = 3.57 mgd 1/

300' x 8", 150 gpm well including testing and pump house = $16,000 32/

3.57 mgd = 2,500 gpm ∴ 17 wells needed

Total Cost	=	$272,000
Pump and motor @ $3,000 per well 32/	=	51,000
Well field collection system	=	294,100
Total first cost		$617,100

Amortize private investment for 25 years @ 4 percent
(617,100)(.06401) = $39,500

Convert to equivalent Federal investment @ 3 1/8 percent for 100 years
39,500 (17.17308)(.03276) = $22,200 per year

Annual Energy Cost = $\frac{100' \text{ head } (.00315)}{.85}$ (1,303,050 thousand gal./yr) ($.006/kwh) = $2,900

Annual Operation and Maintenance =	$1,000
Total Annual Cost =	$26,100

or unit value of Leona River Springs water = 2.0¢/1000 gal.

Increase in resources:	Acre-feet/yr. 1/	Percent 1/
Total	63,900	100.00
Montell Reservoir	26,600	41.63
Concan Reservoir	21,500	33.65
Sabinal Reservoir	15,800	24.72

Annual benefit for increased pumping potential
29,000 AF/yr = 9,449,679 (1000 gal/yr) @ 13.6¢ = $1,285,500

Prorating:		
	Montell	$535,200
	Concan	$432,600
	Sabinal	$317,700

Annual benefit for increased spring flow from Comal, San Marcos and Hueco Springs
17,600 AF/yr = 5,736,632 (1,000 gal/yr) @ 7.3¢ = $418,800

Prorating:		
	Montell	$174,300
	Concan	$140,900
	Sabinal	$103,600

Annual benefit for increased spring flow from San Antonio and San Pedro Springs
13,300 AF/yr = 4,335,069 (1,000 gal/yr) @ 16.0¢ = $693,600

Prorating:		
	Montell	$288,700
	Concan	$233,400
	Sabinal	$171,500

Annual benefit for increased spring flow from Leona River Springs
4,000 AF/yr = 1,303,050 (1,000 gal/yr) @ 2.0¢ = $26,100

Prorating:		
	Montell	$10,900
	Concan	$ 8,800
	Sabinal	$ 6,400

Decrease in Pumping Head

Another creditable benefit is realized from reduced pumping head in the underground reservoir.

Average reduction in total head - 1.79 feet 1/

Total pumpage = 263,000 AF/yr = 85,723,535 (1,000 gal/yr)

Assumed pump efficiency = 85 percent

Assumed energy cost = $0.006 per kwh

Annual kwh = $\frac{1.79\ (.00315)}{0.85}$ (85,723,535) = 568,700

Annual electrical saving = 568,700 (.006) = $3,400

Prorating		
	Montell	$1,400
	Concan	$1,100
	Sabinal	$ 900

Summary of Annual Recharge Benefits for Montell, Concan, and Sabinal Reservoirs

		Increased Spring Flow				
Reservoir	Increased Pumping Potential	Comal, San Marcos & Hueco	San Antonio & San Pedro	Leona River	Decreased Pumping Head	Total
Montell	$535,200	$174,300	$288,700	$10,900	$1,400	$1,010,500
Concan	432,600	140,900	233,400	8,800	1,100	816,800
Sabinal	317,700	103,600	171,500	6,400	900	600,100
TOTAL	$1,285,500	$418,800	$693,600	$26,100	$3,400	$2,427,400

An additional benefit from Montell Reservoir is to the downstream municipal and industrial water users who will receive 4.0 mgd via a pipeline. The most reasonable alternative to this part of the project is a single-purpose reservoir to yield 4.0 mgd.

The estimated cost of this alternative is $2,358,000

Annual Operation and Maintenance is estimated to be $3,400

Amortize private investment for 25 years @ 4 percent
2,358,000 (0.06401) = $150,900

Convert to equivalent Federal investment to provide for same annual payment.

Present worth of 1 per period @ 3 1/8 percent = 17.17308

Then equivalent Federal investment =
($150,900)(17.17308) = $2,591,400

Amortize Federal investment for 100 years @ 3 1/8 percent

Annual Cost = (2,591,400)(0.03276) = $84,900

Estimated Annual Operation and Maintenance 3,400

∴ Annual Benefit = $88,300

ATTACHMENT 3

INFORMATION REQUIRED
BY SENATE RESOLUTION
NO. 148

SURVEY REPORT
ON
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE, SAN ANTONIO AND NUECES RIVERS
AND TRIBUTARIES, TEXAS

INFORMATION CALLED FOR BY SENATE RESOLUTION 148,
85TH CONGRESS, ADOPTED JANUARY 28, 1958

1. AUTHORITY.- The following information is furnished in response to Senate Resolution 148, 85th Congress, adopted January 28, 1958.

2. WATER PROBLEMS.- The Edwards Underground Reservoir is presently the only municipal and industrial water supply for approximately 850,000 people residing in the portion of the Guadalupe, San Antonio, and Nueces River Basins within the study area. The reservoir furnishes a water supply for many farms and ranches; industries; five large military installations; and seventeen cities and communities, the largest of which is the city of San Antonio with estimated 1960 population in excess of 700,000 people. The water demands of this area have exceeded the dependable yield of the Edwards Underground Reservoir since 1962.

3. Within the recorded range of elevations of experienced water levels the reservoir contains about 2,800,000 acre-feet of storage. Under existing conditions of recharge the underground reservoir has a dependable yield for pumping of about 234,000 acre-feet per year without depleting the reservoir below its historic low experienced in 1956. Based on this constant pumping quantity, approximately 292,900 acre-feet per year would be discharged from the aquifer through springs along the southern and southeastern limits of the reservoir, principally from major springs in the Guadalupe and San Antonio River Basins.

4. Streams of the three river basins recharge the underground reservoir as they flow over the outcrop of the Edwards limestone in the Balcones fault zone. Floodflows, however, are frequently greater than the infiltration rate of the streambeds in the Edwards outcrop area. Floods on these streams develop quickly following major storms in the hill and canyon country of the Edwards Plateau. Many have extremely high peak discharges and cause extensive damages to rural and urban areas south of the Balcones escarpment in the Gulf Coastal Plains.

5. PROJECT DESCRIPTION AND ECONOMIC LIFE.- The most practical plan of improvement for the Edwards Underground Reservoir area would consist of the construction of reservoirs on the principal streams

of the Edwards Plateau to control floods and provide increased water resources for conventional water supply and recharge of the Edwards aquifer. The plan found justified at this time would include the construction by the Federal Government of four reservoirs on major streams of the Edwards Plateau. Three of these reservoirs would be located on rivers in the Nueces River Basin, streams that would provide the greatest quantity of increased water resources for recharge. The reservoirs would be Montell on the Nueces River, Concan on the Frio River, and Sabinal on the Sabinal River. In this semiarid region where high evaporation losses would occur from a permanent pool the most efficient and effective plan would be to construct the reservoirs to contain joint-storage for flood-control and recharge purposes and to operate them to release floodflows immediately after each rain at a rate equal to the infiltration rate of the streambeds in the Edwards outcrop area. A small permanent pool would be maintained in the Montell Reservoir for a downstream water supply. The plan of improvement would also provide for construction of a channel dam and pipeline to transport this water across the loss zone on the Nueces River to the downstream interests. Since all of the streams of the Edwards Plateau are perennial streams with flows maintained by springs issuing from the Edwards formation and are located in a scenic area, recreation has been included as a project purpose in the three reservoirs.

6. The fourth reservoir proposed for Federal construction is the Cloptin Crossing Reservoir on the Blanco River, a tributary of the Guadalupe River. Although this project would be located in the watershed of the artesian reservoir, the Blanco River contributes very little to the recharge of the aquifer. It has been found, however, that the Cloptin Crossing Reservoir would be very effective in reducing flood damages downstream and would provide a substantial quantity of surface water which could be made available to supplement the ground-water supply through area-wide agreement on development of water resources. Full development of basic recreation lands and facilities is also proposed for this project. A summary of pertinent data on the four projects recommended for Federal construction is presented in table 1.

TABLE 1

PERTINENT DATA
PROPOSED RESERVOIRS
PLAN OF DEVELOPMENT
EDWARDS UNDERGROUND RESERVOIR AREA

	MULTIPLE PURPOSE RESERVOIRS			
	Montell Reservoir	Cloptin Crossing Reservoir	Concan Reservoir	Sabinal Reservoir
DRAINAGE AREA				
Square miles	707	307	391	210
SPILLWAY DESIGN FLOOD				
Peak inflow, cfs	893,900	414,900	592,500	381,000
Volume, acre-feet	821,300	353,000	489,400	249,000
Volume, inches	21.78	21.56	23.47	22.23
Peak outflow, cfs	581,000(1)	196,400(1)	433,000(1)	270,600

RESERVOIR	Montell Elev.(2) (feet)	Area (acres)	Capacity (ac-ft)	Capacity (inch)	Cloptin Crossing Elev.(2) (feet)	Area (acres)	Capacity (ac-ft)	Capacity (inch)	Concan Elev.(2) (feet)	Area (acres)	Capacity (ac-ft)	Capacity (inch)	Sabinal Elev.(2) (feet)	Area (acres)	Capacity (ac-ft)	Capacity (inch)
Top of dam	1371.0	-	-	-	1023.0	-	-	-	1399.5	-	-	-	1244.0	-	-	-
Maximum design water surface	1366.0	10,280	533,100	14.14	1017.5	9,600	573,000	35.00	1394.2	5,670	280,600	13.46	1238.8	3,860	135,200	12.07
Top of flood control pool and spillway crest	1331.5(3)	6,200	252,300	6.69	998.0	7,730	404,000	24.67	1366.5(3)	3,830	149,000	7.15	1226.5(3)(5)	2,990	91,300	8.33
Top of conservation pool	1237.0	260	2,200	0.06	980.5	6,060	283,400	17.31	-	-	-	-	-	-	-	-
Sediment storage - Total	1331.0	-	12,000	0.32	998.0	-	9,200	0.56	1366.5	-	7,800	0.37	1226.5	-	4,200	0.37
Sediment storage - Conservation Pool	1237.0	-	1,200	0.03	980.5	-	8,500	0.52	-	-	-	-	-	-	-	-

	Montell Reservoir	Cloptin Crossing Reservoir	Concan Reservoir	Sabinal Reservoir
STORAGE SUMMARY				
Flood control, ac-ft	239,300(4)	119,900	141,200(4)	89,100(4)
Water conservation, ac-ft	1,000	274,900	-	-
Sediment, ac-ft	12,000	9,200	7,800	4,200
Total	252,300	404,000	149,000	93,300
DAM				
Type	Earth and rock fill	Earth and rock fill	Earth and rock fill	Earth and rock fill
Total length, feet	7,360	7,520	2,955	2,150
Embankment section:				
Type	Earth and rock fill	Earth and rock fill	Earth and rock fill	Earth and rock fill
Total length, feet	7,360	7,520	2,955	1,500
Height above streambed, feet	158.0	200.0	164.0	114.0
Freeboard, feet	5.0	5.5	5.3	5.2
Crown width, feet	30	30	30	30
Side slopes:				
Upstream	1 on 3.5	1 on 3.5	1 on 3.5	1 on 3.0
Downstream	1 on 3.0	1 on 3.0	1 on 3.0	1 on 3.0
SPILLWAY				
Type	Broadcrested	Broadcrested	Broadcrested	Gated
Net length, feet	960	760	1,030	240
Gates:				
Type	-	-	-	Tainter
Number	-	-	-	6
Size (width x height)	-	-	-	40' x 30'
Spillway discharge, cfs:				
Maximum design water surface	570,600	187,200	425,300	270,600
OUTLET WORKS				
Type	Gate-controlled conduit	Gate-controlled conduit	Gate-controlled conduit	Gate-controlled sluices
Number of conduits	1	1	1	2
Dimensions	15' diameter	13' diameter	13' diameter	3'-0" x 6'-0"
Invert elevation, feet	1216.0	955.0	1240.0	1130.0
Control	3 - 5'-8" x 12' tractor-type gates	2 - 6' x 13' tractor-type gates	2 - 6' x 13' tractor-type gates	2 - 3' x 6' slide gates
RELOCATIONS				
Roads and highways:				
U. S. highways, miles	-	-	0.3	-
State highways, miles	10.5	-	-	-
F.M. highways, miles	-	-	-	6.0
State park roads, miles	-	-	0.2	-
County roads, miles	1.8	1.3	6.3	-
Access roads, miles	4.5	-	-	-
Bridges, feet	390	400	100	-
Utilities:				
Power lines, miles	27	2.0	5.0	8.7
Telephone lines, miles	20	2.0	5.0	8.7
Cemetery graves	340	-	-	-
LANDS				
Dam and reservoir				
Clearing, acres	260	3,750	-	-
Land acquisition:				
Fee simple, acres	700	8,390	400	400
Flood easement, acres	6,140	-	3,960	3,000
(Guide taking line)	(1336.0)	(1003.0)	(1371.5)	(1229.5)
Recreation				
Clearing, acres	80	2,420	30	30
Land acquisition:				
Fee simple, acres	100	2,210	10	10
PIPELINE AND CHANNEL DAM				
Channel dam height (feet)	6			
Pipeline				
Diameter (inches)	24			
Length (miles)	8.5			
Control	Gate valve			

(1) Includes discharge through outlet works as follows: 10,400 (Montell), 9,200 (Cloptin Crossing), 7,700 (Concan)
(2) All elevations refer to mean sea level.
(3) Top of controlled storage - joint storage for flood control and recharge purposes.
(4) Joint-storage for flood control and recharge.
(5) Top of controlled storage and top of gate elev. 1226.5; spillway crest elev. 1196.5.

7. The economic life of the four reservoirs proposed for Federal construction is considered to be 100 years.

8. PROJECT COSTS.- Exclusive of preauthorization study costs of $375,000, of which $150,000 was provided by the Edwards Underground Water District, an agency of the State of Texas, the estimated first cost of the four reservoir projects proposed for Federal construction would be $84,048,000, of which $51,620,000 would be reimbursable to the United States. The annual operation maintenance and major replacement costs are estimated to be $379,400, of which the local interest share would be $147,300. The project costs are based on July 1964 price levels and on existing conditions of watershed development. A summary of the first costs and annual operation, maintenance and replacement costs, is shown in the following tabulation:

Reservoir Project	First Costs	Annual Operation, Maintenance and Replacement Costs (1)
Montell	$32,545,000	$90,400
Concan	15,650,000	54,800
Sabinal	11,413,000	49,200
Cloptin Crossing	24,440,000	185,000
TOTAL	$84,048,000	$379,400

(1) Based on 100-year economic life.

9. BENEFIT-COST RATIOS.- For the 4 reservoir projects the total annual charges are estimated at $3,313,300 and the total average annual benefits for flood control, water supply (including recharge), and recreation are estimated at $5,949,700. The benefit-cost ratio is 1.8 based on a 100-year period of analysis. The annual charges, annual benefits and benefit-cost ratios for each reservoir project based on 100-year and 50-year economic life are presented in table 2.

TABLE 2

ANNUAL CHARGES, ANNUAL BENEFITS AND BENEFIT-COST RATIOS
50-YEAR AND 100-YEAR ECONOMIC LIFE

Item	Based on 100-year economic life as shown in the report	Based on 50-year economic life
	(Interest Rate:	3.125%)
MONTELL RESERVOIR PROJECT:		
Average annual costs:		
Interest and amortization	$1,147,100	$1,387,100
Operation, maintenance and replacements	90,400	80,800
Total:	$1,237,500	$1,467,900
Average annual benefits:		
Flood control	$ 602,100	$ 602,100
Downstream water supply	88,300	88,300
Recharge to underground reservoir	1,010,500	1,010,500
Recreation - F&W	101,500	101,500
Total:	$1,802,400	$1,802,400
Ratio of benefits to costs	1.5	1.2
CONCAN RESERVOIR PROJECT:		
Average annual costs:		
Interest and amortization	$ 544,700	$ 661,700
Operation, maintenance, and replacements	54,800	49,100
Total:	$ 599,500	$ 710,800
Average annual benefits:		
Flood control	$ 59,300	$ 59,300
Recharge to underground reservoir	816,800	816,800
Recreation	13,500	13,500
Total:	$ 889,600	$ 889,600
Ratio of benefits to costs	1.5	1.3

TABLE 2 (CONT'D)

Item	Based on 100-year economic life as shown in the report	Based on 50-year economic life
	(Interest Rate:	3.125%)
SABINAL RESERVOIR PROJECT:		
Average annual costs:		
Interest and amortization	$ 391,400	$ 475,500
Operation, maintenance, and replacements	49,200	41,700
Total:	$ 440,600	$ 517,200
Average annual benefits:		
Flood control	$ 46,300	$ 46,300
Recharge to underground reservoir	600,100	600,100
Recreation	13,500	13,500
Total:	$ 659,900	$ 659,900
Ratio of benefits to cost:	1.5	1.3
CLOPTIN CROSSING RESERVOIR PROJECT:		
Average annual costs:		
Interest and amortization	$ 850,700	$1,033,300
Operation, maintenance, and replacements	185,000	174,800
Total:	$1,035,700	$1,208,100
Average annual benefits:		
Flood control	$ 659,000	$ 659,000
Water conservation (surface supply)	653,000	653,000
Recreation - F&W	1,285,800	1,285,800
Total:	$2,597,800	$2,597,800
Ratio of benefits to cost:	2.5	2.2

10. INTANGIBLE PROJECT EFFECTS.- The provision of flood-control storage in Montell, Concan, Sabinal and Cloptin Crossing Reservoirs would serve to reduce the threat to lives and destruction to property in the area downstream from these projects. In this manner the projects would aid in stabilization of the economy in the area subject to flooding. Important intangible benefits could be realized through provision of additional recharge water for the underground reservoir and a supplemental surface water supply. Maintaining higher water levels in the aquifer would decrease the danger of contamination of the important well fields in the San Antonio area from hydrogen sulfide or saline water along the southern or southeastern limits of the reservoir. An increased dependable water supply, added springflow in the region, and additional lands and facilities for recreation and fish and wildlife would improve the social well-being of a great number of people living in the general area.

11. PHYSICAL FEASIBILITY AND COST OF PROVIDING FOR FUTURE NEEDS.- The proposed plan of improvement represents maximum water resource development that could be economically justified at this time. The current water demands on the underground reservoir are exceeding the dependable yield of the resource, and projections of future water demands within the Edwards Reservoir area indicate a water demand far in excess of the available supply, even with maximum watershed development. The four reservoir projects proposed for Federal construction would make available an additional 110,900 acre-feet of water annually, of which 63,900 acre-feet are indicated for recharge of the Edwards aquifer. An additional quantity of 46,400 acre-feet per year could be made available through development by local interests of a water supply project at approximately the Dam No. 7 site on the Guadalupe River upstream from the recently completed Corps of Engineers' Canyon Reservoir. Construction of these reservoirs would provide a sufficient water supply to meet the projected needs within the Edwards Reservoir area to approximately the year 2000. To supply the water demands beyond this date will require more adequate use of return flows and development of an additional water supply outside the Edwards Underground Reservoir area. Because of the limitations imposed by the authorization for this report, no overall basin water supply plan has been investigated for the three river basins.

12. The construction of Montell, Concan, and Sabinal Reservoirs to contain 469,600 acre-feet of joint-storage for flood-control and recharge purposes would provide flood protection for developments along the Nueces, Frio, and Sabinal Rivers from floods up to a 50-year frequency originating on the Edwards Plateau upstream from the dam sites. The largest portion of the benefits would be creditable to Montell Reservoir and would be derived from protection

of the urban and extensive agricultural developments along the Nueces River, particularly in the "winter garden" area downstream from the Balcones fault zone in the vicinity of La Pryor, Crystal City, and Cotulla. Additional benefits would also be realized in areas further downstream, including the cities of Tilden and Three Rivers. The provision of 119,900 acre-feet of flood-control storage in Cloptin Crossing Reservoir would provide flood protection to the agricultural lands, transportation and utility facilities and other improvements along the river valley of the Blanco and Guadalupe Rivers downstream from the dam site. It would also provide protection to the cities of San Marcos and Gonzales from 75-year frequency floods originating on the Blanco River upstream from the dam site.

13. ALLOCATION OF COSTS.- The results of cost allocations for the four recommended reservoir projects by the Separable Costs-Remaining Benefits method and by alternative methods listed in Senate Resolution 148, based on assumed economic lives of 100 years and 50 years, are presented in tables 3 - 6. The allocated cost of storage for conventional water supply has been apportioned to non-Federal interests; however, the allocated cost of storage for recharge of the underground reservoir has been apportioned both to the Federal Government and to local interests, based on percentage of the total quantity of water pumped from the aquifer by military installations in the San Antonio area. The allocated cost to recreation has been apportioned to the Federal Government within the limits established by H.R. 9032, dated November 6, 1963. A summary of the allocated water supply costs to be borne by local interests is shown in the following tabulation:

Reservoir	First costs	Percent	Annual O&M charges	Percent
Montell	$18,986,000	58.34	$52,600	58.19
Concan	13,451,000	85.95	34,000	62.04
Sabinal	9,722,000	85.18	30,300	61.59
Cloptin Crossing	9,461,000	38.71	30,400	16.43
TOTAL	$51,620,000	(61.42)	$147,300	(38.82)

14. EXTENT OF INTEREST IN THE PROJECT.- The Edwards Underground Water District, an agency of the State of Texas, has participated in this cooperative study as required by Public Law 86-645. The District contributed $150,000, or 40 percent of the cost of the study. By

letter dated March 23, 1965, the District stated that in signing the cooperative report it expresses its full approval of the proposed plan of improvement for the comprehensive development of the water resources of the Edwards area and will endeavor to provide the necessary local cooperation.

15. REPAYMENT SCHEDULES.- All construction, operation and maintenance, replacement, and interest costs incurred by the Federal Government and allocated to water supply are to be repaid by local interests, except 5.5 percent of those costs pertaining to recharge of the Edwards Underground Reservoir. No payment is required for the costs allocated to future water supply until such time as the project is first used for that purpose, except for the payment of interest charges on the unpaid balance after the interest free period, which shall not exceed 10 years. The construction costs, including interest during construction and interest on the unpaid balance, may be paid in a lump sum or in equal annual payments within the life of the project, but not to exceed 50 years after water supply use is initiated. In addition, annual payments must be made for the operation and maintenance costs allocated to water supply, beginning with the first use of storage for water supply, plus payment of applicable replacement costs when incurred. The above requirements are equally applicable to provisions for additional water supply and at such time that portions of reservoir storage are converted to meet long-term demands. Project costs allocated to recreation have been apportioned to the Federal Government and are within limits of the cost-sharing policy adopted by the Administration and outlined in H.R. 9032, 88th Congress. In addition to the foregoing, responsible local interests designated by the State will be required to furnish assurances satisfactory to the Secretary of the Army that they will:

(1) Enter into a contract prior to initiation of the construction work and in accordance with repayment provisions of the Water Supply Act of 1958, as amended, to reimburse the Federal Government for that portion of the construction costs allocated to water supply and apportioned to non-Federal interests, including the channel dam and pipeline in connection with the Montell Reservoir project.

(2) Obtain without cost to the United States all water rights necessary for operation of the projects in the interest of conventional water supply and recharge to the underground reservoir.

16. ALTERNATIVE PROJECT CONSIDERATIONS.- Studies were made of all streams of the three river basins which cross the outcrop of the Edwards limestone in the Balcones fault zone. The studies were made to determine the additional water resources that could be developed for recharge of the Edwards aquifer, the portion of this quantity of

water that would be available for pumping, and the portion that would be discharged from the major springs in the region. The Public Health Service determined that the most reasonable alternative project for the recharge reservoirs was Cuero Reservoir on the Guadalupe River, a project under study by the Bureau of Reclamation. The recharge benefits were evaluated as being equal to the cost of delivered water from the alternative source, taking into account the differential costs of pumping and treatment. Credit was taken only for the increase in pumping and springflow attributable to the recharge projects. Single-purpose water supply reservoirs at the same sites were considered to be the most reasonable alternative projects for conservation storage in Cloptin Crossing and Montell Reservoirs.

17. Several alternative plans of operation were investigated for the recharge projects found justified in the preliminary analysis. By constructing the reservoirs to contain joint-storage for flood-control and recharge purposes, and operating them to release the flood-water for recharge of the Edwards aquifer immediately after each rain, large losses of available resources by evaporation would be averted and construction costs would be substantially reduced. Project locations, sizes, and combinations of purposes were selected that would give greatest excess benefits over cost. The only exception was the selected conservation storage at Cloptin Crossing Reservoir, where full development of maximum watershed resources was considered to be in the best interest of the Edwards Reservoir area.

TABLE 3

ALLOCATION OF COSTS
MONTELL RESERVOIR
(SENATE RESOLUTION 148)
(in thousand dollars)

	Separable Costs: Remaining Benefits Method	Priority of Use Method	Incremental Cost Method
ECONOMIC LIFE OF 100 YEARS			
Allocations to flood control			
a. First cost	10,873.0	17,047.0	30,755.0
(Percent)	(33.41)	(52.38)	(94.50)
b. Annual operation, maintenance, and replacement cost	19.2	23.5	31.6
(Percent)	(21.24)	(26.00)	(34.96)
Allocations to water conservation			
a. First cost	547.0	354.0	45.0
(Percent)	(1.68)	(1.09)	(0.14)
b. Annual operation, maintenance, and replacement cost	12.8	12.5	12.5
(Percent)	(14.16)	(13.83)	(13.83)
Allocations to channel dam and pipeline			
a. First cost	900.0	900.0	900.0
(Percent)	(2.76)	(2.76)	(2.76)
b. Annual operation, maintenance, and replacement cost	16.6	16.6	16.6
(Percent)	(18.36)	(18.36)	(18.36)
Allocations to recharge of underground reservoir			
a. First cost	18,560.0	11,370.0	570.0
(Percent)	(57.03)	(34.94)	(1.75)
b. Annual operation, maintenance, and replacement cost	24.6	20.6	13.4
(Percent)	(27.21)	(22.79)	(14.82)
Allocations to recreation			
a. First cost	1,665.0	2,874.0	275.0
(Percent)	(5.12)	(8.83)	(0.85)
b. Annual operation, maintenance, and replacement cost	17.2	17.2	16.3
(Percent)	(19.03)	(19.02)	(18.03)
Total			
a. First cost	32,545.0	32,545.0	32,545.0
b. Annual operation, maintenance, and replacement cost	90.4	90.4	90.4

TABLE 3 (CONT'D)

	Separable Costs: Remaining Benefits Method	Priority of Use Method	Incremental Cost Method
ECONOMIC LIFE OF 50 YEARS			
Allocations to flood control			
a. First cost	10,889.0	14,034.0	30,755.0
(Percent)	(33.46)	(43.12)	(94.50)
b. Annual operation, maintenance, and replacement cost	16.8	16.8	16.8
(Percent)	(20.79)	(20.79)	(20.79)
Allocations to water conservation			
a. First cost	551.0	291.0	45.0
(Percent)	(1.69)	(0.89)	(0.14)
b. Annual operation, maintenance, and replacement cost	12.7	12.5	12.5
(Percent)	(15.72)	(15.47)	(15.47)
Allocation to channel dam and pipeline			
a. First cost	900.0	900.0	900.0
(Percent)	(2.77)	(2.77)	(2.76)
b. Annual operation, maintenance, and replacement cost	16.6	16.6	16.6
(Percent)	(20.55)	(20.55)	(20.55)
Allocation to recharge of underground reservoir			
a. First cost	18,522.0	14,954.0	570.0
(Percent)	(56.91)	(45.95)	(1.75)
b. Annual operation, maintenance, and replacement cost	20.5	20.7	18.6
(Percent)	(25.37)	(25.62)	(23.02)
Allocation to recreation			
a. First cost	1,683.0	2,366.0	275.0
(Percent)	(5.17)	(7.27)	(0.85)
b. Annual operation, maintenance, and replacement cost	14.2	14.2	16.3
(Percent)	(17.57)	(17.57)	(20.17)
Total			
a. First cost	32,545.0	32,545.0	32,545.0
b. Annual operation, maintenance, and replacement cost	80.8	80.8	80.8

TABLE 4

ALLOCATION OF COSTS
CONCAN RESERVOIR
(SENATE RESOLUTION 148)
(in thousand dollars)

	Separable Costs Remaining Benefits Method	Priority of Use Method	Incremental Cost Method
ECONOMIC LIFE OF 100 YEARS			
Allocations to flood control			
a. First cost	1,189.0	1,704.0	15,156.0
(Percent)	(7.60)	(10.89)	(96.84)
b. Annual operation, maintenance, and replacement cost	13.7	11.7	38.3
(Percent)	(25.00)	(21.35)	(69.89)
Allocations to recharge of underground reservoir			
a. First cost	14,234.0	13,558.0	422.0
(Percent)	(90.95)	(86.63)	(2.70)
b. Annual operation, maintenance, and replacement cost	36.0	38.0	11.7
(Percent)	(65.69)	(69.34)	(21.35)
Allocations to recreation			
a. First cost	227.0	388.0	72.0
(Percent)	(1.45)	(2.48)	(0.46)
b. Annual operation, maintenance, and replacement cost	5.1	5.1	4.8
(Percent)	(9.31)	(9.31)	(8.76)
Total			
a. First cost	15,650.0	15,650.0	15,650.0
b. Annual operation, maintenance, and replacement cost	54.8	54.8	54.8
ECONOMIC LIFE OF 50 YEARS			
Allocations to flood control			
a. First cost	1,009.0	1,402.0	15,214.0
(Percent)	(6.45)	(8.96)	(97.21)
b. Annual operation, maintenance, and replacement cost	13.1	11.7	33.2
(Percent)	(26.68)	(23.83)	(67.62)
Allocations to recharge of underground reservoir			
a. First cost	14,434.0	13,929.0	364.0
(Percent)	(92.23)	(89.00)	(2.33)
b. Annual operation, maintenance, and replacement cost	31.6	32.9	11.7
(Percent)	(64.36)	(67.01)	(23.83)
Allocation to recreation			
a. First cost	207.0	319.0	72.0
(Percent)	(1.32)	(2.04)	(0.46)
b. Annual operation, maintenance, and replacement cost	4.4	4.5	4.2
(Percent)	(8.96)	(9.16)	(8.55)
Total			
a. First cost	15,650.0	15,650.0	15,650.0
b. Annual operation, maintenance, and replacement cost	49.1	49.1	49.1

TABLE 5

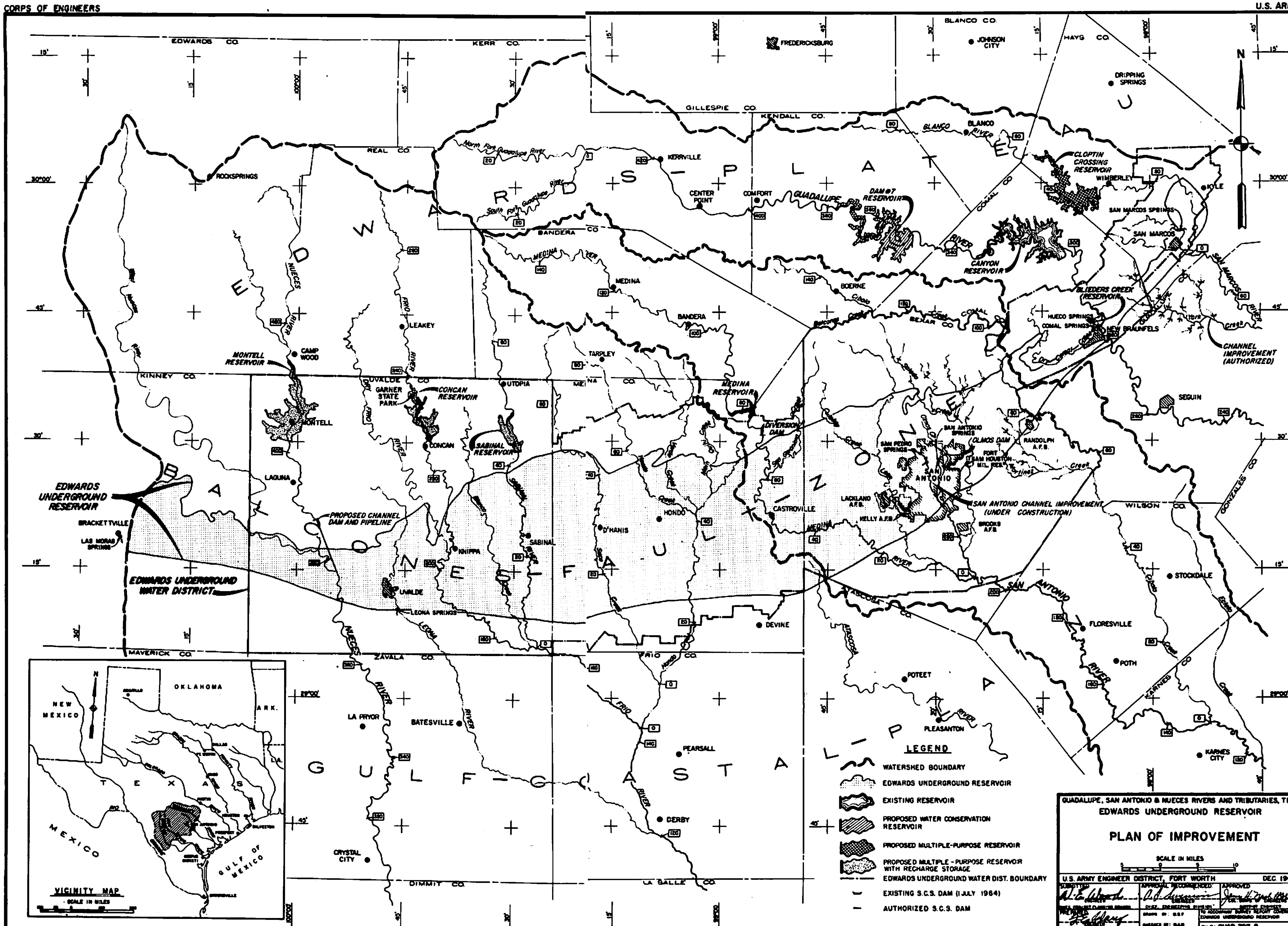
ALLOCATION OF COSTS
SABINAL RESERVOIR
(SENATE RESOLUTION 148)
(in thousand dollars)

	Separable Costs Remaining Benefits Method	Priority of Use Method	Incremental Cost Method
ECONOMIC LIFE OF 100 YEARS			
Allocations to flood control			
a. First cost	898.0	1,350.0	10,859.0
(Percent)	(7.87)	(11.83)	(95.15)
b. Annual operation, maintenance, and replacement cost	12.0	10.0	33.4
(Percent)	(24.39)	(20.33)	(67.89)
Allocations to recharge of underground reservoir			
a. First cost	10,288.0	9,669.0	482.0
(Percent)	(90.14)	(84.72)	(4.22)
b. Annual operation, maintenance, and replacement cost	32.1	34.1	11.0
(Percent)	(65.24)	(69.31)	(22.36)
Allocations to recreation			
a. First cost	227.0	394.0	72.0
(Percent)	(1.99)	(3.45)	(0.63)
b. Annual operation, maintenance, and replacement cost	5.1	5.1	4.8
(Percent)	(10.37)	(10.36)	(9.75)
Total			
a. First cost	11,413.0	11,413.0	11,413.0
b. Annual operation, maintenance, and replacement cost	49.2	49.2	49.2
ECONOMIC LIFE OF 50 YEARS			
Allocations to flood control			
a. First cost	770.0	1,111.0	10,859.0
(Percent)	(6.75)	(9.73)	(95.15)
b. Annual operation, maintenance, and replacement cost	11.2	10.0	26.3
(Percent)	(26.86)	(23.98)	(63.07)
Allocations to recharge of underground reservoir			
a. First cost	10,441.0	9,978.0	482.0
(Percent)	(91.48)	(87.43)	(4.22)
b. Annual operation, maintenance, and replacement cost	25.9	27.1	11.0
(Percent)	(62.11)	(64.99)	(26.38)
Allocations to recreation			
a. First cost	202.0	324.0	72.0
(Percent)	(1.77)	(2.84)	(0.63)
b. Annual operation, maintenance, and replacement cost	4.6	4.6	4.4
(Percent)	(11.03)	(11.03)	(10.55)
Total			
a. First cost	11,413.0	11,413.0	11,413.0
b. Annual operation, maintenance, and replacement cost	41.7	41.7	41.7

TABLE 6

ALLOCATION OF COSTS
CLOPTIN CROSSING RESERVOIR
(SENATE RESOLUTION 148)
(in thousand dollars)

	Separable Costs Remaining Benefits Method	Priority of Use Method	Incremental Cost Method
ECONOMIC LIFE OF 100 YEARS			
Allocations to flood control			
a. First cost	7,628.0	12,304.0	13,439.0
(Percent)	(31.21)	(50.34)	(54.99)
b. Annual operation, maintenance, and replacement cost	27.3	37.0	37.0
(Percent)	(14.76)	(20.00)	(20.00)
Allocations to water conservation			
a. First cost	9,461.0	6,042.0	8,356.0
(Percent)	(38.71)	(24.72)	(34.19)
b. Annual operation, maintenance, and replacement cost	30.4	24.0	28.0
(Percent)	(16.43)	(12.97)	(15.13)
Allocations to recreation			
a. First cost	7,351.0	6,094.0	2,645.0
(Percent)	(30.08)	(24.94)	(10.82)
b. Annual operation, maintenance, and replacement cost	127.3	124.0	120.0
(Percent)	(68.81)	(67.03)	(64.87)
Total			
a. First cost	24,440.0	24,440.0	24,440.0
b. Annual operation, maintenance, and replacement cost	185.0	185.0	185.0
ECONOMIC LIFE OF 50 YEARS			
Allocations to flood control			
a. First cost	7,882.0	13,187.0	13,439.0
(Percent)	(32.25)	(53.96)	(54.99)
b. Annual operation, maintenance, and replacement cost	26.6	33.0	33.0
(Percent)	(15.22)	(18.88)	(18.88)
Allocations to water conservation			
a. First cost	8,803.0	5,915.0	8,356.0
(Percent)	(36.02)	(24.20)	(34.19)
b. Annual operation, maintenance, and replacement cost	28.1	23.9	29.7
(Percent)	(16.07)	(13.67)	(16.99)
Allocations to recreation			
a. First cost	7,755.0	5,338.0	2,645.0
(Percent)	(31.73)	(21.84)	(10.82)
b. Annual operation, maintenance, and replacement cost	120.1	117.9	112.1
(Percent)	(68.71)	(67.45)	(64.13)
Total			
a. First cost	24,440.0	24,440.0	24,440.0
b. Annual operation, maintenance, and replacement cost	174.8	174.8	174.8


GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
PLAN OF IMPROVEMENT
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC 1964
FILE: GUAD. 707-2
LEGEND
WATERSHED BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE - PURPOSE RESERVOIR WITH RECHARGE STORAGE
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EXISTING S.C.S. DAM (1 JULY 1964)
AUTHORIZED S.C.S. DAM
VICINITY MAP
NEW MEXICO
OKLAHOMA
ARK.
LA.
TEXAS
MEXICO
GULF OF MEXICO
EDWARDS PLATEAU
BALCONES FAULT ZONE
GULF COASTAL PLAIN
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
PROPOSED CHANNEL DAM AND PIPELINE
MONTELL RESERVOIR
CONCAN RESERVOIR
SABINAL RESERVOIR
MEDINA RESERVOIR
DIVERSION DAM
OLMOS DAM
CANYON RESERVOIR
CLOPTIN CROSSING RESERVOIR
DAM #7 RESERVOIR
BLIEDERS CREEK RESERVOIR
CHANNEL IMPROVEMENT (AUTHORIZED)
SAN ANTONIO CHANNEL IMPROVEMENT (UNDER CONSTRUCTION)
EDWARDS CO.
KERR CO.
REAL CO.
KINNEY CO.
UVALDE CO.
MEDINA CO.
BANDERA CO.
GILLESPIE CO.
KENDALL CO.
BLANCO CO.
HAYS CO.
COMAL CO.
BEXAR CO.
GUADALUPE RIVER
MAVERICK CO.
ZAVALA CO.
FRIO CO.
ATASCOSA CO.
WILSON CO.
GONZALES CO.
KARNES CO.
DIMMIT CO.
LA SALLE CO.
ROCKSPRINGS
CAMP WOOD
LEAKEY
MONTELL
GARNER STATE PARK
CONCAN
UTOPIA
LAGUNA
BRACKETTVILLE
LAS MORAS SPRINGS
KNIPPA
UVALDE
LEONA SPRINGS
SABINAL
D'HANIS
HONDO
CASTROVILLE
TARPLEY
MEDINA
BANDERA
KERRVILLE
CENTER POINT
COMFORT
BOERNE
FREDERICKSBURG
JOHNSON CITY
DRIPPING SPRINGS
BLANCO
WIMBERLEY
KYLE
SAN MARCOS SPRINGS
SAN MARCOS
HUECO SPRINGS
COMAL SPRINGS
NEW BRAUNFELS
SEGUIN
SAN ANTONIO
SAN ANTONIO SPRINGS
SAN PEDRO SPRINGS
RANDOLPH A.F.B.
FORT SAM HOUSTON MIL. RES.
LACKLAND A.F.B.
KELLY A.F.B.
BROOKS A.F.B.
STOCKDALE
FLORESVILLE
POTH
KARNES CITY
DEVINE
POTEET
PLEASANTON
PEARSALL
DERBY
LA PRYOR
BATESVILLE
CRYSTAL CITY
NUECES RIVER
FRIO RIVER
SABINAL RIVER
MEDINA RIVER
SAN ANTONIO RIVER
ATASCOSA RIVER
LEONA RIVER
BLANCO RIVER
SAN MARCOS RIVER
N

APPENDIX II

HYDROLOGY AND HYDRAULIC DESIGN

SURVEY REPORT
ON
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE, SAN ANTONIO AND NUECES RIVERS
AND TRIBUTARIES, TEXAS

APPENDIX II

HYDROLOGY AND HYDRAULIC DESIGN

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

TABLES

CONTENTS (Continued)

TABLES (Continued)

CONTENTS (Continued)

TABLES (Continued)

PLATES

CONTENTS (Continued)

PLATES (Continued)

CONTENTS (Continued)

PLATES (Continued)

SURVEY REPORT
ON
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE, SAN ANTONIO, AND NUECES RIVERS
AND TRIBUTARIES, TEXAS

APPENDIX II

HYDROLOGY AND HYDRAULIC DESIGN

GENERAL

1. SCOPE.- This appendix presents analyses of problems associated with the water resources of the Edwards Reservoir and the analyses of some of the water resource problems of the Nueces, Guadalupe, and San Antonio River Basins. Only those portions of these three river basins which would be affected by projects constructed to alter the existing recharge of the Edwards Reservoir are considered to be within the scope of this report. Such projects were investigated with a view toward the possible improvement of the yield of the underground reservoir together with the provision of flood control and water conservation measures.

2. It is noted that because of its importance, the Edwards Reservoir is the most intensely studied aquifer in Texas. A voluminous amount of data relative to the aquifer have been published as a result of investigations by the U. S. Geological Survey and by private consultants in cooperation with the Texas Water Commission, the San Antonio City Water Board, the San Antonio City Public Service Board, the Bexar County Metropolitan Water District, and the Edwards Underground Water District.

3. The investigation of those items covered by reports of these agencies was limited to checking the accuracy of the basic data contained and determining the reasonableness of the approach to the analysis and of conclusions reached. The maximum practicable use was made of the data contained in these reports which are listed in the Bibliography, exhibit 1.

4. DESCRIPTION OF STUDY AREA.- The area covered by this study lies in the south-central portion of the state of Texas, approximately between 98°00' and 100°30' west longitude and 29°00' and 30°15' north latitude. It is bound on the west by the Rio Grande River Basin, on the north by the Colorado River Basin, and on the south and east by the Balcones Escarpment. The study area includes an area of nearly 6,400 square miles consisting of parts of the upper basins of the Nueces River, the San Antonio River, and the Guadalupe River.

5. From west to east the area in the Nueces River Basin is drained by the West Nueces River, the Nueces River, the Dry Frio River, the Frio River, Blanco Creek, the Sabinal River, Seco Creek, Hondo Creek, and Verde Creek. The area in the San Antonio River Basin is drained by the Medina River, Leon Creek, Salado Creek, and Cibolo Creek. The area in the Guadalupe River Basin is drained by Dry Comal Creek, the Guadalupe River, and the Blanco River. In general, these streams originate on the Edwards Plateau, commonly known as the "hill country" north of the Balcones Escarpment.

6. The terrain of the plateau is rough and broken with thin soil cover and the drainage is characterized by steep slopes, resulting in sharp-peaked runoff hydrographs. In addition, most of the streams exhibit a small base flow except in periods of drought. The Edwards limestone covers most of the surface through the Edwards Plateau except in portions of the Guadalupe and San Antonio River Basins where remnants of the limestone cap the hills. For the most part, the streams have cut deep gorges through the Edwards limestones and are bedded in the more impervious Glen Rose limestones. The Edwards limestone absorbs a substantial amount of rainfall. This water percolates downward through cracks and fissures to the lower parts of the Edwards formation where it comes in contact with relatively impermeable formations, forming an unconfined water body. The water then moves by gravity flow laterally through the limestone with much of it reappearing as springflow at or near the contact between the pervious and impervious zones in the valleys that have been cut by the streams. These springs are the source of the base flow of the streams that drain the Edwards Plateau country. Each of the streams then, with the exception of the Guadalupe River, lose their entire base flow and much of their flood flow to the Edwards Reservoir as they cross long stretches of honeycombed and cavernous limestone in the Balcones fault zone. The location of the Edwards Reservoir is shown on plate 1.

7. Those streams crossing the recharge area and the approximate lengths and drainage areas above the downstream limit of the recharge area are shown in table 1. The major watershed drainage areas are delineated and tabulated on plates 2 and 3, Drainage Areas, Nueces and Guadalupe-San Antonio River Basins.

8. EXISTING AND AUTHORIZED FEDERAL IMPROVEMENTS.- The Federal improvements in the study area are limited to those constructed and authorized by the Corps of Engineers and the Soil Conservation Service of the Department of Agriculture. These improvements are discussed in the following paragraphs.

a. Corps of Engineers Projects.- The Canyon Reservoir is the only Corps of Engineers reservoir in operation in the study area and is located at river mile 303.0 on the Guadalupe River

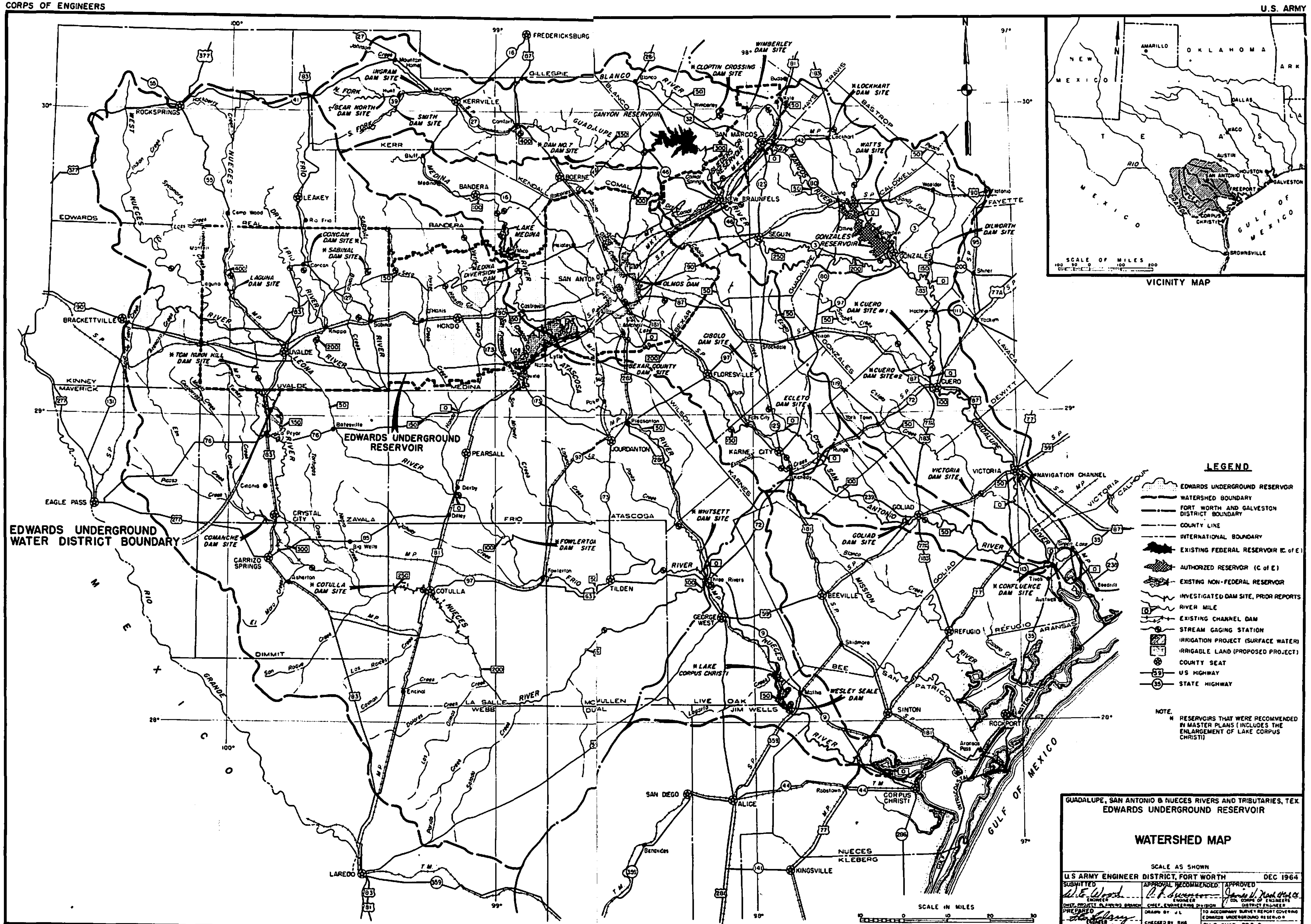
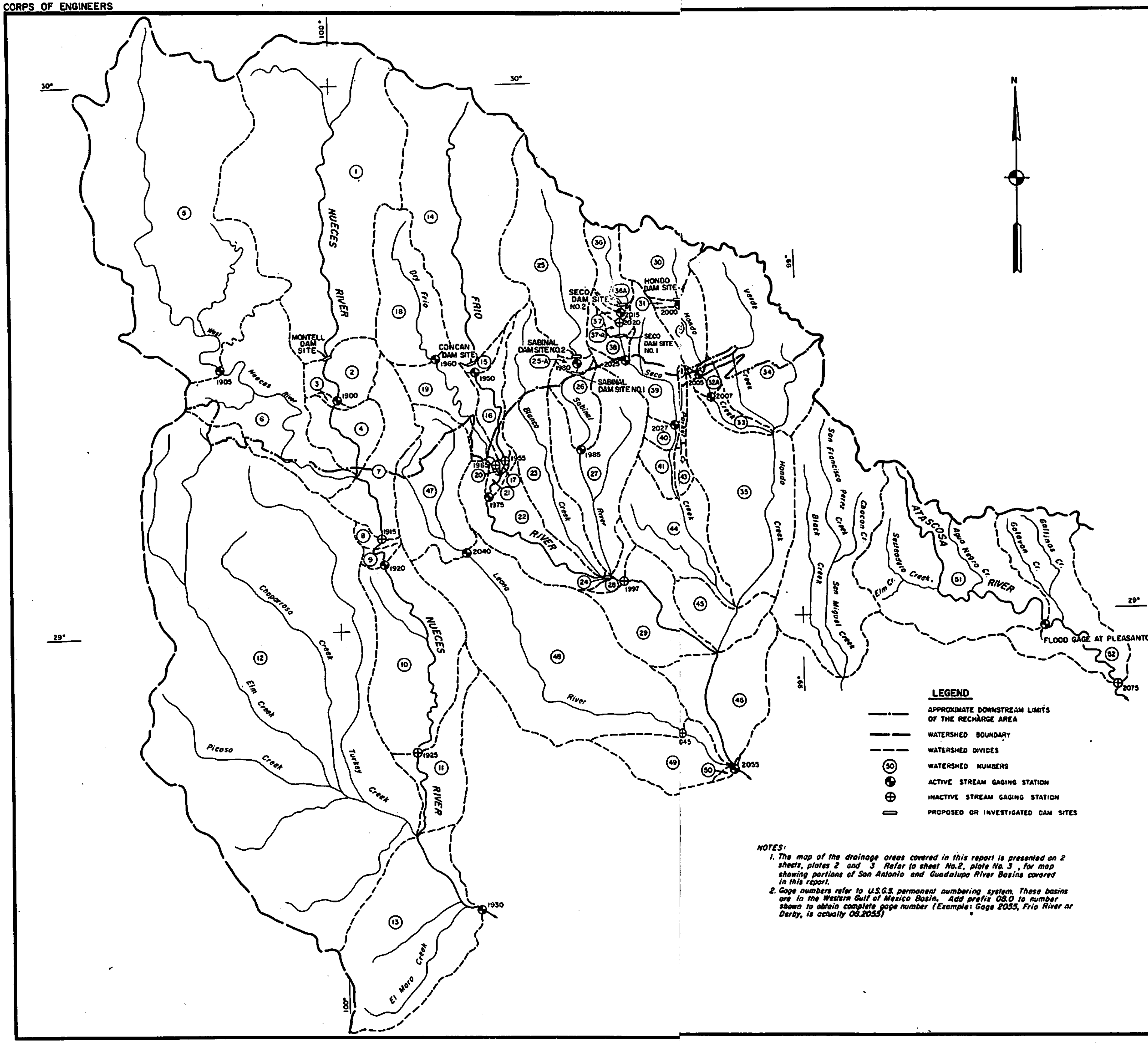

VICINITY MAP
LEGEND
EDWARDS UNDERGROUND RESERVOIR
WATERSHED BOUNDARY
FORT WORTH AND GALVESTON DISTRICT BOUNDARY
COUNTY LINE
INTERNATIONAL BOUNDARY
EXISTING FEDERAL RESERVOIR (C. of E.)
AUTHORIZED RESERVOIR (C of E)
EXISTING NON-FEDERAL RESERVOIR
INVESTIGATED DAM SITE, PRIOR REPORTS
RIVER MILE
EXISTING CHANNEL DAM
STREAM GAGING STATION
IRRIGATION PROJECT (SURFACE WATER)
IRRIGABLE LAND (PROPOSED PROJECT)
COUNTY SEAT
US HIGHWAY
STATE HIGHWAY
NOTE.
RESERVOIRS THAT WERE RECOMMENDED IN MASTER PLANS (INCLUDES THE ENLARGEMENT OF LAKE CORPUS CHRISTI)
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT BOUNDARY
GULF OF MEXICO
SCALE IN MILES
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
WATERSHED MAP
SCALE AS SHOWN
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC 1964
SUBMITTED
APPROVAL RECOMMENDED
APPROVED
FILE GUAD 707-2

TABLE 1

STREAMS OF THE EDWARDS RESERVOIR AREA
GUADALUPE, SAN ANTONIO, AND NUECES RIVER BASINS

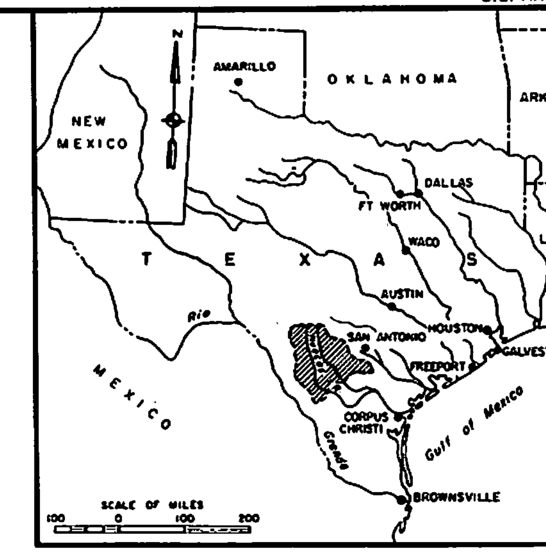
Stream	Above downstream limits of recharge area*: Approx. length (miles)	Above downstream limits of recharge area*: Drainage area (sq.mi.)
GUADALUPE RIVER BASIN		
Blanco River and adjacent area	70	514
Guadalupe River	155	1,510
Dry Comal Creek	8	98
Sub-total		2,122
SAN ANTONIO RIVER BASIN		
Cibolo Creek	61	258
Salado Creek	18	
San Geronimo Creek	19	270 (Salado, San Geronimo, Leon Creeks combined)
Leon Creek	19	
Medina River	83	630
Sub-total		1,158
NUECES RIVER BASIN		
Verde Creek	27	
Hondo Creek	32	412 (Verde, Hondo, Seco Creeks combined)
Seco Creek	21	
Sabinal River	38	256 (Sabinal River and Blanco Creek combined)
Blanco Creek	14	
Frio River	58	450
Dry Frio River	45	193
Nueces River	64	896
West Nueces River	76	905
Sub-total		3,112
Total		6,392

* See plates 2 and 3



NOTES:

1. The map of the drainage areas covered in this report is presented on 2 sheets, plates 2 and 3 Refer to sheet No.2, plate No. 3, for map showing portions of San Antonio and Guadalupe River Basins covered in this report.
2. Gage numbers refer to U.S.G.S. permanent numbering system. These basins are in the Western Gulf of Mexico Basin. Add prefix 08.0 to number shown to obtain complete gage number (Example: Gage 2055, Frio River at Derby, is actually 08.2055)



VICINITY MAP

WATERSHED AREAS

COMPONENT AREAS: WATERSHED NUMBER	COMPONENT AREAS: AREA SQ. MI.	CUMULATIVE AREAS: AREA SQ. MI.	CUMULATIVE AREAS: POINT OF MEASUREMENT
			NUECES RIVER
1	707	707	ABOVE MONTELL DAM SITE
2	57	764	ABOVE GAGE NO. 1900 AT LAGUNA
3	4	768	ABOVE LAGUNA DAM SITE
4	68	836	ABOVE MOUTH WEST NUECES RIVER
5-6	937	1,773	BELOW MOUTH WEST NUECES RIVER
7	157	1,930	ABOVE GAGE NO. 1915 NR. UVALDE (DISCONTINUED)
8	7	1,937	ABOVE TOM NUNN HILL DAM SITE
9	10	1,947	ABOVE GAGE NO.1920 NR. UVALDE
10	203	2,150	ABOVE GAGE NO.1925 NR. CINONIA (DISCONTINUED)
11	97	2,247	ABOVE MOUTH TURKEY CREEK
12	1,569	3,816	BELOW MOUTH TURKEY CREEK
13	266	4,082	ABOVE GAGE NO. 1930 NR. ASHERTON
			WEST NUECES RIVER
5	700	700	ABOVE GAGE NO.1905 NR. BRACKETTVILLE
6	237	937	ABOVE MOUTH WEST NUECES RIVER
			FRIO RIVER
14	391	391	ABOVE CONCAN DAM SITE
15	14	405	ABOVE GAGE NO.1950 AT CONCAN
16	63	468	ABOVE GAGE NO.1955 AT KNIPPA (DISCONTINUED)
17	1	469	ABOVE MOUTH DRY FRIO RIVER
18-20	187	656	BELOW MOUTH DRY FRIO RIVER
21	5	661	ABOVE GAGE NO.1975 NR UVALDE
22	161	822	ABOVE MOUTH BLANCO RIVER
23	183	1,005	BELOW MOUTH BLANCO RIVER
24	1	1,006	ABOVE MOUTH SABINAL RIVER
25-27	437	1,443	BELOW MOUTH SABINAL RIVER
28	17	1,460	ABOVE GAGE NO. 1997 NR FRIO TOWN (DISCONTINUED)
29	122	1,582	ABOVE MOUTH HONDO CREEK
30-45	1,086	2,668	BELOW MOUTH HONDO CREEK
46	142	2,810	ABOVE MOUTH LEONA RIVER
47-49	680	3,490	BELOW MOUTH LEONA RIVER
50	3	3,493	ABOVE GAGE NO. 2055 NR DERBY
			DRY FRIO RIVER
18	117	117	ABOVE GAGE NO. 1960 NR. REAGAN WELLS
19	62	179	ABOVE GAGE NO. 1965 AT KNIPPA (DISCONTINUED)
20	8	187	ABOVE MOUTH DRY FRIO RIVER
			SABINAL RIVER
25	206	206	ABOVE SABINAL DAM SITE NO.2 (GAGE NO 1980 NR. SABINAL)
25-A	4	210	ABOVE SABINAL DAM SITE NO.1
26	41	247	ABOVE GAGE NO 1985 AT SABINAL
27	190	437	ABOVE MOUTH SABINAL RIVER
			HONDO CREEK
30	96	96	ABOVE HONDO DAM SITE
31	5	101	ABOVE GAGE NO. 2000 NR TARPLEY
32	31	132	ABOVE GAGE NO. 2005 NR HONDO
32A	10	142	ABOVE GAGE NO. 2007 AT KING'S WATERHOLE NR HONDO
33	23	165	ABOVE MOUTH VERDE CREEK
34	245	410	BELOW MOUTH VERDE CREEK
35	239	649	ABOVE MOUTH SECO CREEK
36-44	369	1,017	BELOW MOUTH SECO CREEK
45	69	1,086	ABOVE MOUTH HONDO CREEK
			SECO CREEK
36	36	36	ABOVE SECO DAM SITE NO.2
36-A	7	43	ABOVE GAGE NO 2015 AT MILLER'S RANCH NR UTOPIA
37	10	53	ABOVE GAGE NO 2020 NR UTOPIA (DISCONTINUED)
37-A	6	59	ABOVE SECO DAM SITE NO.1
38	28	87	ABOVE GAGE NO 2025 NR D'HANIS
39	81	168	ABOVE GAGE NO 2027 CROOK'S RANCH NR. D'HANIS
40	16	184	ABOVE D'HANIS
41	22	206	ABOVE MOUTH PARKER CREEK
42-43	32	238	BELOW MOUTH PARKER CREEK
44	130	368	ABOVE MOUTH SECO CREEK
			PARKER CREEK
42	16	16	ABOVE D'HANIS
43	16	32	ABOVE MOUTH PARKER CREEK
			LEONA RIVER
47	146	146	ABOVE GAGE NO 2040 NR. UVALDE
48	419	565	ABOVE GAGE NO 2045 NR. DIVOT (DISCONTINUED)
49	115	680	ABOVE MOUTH LEONA RIVER
			ATASCOSA RIVER
51	341	341	ABOVE FLOOD GAGE AT PLEASANTON
52	189	530	ABOVE GAGE NO. 2075 NR. McCOY (DISCONTINUED)

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

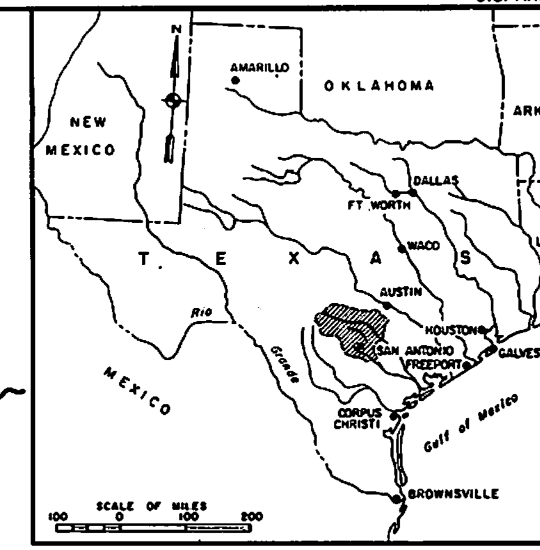
EDWARDS UNDERGROUND RESERVOIR

NUECES RIVER BASIN
DRAINAGE AREA MAP

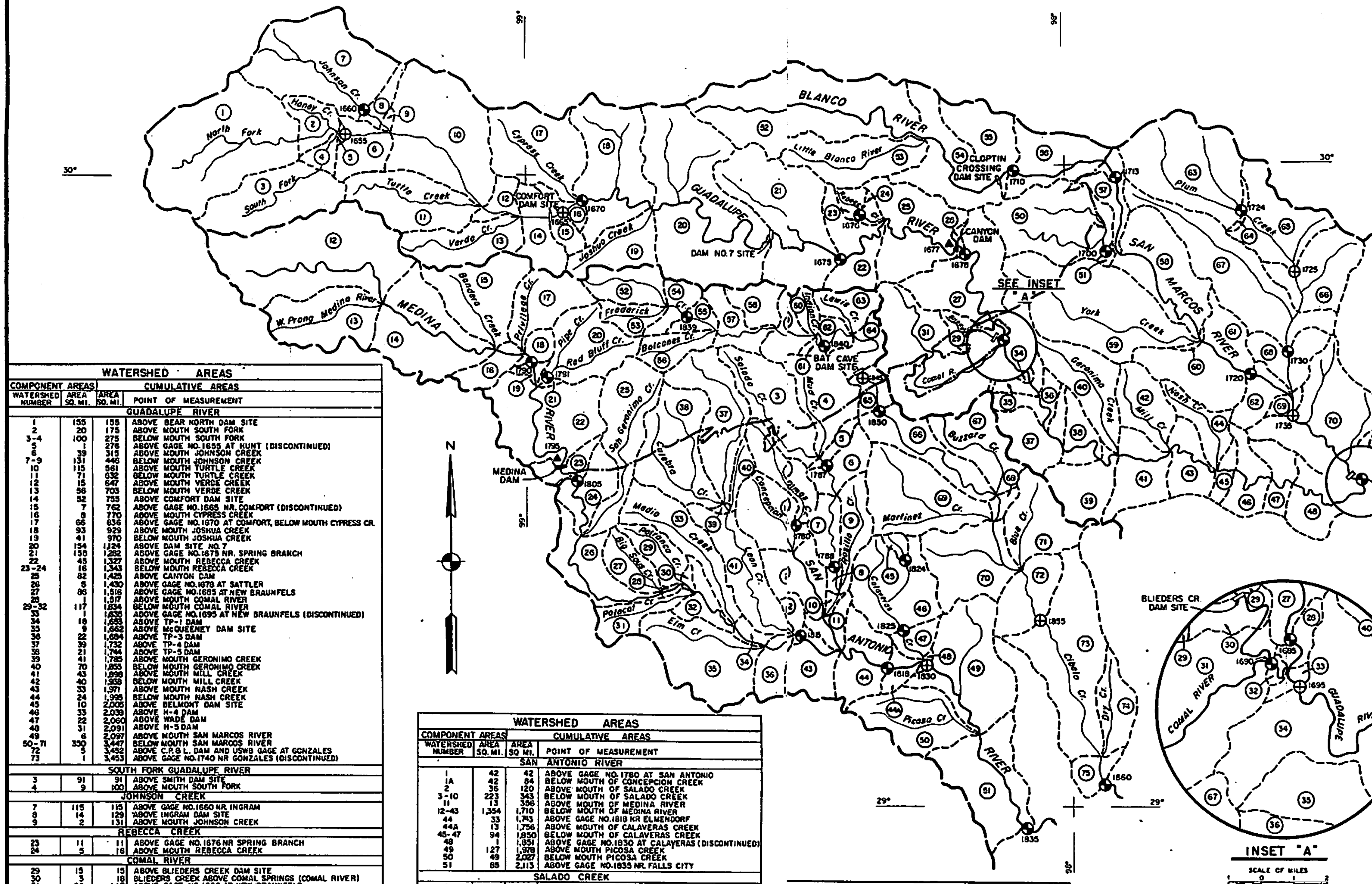
SCALE IN MILES
5 0 5 10

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1984

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
W. E. Wood (signature) — ENGINEER, CHIEF, PROJECT PLANNING BRANCH	C. P. (signature) — ENGINEER, CHIEF, ENGINEERING DIVISION	(signature) — COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED (signature) — ENGINEER, CHIEF, HYDROLOGY SECTION	DRAWN BY: G.M.P. / CHECKED BY: R.H.S.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR / FILE: QUAD 707-2

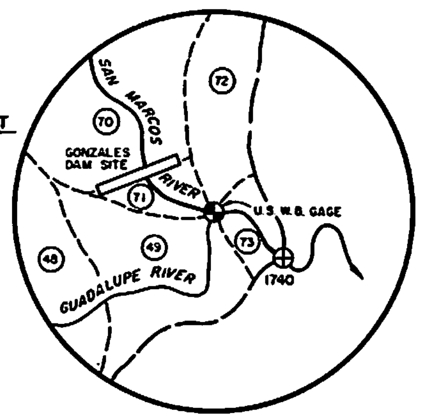


VICINITY MAP



INSET "A"

SCALE OF MILES



INSET "B"

SCALE OF MILES

WATERSHED AREAS

COMPONENT AREAS		CUMULATIVE AREAS	
WATERSHED NUMBER	AREA SQ. MI.	AREA SQ. MI.	POINT OF MEASUREMENT
			GUADALUPE RIVER
1	155	155	ABOVE BEAR NORTH DAM SITE
2	20	175	ABOVE MOUTH SOUTH FORK
3-4	100	275	BELOW MOUTH SOUTH FORK
5	1	276	ABOVE GAGE NO.1655 AT HUNT (DISCONTINUED)
6	39	315	ABOVE MOUTH JOHNSON CREEK
7-9	131	446	BELOW MOUTH JOHNSON CREEK
10	115	561	ABOVE MOUTH TURTLE CREEK
11	71	632	BELOW MOUTH TURTLE CREEK
12	15	647	ABOVE MOUTH VERDE CREEK
13	56	703	BELOW MOUTH VERDE CREEK
14	52	755	ABOVE COMFORT DAM SITE
15	7	762	ABOVE GAGE NO.1665 NR. COMFORT (DISCONTINUED)
16	8	770	ABOVE MOUTH CYPRESS CREEK
17	66	836	ABOVE GAGE NO.1670 AT COMFORT, BELOW MOUTH CYPRESS CR.
18	93	929	ABOVE MOUTH JOSHUA CREEK
19	41	970	BELOW MOUTH JOSHUA CREEK
20	154	1,124	ABOVE DAM SITE NO.7
21	158	1,282	ABOVE GAGE NO.1675 NR. SPRING BRANCH
22	45	1,327	ABOVE MOUTH REBECCA CREEK
23-24	16	1,343	BELOW MOUTH REBECCA CREEK
25	82	1,425	ABOVE CANYON DAM
26	5	1,430	ABOVE GAGE NO.1678 AT SATTLER
27	86	1,516	ABOVE GAGE NO.1685 AT NEW BRAUNFELS
28	1	1,517	ABOVE MOUTH COMAL RIVER
29-32	117	1,634	BELOW MOUTH COMAL RIVER
33	1	1,635	ABOVE GAGE NO.1695 AT NEW BRAUNFELS (DISCONTINUED)
34	18	1,653	ABOVE TP-1 DAM
35	9	1,662	ABOVE McQUEENEY DAM SITE
36	22	1,684	ABOVE TP-3 DAM
37	39	1,732	ABOVE TP-4 DAM
38	21	1,744	ABOVE TP-5 DAM
39	41	1,785	ABOVE MOUTH GERONIMO CREEK
40	70	1,855	BELOW MOUTH GERONIMO CREEK
41	43	1,898	ABOVE MOUTH MILL CREEK
42	40	1,938	BELOW MOUTH MILL CREEK
43	33	1,971	ABOVE MOUTH NASH CREEK
44	24	1,995	BELOW MOUTH NASH CREEK
45	10	2,005	ABOVE BELMONT DAM SITE
46	33	2,038	ABOVE H-4 DAM
47	22	2,060	ABOVE WADE DAM
48	31	2,091	ABOVE H-5 DAM
49	6	2,097	ABOVE MOUTH SAN MARCOS RIVER
50-71	350	3,447	BELOW MOUTH SAN MARCOS RIVER
72	5	3,452	ABOVE C.P.& L. DAM AND USWB GAGE AT GONZALES
73	1	3,453	ABOVE GAGE NO.1740 NR GONZALES (DISCONTINUED)
			SOUTH FORK GUADALUPE RIVER
3	91	91	ABOVE SMITH DAM SITE
4	9	100	ABOVE MOUTH SOUTH FORK
			JOHNSON CREEK
7	115	115	ABOVE GAGE NO.1660 NR. INGRAM
8	14	129	ABOVE INGRAM DAM SITE
9	2	131	ABOVE MOUTH JOHNSON CREEK
			REBECCA CREEK
23	11	11	ABOVE GAGE NO.1676 NR SPRING BRANCH
24	5	16	ABOVE MOUTH REBECCA CREEK
			COMAL RIVER
29	15	15	ABOVE BLIEDERS CREEK DAM SITE
30	3	18	BLIEDERS CREEK ABOVE COMAL SPRINGS (COMAL RIVER)
31	99	117	ABOVE GAGE NO.1690 AT NEW BRAUNFELS
32	0.35	117	ABOVE MOUTH COMAL RIVER
			SAN MARCOS RIVER
50	84	84	ABOVE SPRING FLOW GAGE NO.1700 AT SAN MARCOS
51	2	86	ABOVE MOUTH BLANCO RIVER
52-57	428	514	BELOW MOUTH BLANCO RIVER
58	94	608	ABOVE MOUTH YORK CREEK
59	143	751	BELOW MOUTH YORK CREEK
60	1	752	ABOVE FENTRESS DAM SITE
61	81	833	ABOVE GAGE NO. 1720 AT LULING
62	21	854	ABOVE MOUTH PLUM CREEK
63-68	386	1,240	BELOW MOUTH PLUM CREEK
69	9	1,249	ABOVE GAGE NO.1735 AT OTTINE (DISCONTINUED)
70	95	1,344	ABOVE GONZALES DAM SITE
71	6	1,350	ABOVE MOUTH SAN MARCOS RIVER
			BLANCO RIVER
52	170	170	ABOVE MOUTH LITTLE BLANCO RIVER
53	69	239	BELOW MOUTH LITTLE BLANCO RIVER
54	68	307	ABOVE CLOPTIN CROSSING DAM SITE
55	46	353	ABOVE GAGE NO.1710 AT WIMBERLEY
56	57	410	ABOVE GAGE NO.1713 NR. KYLE
57	18	428	ABOVE MOUTH BLANCO RIVER
			PLUM CREEK
63	113	113	ABOVE GAGE NO.1724 AT LOCKHART
64	5	118	ABOVE LOCKHART DAM SITE
65	66	184	ABOVE GAGE NO.1725 NR LOCKHART (DISCONTINUED)
66	61	245	ABOVE WATTS DAM SITE
67	111	356	ABOVE GAGE NO.1730 NR. LULING
68	30	386	ABOVE MOUTH PLUM CREEK

WATERSHED AREAS

COMPONENT AREAS		CUMULATIVE AREAS	
WATERSHED NUMBER	AREA SQ. MI.	AREA SQ. MI.	POINT OF MEASUREMENT
			SAN ANTONIO RIVER
1	42	42	ABOVE GAGE NO.1780 AT SAN ANTONIO
1A	42	84	BELOW MOUTH OF CONCEPCION CREEK
2	36	120	ABOVE MOUTH OF SALADO CREEK
3-10	223	343	BELOW MOUTH OF SALADO CREEK
11	13	356	ABOVE MOUTH OF MEDINA RIVER
12-43	1,354	1,710	BELOW MOUTH OF MEDINA RIVER
44	33	1,743	ABOVE GAGE NO.1818 NR ELMENDORF
44A	13	1,756	ABOVE MOUTH OF CALAVERAS CREEK
45-47	94	1,850	BELOW MOUTH OF CALAVERAS CREEK
48	1	1,851	ABOVE GAGE NO.1830 AT CALAVERAS (DISCONTINUED)
49	127	1,978	ABOVE MOUTH PICOSA CREEK
50	49	2,027	BELOW MOUTH PICOSA CREEK
51	85	2,113	ABOVE GAGE NO.1835 NR. FALLS CITY
			SALADO CREEK
3	75	75	ABOVE MOUTH OF MUD CREEK
4	51	126	BELOW MOUTH OF MUD CREEK
5	11	137	ABOVE GAGE NO.1787 AT UPPER SAN ANTONIO
6	23	160	BELOW RITTMAN ROAD
7	29	189	ABOVE GAGE NO.1788 AT LOWER SAN ANTONIO
8	3	192	ABOVE MOUTH OF ROSILLO CREEK
9	28	220	BELOW MOUTH OF ROSILLO CREEK
10	3	223	ABOVE MOUTH OF SALADO CREEK
			MEDINA RIVER
12	160	160	ABOVE MOUTH WEST PRONG MEDINA RIVER
13	76	236	BELOW MOUTH WEST PRONG MEDINA RIVER
14	100	336	ABOVE MOUTH BANDERA CREEK
15	67	403	BELOW MOUTH BANDERA CREEK
16	18	421	ABOVE MOUTH PRIVILEGE CREEK
17	41	462	BELOW MOUTH PRIVILEGE CREEK
18	12	474	ABOVE GAGE NO.1790 NR. PIPE CREEK
19	4	478	ABOVE MOUTH RED BLUFF CREEK
20-21	58	536	BELOW MOUTH RED BLUFF CREEK
22	98	634	ABOVE MEDINA DAM SITE & GAGE NO.1795
23	16	650	ABOVE GAGE NO. 1805 NR. RIOMEDINA
24	35	685	ABOVE MOUTH SAN GERONIMO CREEK
25	74	759	BELOW MOUTH SAN GERONIMO CREEK
26	57	816	ABOVE MOUTH BIG SOUS CREEK
27	24	840	BELOW MOUTH BIG SOUS CREEK
28	2	842	ABOVE MOUTH POTRANCA CREEK
29	25	867	BELOW MOUTH POTRANCA CREEK
30	2	869	ABOVE MOUTH POLECAT CREEK
31	19	888	BELOW MOUTH POLECAT CREEK
32	22	910	ABOVE MOUTH MEDIO CREEK
33	53	963	BELOW MOUTH MEDIO CREEK
34	8	971	ABOVE MOUTH ELM CREEK
35	78	1,049	BELOW MOUTH ELM CREEK
36	20	1,069	ABOVE MOUTH LEON CREEK
37-41	237	1,306	BELOW MOUTH LEON CREEK
42	11	1,317	ABOVE GAGE NO.1815 NR. SAN ANTONIO
43	37	1,354	ABOVE MOUTH MEDINA RIVER

WATERSHED AREAS

COMPONENT AREAS		CUMULATIVE AREAS	
WATERSHED NUMBER	AREA SQ. MI.	AREA SQ. MI.	POINT OF MEASUREMENT
			RED BLUFF CREEK
20	56	56	ABOVE GAGE NO.1791 NR PIPE CREEK
21	2	58	ABOVE MOUTH RED BLUFF CREEK
			LEON CREEK
37	77	77	ABOVE MOUTH CULEBRA CREEK
38	83	160	BELOW MOUTH CULEBRA CREEK
39	1	161	ABOVE MOUTH HUEBNER CREEK
40	12	173	BELOW MOUTH HUEBNER CREEK
41	64	237	ABOVE MOUTH LEON CREEK
			CALAVERAS CREEK
45	7	7	ABOVE GAGE NO.1824 NR ELMENDORF
46	70	77	ABOVE GAGE NO.1825 NR ELMENDORF
47	17	94	ABOVE MOUTH CALAVERAS CREEK
			CIBOLO CREEK
52	35	35	ABOVE MOUTH OF FREDERICK CREEK
53	17	52	BELOW MOUTH OF FREDERICK CREEK
54	16	68	ABOVE GAGE NO.1839 NR. BOERNE
55	11	79	ABOVE MOUTH BALCONES CREEK
56	23	102	BELOW MOUTH BALCONES CREEK
57	20	128	ABOVE MOUTH CREEK AT RM.115.4
58	24	152	BELOW MOUTH CREEK AT RM.115.4
59	30	182	ABOVE MOUTH INDIAN CREEK
60	11	193	ABOVE BULVERDE DAM SITE (BELOW MOUTH INDIAN CR.)
61	5	198	ABOVE GAGE NO.1840 NR BULVERDE
62	10	208	ABOVE MOUTH LEWIS CREEK
63	23	231	BELOW MOUTH LEWIS CREEK
64	19	250	ABOVE BAT CAVE DAM SITE (GAGE NO.1845 AT BRACKEN)(DISCONT.)
65	24	274	ABOVE GAGE NO.1850 AT SELMA

WATERSHED AREAS

COMPONENT AREAS		CUMULATIVE AREAS	
WATERSHED NUMBER	AREA SQ. MI.	AREA SQ. MI.	POINT OF MEASUREMENT
			CIBOLO CREEK (CONTD.)
66	45	319	ABOVE MOUTH BUZZARD CREEK
67	63	382	BELOW MOUTH BUZZARD CREEK
68	6	388	ABOVE MOUTH MARTINEZ CREEK
69	88	476	BELOW MOUTH MARTINEZ CREEK
70	69	545	ABOVE MOUTH BLUE CREEK
71	59	604	BELOW MOUTH BLUE CREEK
72	43	647	ABOVE GAGE NO.1855 AT SUTHERLAND SPRINGS (DISCONTINUED)
73	130	777	ABOVE MOUTH DRY CREEK
74	33	810	BELOW MOUTH DRY CREEK
75	17	827	ABOVE GAGE NO.1860 NR FALLS CITY

LEGEND

—·—	APPROXIMATE DOWNSTREAM LIMITS OF THE RECHARGE AREA
——	WATERSHED BOUNDARY
- - -	WATERSHED DIVIDE
(50)	WATERSHED NUMBER
◕	ACTIVE STREAM GAGING STATION
⊕	INACTIVE STREAM GAGING STATION
▲	ACTIVE RESERVOIR GAGING STATION
▬	EXISTING DAM
▭	PROPOSED OR INVESTIGATED DAM SITE

NOTES:

1. *The map of the drainage areas covered in this report is presented on 2 sheets, plates 2 and 3 Refer to sheet No.1, plate No. 2, for map showing portions of Nueces River Basin covered in this report.*
2. *Gage numbers refer to U.S.G.S. permanent numbering system. These basins are in the Western Gulf of Mexico Basin. Add prefix 08.0 to number shown to obtain complete gage number (Example: Gage 1835, San Antonio River nr. Falls City, is actually 08.1835).*

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

EDWARDS UNDERGROUND RESERVOIR

GUADALUPE & SAN ANTONIO RIVER BASINS

DRAINAGE AREA MAP

SCALE IN MILES

5 0 5 10

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
W. E. Wood, ENGINEER, CHIEF, PROJECT PLANNING BRANCH	ENGINEER, CHIEF, ENGINEERING DIVISION	LT. COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ENGINEER, CHIEF, HYDROLOGY SECTION	DRAWN BY: A.W.F. / CHECKED BY: R.H.G.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR / FILE: GUAD. 707-2

about 12 miles northwest of New Braunfels. It was constructed for flood control, water supply, and recreational purposes. Construction of the project began in April 1958 and deliberate impoundment began on June 16, 1964. Blieders Creek Reservoir, a flood control only project to be located at river mile 5.8 on Blieders Creek, 1.5 miles north of New Braunfels, is in the advance planning stage. Blieders Creek Reservoir, when constructed, will control the runoff from a 14.8 square mile area and provide flood protection to the city of New Braunfels. The Corps of Engineers also has under construction a channel improvement project in the city of San Antonio which includes the clearing, widening, deepening, and straightening of approximately 31 miles of river and creek channels and construction of certain related structures. This project was begun in November 1957 and, when completed, will control the runoff from approximately 114 square miles of drainage area in and adjacent to the city of San Antonio. Pertinent data for the Canyon and Blieders Creek Reservoir projects and the San Antonio Channel Improvement project are given in tables 2, 3, and 4, respectively.

b. Soil Conservation Service Program.-

(1) Watershed Work Plans.- The Soil Conservation Service of the U. S. Department of Agriculture has formulated "Work Plans" for the Martinez, York, and Salado Creeks watershed within the Edwards Reservoir area. The plans provide for construction of 38 watershed protection and floodwater retarding structures to provide control over a drainage area of about 218 square miles. The structures will contain a total of about 63,767 acre-feet of detention storage. On July 1, 1964 the Soil Conservation Service had in operation 18 structures in two of the watersheds in the study area. Of these structures, five are located in the watershed on Martinez Creek, a tributary of Cibolo Creek in Bexar County, and 13 are in the watershed of York Creek, a tributary of the San Marcos River. Pertinent data on the projects which have been constructed and on those additional projects which are planned for the watersheds listed above are presented in table 5, and the locations of the projects are given on plate 4.

(2) Projected Development.- In connection with the report of the United States Study Commission - Texas, the Soil Conservation Service published the results of investigations of the long-range needs for floodwater retarding structures in most of the Texas river basins. These reports were titled "Upstream Flood Prevention and Water Resources Development." The reports for the three basins being studied in this report were published as follows: Guadalupe River Basin, August 1960; San Antonio River Basin, September 1960; and the Nueces River Basin, November 1960. These data have been summarized and supplemented in another SCS publication, "Upstream Flood Prevention in Texas - A Summary Report",

dated June 1963. Pertinent data taken from these reports for additional SCS projects in the study area are given in table 5.

9. EXISTING NON-FEDERAL IMPROVEMENTS.- Development of surface water resources by local interests in the Edwards Reservoir area has been minimal due largely to the availability of ground-water resources. The principal reservoir projects within the three basins are described below.

a. Guadalupe River Basin.- In the Guadalupe River Basin, Comal County has constructed one floodwater retarding structure, with a detention capacity of 350 acre-feet, in the Comal Creek watershed to increase ground-water recharge and to provide flood protection.

b. San Antonio River Basin.- Local interests developments on the San Antonio River and tributaries consist of Lake Medina and Medina Diversion Reservoir on the Medina River, and Olmos Reservoir on Olmos Creek in San Antonio. Lake Medina with a capacity of 254,000 acre-feet, and Medina Diversion Reservoir with a capacity of 5,750 acre-feet, were completed in 1913. These projects are owned and operated by the Bexar-Medina-Atascosa Counties Water Improvement District No. 1 to provide a water supply and gravity diversion for irrigation of lands in the District. In 1926 the City of San Antonio constructed Olmos Reservoir on Olmos Creek to provide flood protection for certain urban areas of the city. Olmos Reservoir has a storage capacity of about 15,500 acre-feet at top of dam and controls the runoff from about 32 square miles of drainage area. Upon completion of the San Antonio Channel Improvement Project, discussed previously, Olmos Reservoir will become an integral part of the plan for flood protection of the San Antonio area. Pertinent data for the Olmos and Medina Reservoir projects are presented in tables 6 and 7.

c. Nueces River Basin.- There has been no significant development by local interests in the Nueces River Basin upstream of the Balcones fault zone of reservoirs for surface water supply or flood control; however, thirteen structures have been built in Uvalde County near Uvalde to improve the natural facilities for ground-water recharge. The recharging of an aquifer artificially may be accomplished by water spreading or injection of water through wells, pits, shafts, or other natural surface openings. The thirteen structures in Uvalde County are of the latter type, consisting generally of small impounding structures and preservation of existing surface openings into the water-bearing formations of the area. The impounding structures allow an increased amount of water, collected during periods of high discharge, to enter the water-bearing formations through the existing openings by reducing the velocity of the water across the land surface. The addition of the impounding structures and installation of devices to protect existing openings have resulted in the introduction of surface waters to the underground strata at higher rates.

TABLE 2

CANYON RESERVOIR
(EXISTING)

LOCATION:
R.M. 303 on Guadalupe River and about 12 mi. N.W. of New Braunfels, Texas, in Comal County

DRAINAGE AREA: 1,425 sq. mi.

DAM:

Type:	Rolled earth fill w/spwy in saddle about 2,500 from rt. abutment
Length:	4,410 (main emb.)
Max. Height:	224 ft.
Top Width:	20 ft.
Dike:	10 ft.

SPILLWAY:

Crest:	943.0 ft msl
Length:	1,260 ft. net @ crest
Type:	Broadcrested
Control:	None

INFLOW:

Spillway design flood peak, cfs	687,000
Spillway design flood volume, ac-ft	1,285,800
Spillway design flood runoff, in.	16.92

OUTFLOW: (El. 969.1)

Total routed peak outflow, cfs	508,000
Spillway	502,800
Outlet Works	5,200

OUTLET WORKS:

Type:	1 gate controlled conduit
Dimension:	10' dia.
Invert:	775.0 ft msl
Control:	2 - 5'8"x10' hydraulically operated slide gates

POWER FEATURES:
None

RESERVOIR DATA

Feature	Elev. feet msl	Reservoir Area (acres)	Reservoir Capacity: Accumulative (ac-ft)	Reservoir Capacity: Runoff (inches)	Reservoir Capacity: Incremental (ac-ft)	Spillway Capacity (cfs)	Outlet Works Capacity (cfs)
Top of Dam	974.0						
Maximum Water Surface	969.1	17,120	1,129,300	14.84		502,800	5,200
Flood Control Pool	943.0	12,890	740,900	9.75	346,400		
Spillway Crest	943.0	12,890	740,900	9.75			
Conservation Pool	909.0	8,240	386,200	5.08	366,400		
Sediment Reserve					28,100*		
Total Storage					740,900		
Maximum tailwater	813.9						
Streambed	750.0						

*Sediment distributed as follows:
19,800 ac-ft below El. 909.0
8,300 ac-ft between El. 909.0 & 943.0

TABLE 3

BLIEDERS CREEK RESERVOIR

(ADVANCE PLANNING)

LOCATION:
R.M. 5.8 on Blieders Creek, Guadalupe River Basin,
1.5 miles N. of New Braunfels, Texas

DRAINAGE AREA:
14.8 sq. mi.

DAM:

Type:	Earth fill
Length:	3130' plus 600' dike
Max. height:	84'
Top width:	20'

SPILLWAY:

Crest:	750.5 ft msl
Length:	Variable
Type:	Natural saddle, left bank
Control:	None

INFLOW:

Spillway design flood peak, cfs	70,300
Spillway design flood volume, ac-ft	27,310
Spillway design flood runoff, in.	34.6

OUTFLOW: (El. 763.1)

Total routed peak outflow, cfs	59,000

OUTLET WORKS:

Type:	1 - conduit
Dimension:	60"
Invert:	
Intake	700.0 ft msl
Outlet	698.0 ft msl
Control	None

POWER FEATURES:
None

RESERVOIR DATA

Feature	Elev. feet msl	Reservoir Area (acres)	Reservoir Capacity: Accumulative (ac-ft)	Reservoir Capacity: Runoff (inches)	Reservoir Capacity: Incremental (ac-ft)	Spillway Capacity (cfs)	Outlet Works Capacity (cfs)
Top of Dam	768.0	684					
Maximum Water Surface	763.1	575	13,657	17.3		58,270	730
Top of Flood Control Pool and Spillway Crest	750.5	368	7,712	9.8	7,312		660
Invert of Outlet Conduit	700.0	16	88	0.1			
Conservation Storage					None		
Sediment Reserve (below el 750.5)					400		
Total storage					7,712		
Streambed	684.0						

TABLE 4

SAN ANTONIO CHANNEL IMPROVEMENT

Local Agency	Stream	Drainage area at head of project -(sq. mi.) Controlled	Uncontrolled	Total	Drainage area at lower limit of project (sq.mi.)	River mile limits of project	Improved channel length (ft)
San Antonio River Authority	San Antonio River	32.0	1.6	33.6	113.7	221.8 to 237.3	60,600
	San Pedro Creek	0.0	1.0	1.0	44.5	0.0 to 4.9	26,100
	Apache Creek	0.0	17.6	17.6	22.6	0.0 to 3.4	18,115
	Martinez Creek	0.0	2.6	2.6	7.1	0.0 to 4.5	23,830
	Alazan Creek	0.0	3.9	3.9	17.7	0.0 to 4.3	22,770
	East Fork Martinez Creek	0.0	0.5	0.5	1.7	0.0 to 1.6	8,300
	North Fork Martinez Creek	0.0	0.9	0.9	1.2	0.0 to 0.7	3,910

TABLE 5

SUMMARY OF PERTINENT DATA FOR PROPOSED SOIL CONSERVATION SERVICE RESERVOIRS

Basin	Watershed	Total drainage area (sq.mi.)	No. of structures	Drainage area controlled (sq.mi.)	Pool capacity: Sediment (ac.ft.)	Pool capacity: Flood control (ac.ft.)	Service spillway release rate (cfs)	Number of structures completed
				WORK PLAN DATA (1)				
San Antonio River	Salado Creek	218	16	118	5,263	42,005	1,190	-
San Antonio River	Martinez Creek	87	6	29	2,478	6,511	369	5
Guadalupe River	York Creek	147	16	71	4,950	15,251	393	13
				USSC-T DATA (2)				
Nueces River	NE Utopia Community	4	1	14	42	395	15	-
San Antonio River	Santa Clara Creek	66	8	19	2,127	6,411	190	-
Guadalupe River	Comal Creek	91	6	39	1,280	12,130	240	-

(1) Data from published work plans available as of July 1, 1964; also, see plate 4 for location.

(2) Data from published reports titled "Upstream Flood Prevention and Water Resources Development" prepared by SCS in 1960 for United States Study Commission, Texas.

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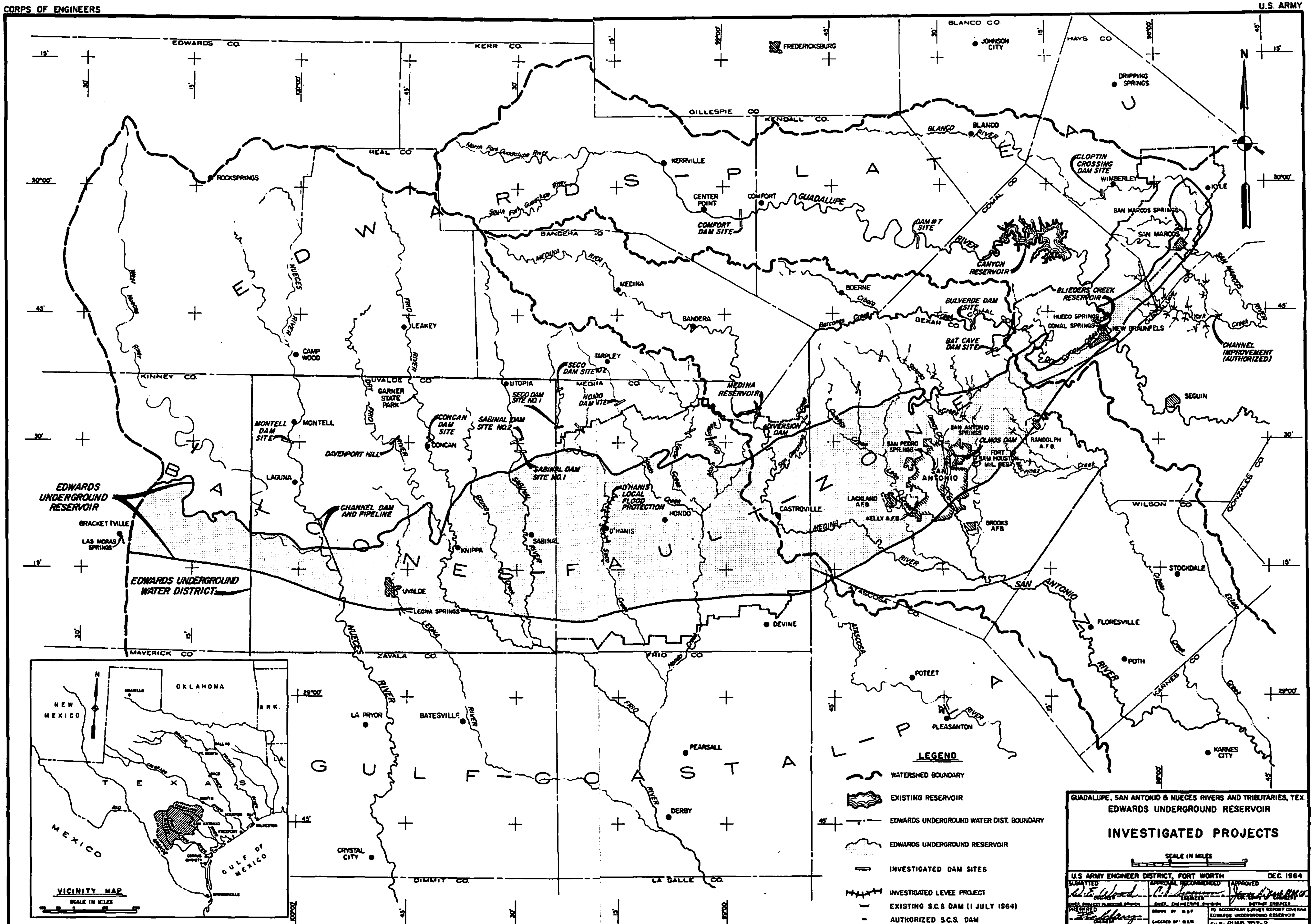


TABLE 6
OLMOS RESERVOIR
(EXISTING)

LOCATION:
On Olmos Creek in north part of San Antonio, Bexar County, approximately 0.8 mile above confluence of Olmos Creek and San Antonio River.

DRAINAGE AREA: 32 sq. mi.

DAM:

Type:	Concrete, gravity-type
Length:	1,941 ft.
Max. height:	57 ft.
Top width:	25 ft.

SPILLWAY:
None

OUTLET WORKS:

Type:	6-gate controlled rectangular conduits
Dimensons:	5'9" x 7'10" each
Invert:	679.53 ft. msl
Control:	6 slide gates

USE:

Flood control

RESERVOIR DATA

Feature	Elev. feet msl	Reservoir area (acres)	Reservoir capacity: Accumulative (ac.ft.)	Reservoir capacity: Runoff (inches)	Reservoir capacity: Incremental (ac.ft.)	Outlet works capacity (cfs)
Top of railing	731.0	1,194	18,800	11.01	3,300	13,500
Top of dam	728.0	1,045	15,500	9.08	10,500	13,100
Floor of gate motor operating room	713.5	458	5,000	2.93	5,000	10,900
Outlet works	679.53	4.5	0			
Total storage					18,800	
Streambed	671.4					

TABLE 7
MEDINA RESERVOIR
(EXISTING)

LOCATION:
R.M. 70.4 on Medina River 13 mi. north of Castroville, Medina County, and about 28 miles west of San Antonio

DRAINAGE AREA: 633 sq. mi.

DAM:

Type:	Concrete, ogee, gravity-type w/spwy in saddle in right abutment adjacent to west end of dam
Length:	1580 ft.
Max. height:	164 ft.
Top width:	25 ft. w/23' roadway

SPILLWAY:

Crest:	1072 ft. msl
Length:	880 ft.
Type:	Broadcrested
Control:	None

OUTLET WORKS:

Left Bank:

Type:	3-gate controlled conduits
Diameter:	60"
Invert:	966.5 ft. msl
Control:	Lift-type gates

Right Bank:

Type:	2-gate controlled sluices
Diameter:	30"
Invert:	922.5 ft. msl
Control:	Lift-type gates

USE:
Irrigation

RESERVOIR DATA

Feature	Elev. feet msl	Reservoir area (acres)	Reservoir capacity: Accumulative (ac.ft.)	Reservoir capacity: Runoff (inches)	Reservoir capacity: Incremental (ac.ft.)	Spillway capacity (cfs)	Outlet works capacity (cfs)
Top of dam	1084.0						
Maximum water surface	1072.0	5,600	254,000	7.52			
Spillway crest	1072.0	5,600	254,000	7.52	249,200		
Sediment reserve	966.5	328	4,800	0.14	4,800		
Total storage					254,000		
Streambed	920.0						

10. CLIMATE.- The climate over the Edwards Plateau is generally mild with hot summers and cool winters. Freezing temperatures and snowfalls are experienced occasionally, caused by the rapid movement of cold high-pressure air masses from the northwestern highlands.

11. The general elevation of the Edwards Plateau ranges from about 3000 feet above mean sea level in the headwaters of the Nueces River Basin to about 600 feet above mean sea level at San Marcos. The only important topographic feature affecting climate in this area is the Balcones Escarpment which extends from Brackettville eastward through San Marcos.

12. Table 8 gives climatological data relative to temperature, growing season, wind velocity, and humidity at representative United States Weather Bureau stations in and adjacent to the Edwards Plateau.

13. HUMIDITY.- The relative humidity over the Edwards Reservoir area is generally moderate, with the humidity decreasing from Austin westward across the Plateau.

14. WINDS.- The prevailing winds are from the south or southeast during the greater part of the year. Dry southwesterly winds are experienced occasionally. During the winter months, December, January, and February, the high-pressure air masses approaching from the north cause the prevailing wind direction to shift to the north. Wind movements are strongest in March and April; and the lightest wind movements generally occur during August, September, and October. The maximum published wind velocity of 74 miles per hour occurred at San Antonio in August 1942, during a severe tropical storm which swept inland over the Matagorda Bay section. In general, wind movements over the basin are relatively mild.

15. TEMPERATURE.- The mean annual temperature varies from 70.0 degrees at Uvalde in the southwestern part of the Edwards Plateau to 64.4 degrees at Kerrville in the north central part of the Plateau. The mean annual temperature over the Edwards Plateau is about 68 degrees. Temperatures in the Edwards Plateau have ranged from a maximum of 114 degrees recorded at Uvalde to a minimum of minus 7 degrees recorded at Kerrville.

16. GROWING SEASON.- The growing season between killing frosts normally varies from 221 days at Kerrville in the upper portion of the Edwards area to 280 days at San Antonio. The average growing season for the Edwards Plateau is about 254 days.

17. SNOWFALL.- Snowfall is generally light over the Edwards Plateau. It occurs at infrequent intervals over the area and melts rapidly. Seasonal accumulations are not experienced in this area and snowfall therefore does not constitute a flood hazard.

18. PRECIPITATION.- Precipitation near the Edwards Reservoir area has been observed officially at Austin since 1858 and at San Antonio since 1866 when stations were established by the U. S. Weather Bureau at these locations. Three other recording gages have been established at Fredericksburg, LaPryor and Rocksprings, in and near the area at later dates. Plate 5 shows the locations of the rainfall stations in and adjacent to the area.

19. Mean annual rainfall over the Edwards area is approximately 27.8 inches, and varies from about 34.0 inches in the eastern part to about 22.0 inches in the western part. Plate 5 shows isohyetals of mean annual precipitation over the area and mean monthly distribution of rainfall at Hondo, San Marcos, and Carr Ranch. Table 9 shows the maximum, minimum, and United States Weather Bureau published normal annual precipitation at stations in and near the area. It is noted that 11 of the stations listed in table 9 were established prior to 1900.

20. Periods of excessive rainfall have been experienced over all parts of the area. Generally, the highest 24-hour and monthly periods have occurred during major storms. However, there are many instances of heavy precipitation resulting from local thunderstorms. Maximum 24-hour and maximum monthly precipitation for representative stations in and adjacent to the area are given in table 10. Table 11 lists rainfall intensities for stations in and near the Edwards Reservoir area for durations of less than 24 hours.

21. EVAPORATION.- Evaporation records from six stations located adjacent to the Edwards Reservoir area were analyzed and adopted for use in this report. These stations and their operating agency are: Austin, Del Rio and Dilley, by the U. S. Weather Bureau; Sonora and Winter Haven by the Texas Agricultural Experiment Station; and San Antonio by the U. S. Field Station, Department of Agriculture. Austin and San Antonio are located northeast and south, respectively, and adjacent to the Edwards Reservoir area. Sonora is 40 miles northwest of the area. Del Rio is 40 miles west. Dilley and Winter Haven are 60 and 70 miles, respectively, south from the area. Austin, Dilley, and Winter Haven each have records for 30 years or more. San Antonio has records for 24 years while Del Rio and Sonora have records of 12 and 11 years, respectively. Table 12 gives pertinent data for the six evaporation stations. Evaporation is greatest in the higher portion of the area to the northwest and least in the lower and more humid southeastern area. Approximately two-thirds of the annual evaporation normally occurs during the six warm months, April through September.

22. RIVER STAGE AND DISCHARGE.- The discussion of the stream gages in the Nueces River Basin is confined to the gages above the Asherton gage on the Nueces River, the Derby gage on the Frio River, and the city of Three Rivers on the Atascosa River. Plate 2 shows

TABLE 8

CLIMATOLOGICAL DATA

Station	Years of complete record (1)	Temperature in degrees Fahrenheit: Mean Annual	Maximum recorded	Minimum recorded
Austin AP (2)	107	68.2	109	-2
Blanco	63	66.4	110	-6
Boerne	69	66.2	112	-4
Del Rio (2) *	14	69.8	111	11
Fredricksburg (2)	54	67.1	109	-5
Hondo	59	69.3	112	4
Kerrville	66	64.4	110	-7
Luling (2)	75	68.9	110	-3
New Braunfels	76	70.0	110	2
San Antonio AP	77	68.7	107	0
San Marcos	59	67.9	111	-2
Seguin (2)	36	69.2	110	0
Uvalde	59	70.0	114	6

Station	Growing season: Av. length (days)	Wind velocity: Av. mph	Wind velocity: Fastest mile	Relative humidity in percent (years): 6 a.m.	Noon	6 p.m.	Midnight
Austin AP (2)	263	9.5	57	81	51	48	71
Del Rio (2) *	287	7.4	62	79	53	46	64
San Antonio AP	280	9.3	74	83	54	52	76

(1) All data as of Dec. 31, 1962.
(2) Station outside of basin.
* Data as of Dec. 31, 1958.

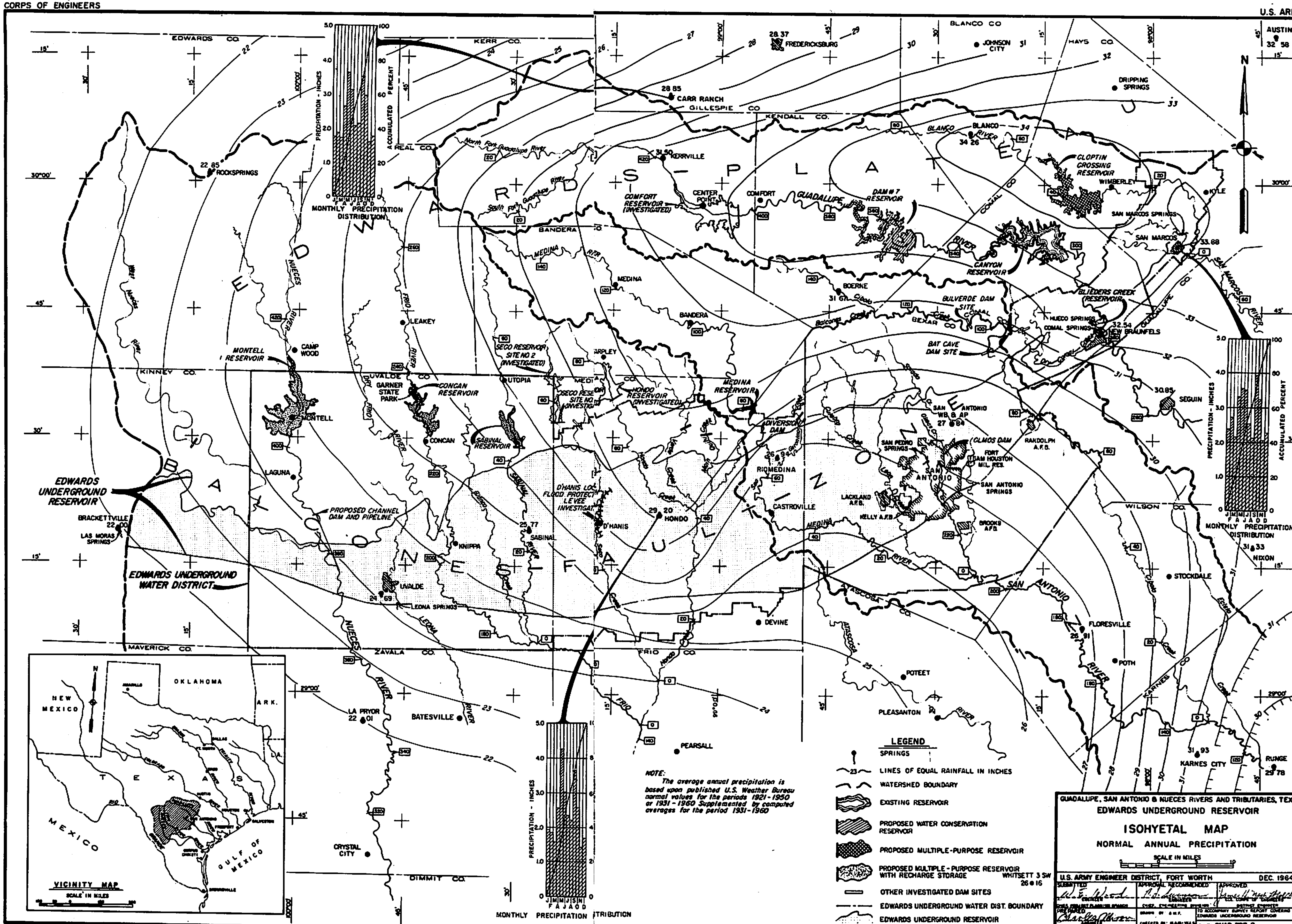

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
ISOHYETAL MAP
NORMAL ANNUAL PRECIPITATION
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC. 1964
SUBMITTED
APPROVAL RECOMMENDED
APPROVED
PREPARED
FILE: GUAD. 707-2
LEGEND
SPRINGS
LINES OF EQUAL RAINFALL IN INCHES
WATERSHED BOUNDARY
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR WITH RECHARGE STORAGE
OTHER INVESTIGATED DAM SITES
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
NOTE:
The average annual precipitation is based upon published U.S. Weather Bureau normal values for the periods 1921-1950 or 1931-1960 Supplemented by computed averages for the period 1931-1960
MONTHLY PRECIPITATION DISTRIBUTION
PRECIPITATION - INCHES
ACCUMULATED PERCENT
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
EDWARDS PLATEAU
BALCONES FAULT ZONE
VICINITY MAP
NEW MEXICO
OKLAHOMA
TEXAS
MEXICO
GULF OF MEXICO
SAN ANTONIO
NEW BRAUNFELS
SAN MARCOS
KERRVILLE
UVALDE
HONDO
SEGUIN
AUSTIN

TABLE 9

PRECIPITATION DATA

Station	Years of complete record (1)	Annual precipitation (in.) Maximum	Minimum	U.S.W.B. normal (2)
Austin *	104	64.68	11.42	32.58
Blanco	66	55.06	12.98	34.26
Boerne	74	62.47	10.29	31.67
Brackettville	85	45.37	6.45	22.00
Carr Ranch *	41	49.31	9.82	28.85
Floresville *	46	46.32	7.88	26.91
Fredericksburg *	54	47.23	11.29	28.37
Hondo	67	58.73	11.92	29.20
Karnes City *	23	56.57	10.68	31.93
Kerrville	66	57.57	12.33	31.50
LaPryor *	44	42.01	5.94	22.01
New Braunfels	74	60.21	10.12	32.54
Nixon *	41	58.10	16.64	31.33
Rio Medina	39	46.27	12.25	26.94
Rock Springs	30	38.16	10.26	22.85
Runge *	66	46.81	13.60	29.78
Sabinal	58	48.21	11.29	25.77
San Antonio *	96	50.30	10.11	27.84
San Marcos	66	52.24	13.42	33.88
Seguin *	58	49.47	13.80	30.85
Uvalde	68	45.02	9.29	24.69
Whitsett *	46	49.36	5.19	26.16

(1) To 31 December 1962. (2) The average annual precipitation is based upon published US Weather Bureau normal values for the periods 1921-1950 or 1931-1960 supplemented by computed averages for the period 1931-1960.
* Outside Edwards Plateau.

TABLE 10

MAXIMUM 24-HOUR AND MAXIMUM MONTHLY PRECIPITATION

Station	Years of complete record through 1962	Maximum 24-hour rainfall (inches)	Maximum monthly rainfall (inches)
Austin AP	104	19.03	20.78
Bankersmith	22	12.95	17.51
Blanco	66	17.51	22.66
Fredericksburg	54	8.03	10.48
Garner State Park	11	4.17	10.97
Hall Ranch	22	3.73	10.26
Hye	22	22.96	24.12
Kerrville	76	11.60	19.94
LaPryor	44	7.78	14.56
Luling	74	6.51	13.76
New Braunfels	74	9.41	16.41
Rocksprings	30	4.47	16.57
San Antonio AP	96	7.08	11.64
Tarpley	24	4.73	10.35

TABLE 11

RAINFALL INTENSITIES IN AND NEAR
THE EDWARDS UNDERGROUND AREA

Station	Total precipitation in inches *				
	1 hr	2 hr	3 hr	6 hr	12 hr
Austin	3.46	4.41	5.47	7.02	8.51
San Antonio	3.07	4.64	5.82	6.11	6.81
Hall Ranch	1.85	3.25	3.25	3.25	3.35
Rocksprings	1.56	2.14	2.47	3.08	3.91
Tarpley	1.90	3.40	4.00	4.41	4.47
Garner State Park	2.23	2.48	2.90	3.59	3.97

* Records published in U. S. Weather Bureau Technical Paper No. 15.

Note: Unofficial observations indicate published records have been exceeded in some areas.

TABLE 12

AVERAGE MONTHLY EVAPORATION DATA
AUSTIN, DEL RIO, DILLEY, SAN ANTONIO, SONORA, AND WINTER HAVEN, TEXAS

Month	Austin, Texas 1930-1960 U. S. Weather Bureau Pan Coefficient 0.69			Del Rio, Texas 1946-1957 U. S. Weather Bureau Pan Coefficient 0.69			Dilley, Texas 1931-1960(1) U. S. Weather Bureau Pan Coefficient 0.69			San Antonio, Texas 1907-1930 Bureau of Plant Industry Pan Coefficient 0.94			Sonora, Texas 1950-1960(2) Bureau of Plant Industry Pan Coefficient 0.94			Winter Haven, Texas 1936-1960 Bureau of Plant Industry Pan Coefficient 0.94		
	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)
January	2.73	1.88	2.32	3.43	2.37	.79	2.94	2.03	1.30	2.46	2.32	1.15	2.56	2.41	1.34	2.09	1.96	1.18
February	3.21	2.21	2.55	4.61	3.18	1.08	3.51	2.42	1.43	3.03	2.85	1.50	3.16	2.97	1.15	2.74	2.58	1.14
March	5.11	3.53	2.09	8.05	5.55	.67	6.08	4.20	0.93	4.46	4.19	1.87	4.97	4.67	1.14	4.66	4.38	1.00
April	6.19	4.27	3.47	9.45	6.52	1.91	7.21	4.96	2.03	5.53	5.20	3.19	5.96	5.60	1.25	5.52	5.19	1.81
May	7.44	5.13	3.88	10.75	7.42	2.51	8.51	5.87	2.90	6.51	6.12	3.15	6.20	5.83	1.86	6.54	6.15	3.46
June	8.95	6.18	3.18	12.58	8.68	1.89	9.89	6.82	2.81	7.95	7.47	2.43	7.71	7.25	2.75	7.93	7.45	2.09
July	9.90	6.83	2.11	14.38	9.92	.97	11.07	7.64	2.12	9.09	8.55	1.66	8.98	8.44	1.62	8.80	8.27	1.74
August	9.79	6.76	1.94	13.37	9.23	1.09	10.87	7.50	1.68	9.19	8.64	1.69	8.37	7.87	1.49	8.70	8.18	2.33
September	7.35	5.07	3.43	9.90	6.83	2.28	11.24	7.76	2.65	6.81	6.40	2.65	6.40	6.02	2.36	6.29	5.91	2.79
October	5.65	3.90	3.00	7.34	5.06	1.23	5.85	4.04	2.08	5.10	4.79	2.91	5.06	4.76	2.09	4.54	4.27	2.13
November	3.64	2.51	2.11	4.97	3.43	.45	3.73	2.57	1.22	3.16	2.97	2.13	3.49	3.28	.50	3.02	2.84	.82
December	2.66	1.84	2.56	3.61	2.49	.52	2.78	1.92	1.56	2.45	2.30	1.75	2.84	2.67	.58	2.14	2.01	1.09
ANNUAL	72.62	50.11	32.64	102.44	70.68	15.39	83.68	57.73	22.71	65.74	61.80	26.08	65.70	61.77	18.13	62.97	59.19	21.58
NET ANNUAL LOSS FROM RESERVOIR SURFACE		17.47"			55.29"			35.02			35.72"			43.64"			37.61"	

(1) No record May-August 1943; January, February 1950.

(2) No record January-May 1950; June 1953.

the location of the gages installed by the U. S. Geological Survey for the systematic collection of records in the study area. The first gages installed in the Nueces River Basin were near Cinonia on the Nueces River and near Derby on the Frio River. The former was installed July 5, 1915 and the latter August 1, 1915. Only a partial record was maintained at the Cinonia gage which was discontinued in September 1925. The record at Derby is complete from time of installation of the gage to date. Gages were established in the latter part of 1923 at Laguna on the Nueces River and Concan on the Frio River. The largest increase in the number of gages took place when seven recording gages were installed in 1952. There were 18 recording gages operating in the upper watershed of the Nueces River Basin as of September 30, 1962.

23. The discussion of the stream gages in the Guadalupe and San Antonio River Basins is confined to the gages upstream from Gonzales on the Guadalupe River and Falls City on the San Antonio River. Plate 3 shows the location of the gages. Observation of streamflow on the Guadalupe River began on September 1, 1904, when the U. S. Weather Bureau established a staff gage at the Gonzales Water Power Company in Gonzales, Texas. The daily stages are published for this gage. The U. S. Geological Survey established gages at New Braunfels and near Comfort in January 1915 and January 1918, respectively. In January 1928, the gage at New Braunfels was moved upstream above the mouth of Comal River eliminating the springflow from Comal Springs from the base flow that was recorded as runoff at the lower site. Since the 1920's, numerous gages have been installed in the Guadalupe and San Antonio River Basins. There were 28 recording streamflow gages and one non-recording gage in the basins as of September 30, 1962.

24. ANNUAL RUNOFF.- The observed average annual runoff at the principal gages in those portions of the Nueces, Guadalupe, and San Antonio River Basins covered by this report are given in tables 13 and 14. Also given are the minimum and maximum annual runoff for the purpose of illustrating the extremes to which the annual runoff in these basins are subject.

25. DROUGHTS.- Hydrologic records for the Edwards Plateau illustrate recurring patterns of long to moderate drought and periods of heavy rainfall. The period of streamflow measurements used in this report includes the most severe drought that has been experienced since accurate records became available. The recent drought which ended in the early part of 1957 is the critical drought of record.

26. The prolonged drought of the period 1947 through 1956, which was experienced over most of the Guadalupe River Basin, was broken by one of the most intense storms of record, that of September 1952. Rainfall records for Blanco and Kerrville, however, show that despite this storm, there was an accumulated rainfall deficiency

of approximately 70 inches and 59 inches, respectively, for the 10-year period. The normal annual rainfall at Blanco is 34.26 inches. The annual rainfall at Blanco during the 1947-1956 period varied from 14.4 inches in 1954 to 53.7 inches in 1952, with an average for the period of 27.3 inches. The normal annual rainfall at Kerrville is 31.50 inches, while the annual rainfall during the 1947-1956 period varied from 14.04 inches in 1956 to 40.9 inches in 1952, with an average for the period of 25.6 inches. The drought ended in the Guadalupe River Basin during the spring of 1957 when over 21 inches of rain fell during the months of April and May.

27. The prolonged drought of the period 1950 through 1956 which was experienced over most of the Nueces River Basin, was broken in the Upper Nueces River watershed in September 1955 by one of the most intense storms of records over the Upper Nueces watershed. The storm, which was centered over the Nueces River upstream of Montell Dam site, produced the maximum known peak discharge at the Laguna gage, downstream from Montell Dam site. The average rainfall during the drought period was approximately 20.0 inches over the Nueces River Basin above the Balcones Fault Zone while the normal annual rainfall is between 26 and 27 inches.

28. STORM CHARACTERISTICS.- The storms that cause precipitation on the Edwards Plateau are of three general types: (1) thunderstorms, resulting in devastating cloudbursts; (2) frontal storms; and (3) cyclonic storms originating in the tropics or the Western Gulf of Mexico. The majority of the precipitation on the plateau results from disturbances of the first two types. Thunderstorms, as here described, are produced and maintained by local convectional currents of the vertical type. They are sometimes accompanied by excessive rainfall for periods up to about 6 or 8 hours, but rarely produce excessive rainfall over extensive areas. Thunderstorms cause major flooding in localized areas and particularly in the headwaters of the basins in the Edwards Plateau. Frontal storms that cause rainfall in the area result from the forced ascension of warm moisture-laden air masses originating over the warm oceanic areas to the south. The lifting of the warmer air mass is accomplished either by direct convergence of a tropical air mass and a polar air mass, or by the convergence and partial encompassing of a tropical air mass by several denser air masses. The cyclonic storms originate in the tropics and the Western Gulf of Mexico. When these storms move inland they tend to curve to the northeast and to pass up the Mississippi Valley. In following this course, the heaviest precipitation is generally experienced in the lower part of the basin with little effect on the Edwards Plateau.

29. MAJOR BASIN STORMS.- Some of the major flood-producing storms that have occurred on or near the Edwards Plateau are as follows: May 25-30, 1929; June 30-July 2, 1932; May 31, 1935; June 10-15, 1935; September 26-27, 1946; September 9-11, 1952;

TABLE 13

ANNUAL RUNOFF DATA (OBSERVED)

NUECES RIVER BASIN

Stream-gaging stations	Drainage area (sq.mi.)	Period of record: From	Period of record: Through	Length: Years	Length: Months	Annual runoff (inches): Maximum (1)	Annual runoff (inches): Minimum (1)	Annual runoff (inches): Mean
Nueces at Laguna	764	10/23	9/62	39	0	10.85	0.41	2.45
Nueces nr Uvalde	1,930	10/28	4/39	11	7	7.18	0.06	1.61
Nueces below Uvalde	1,947	5/39	9/62	23	5	3.13	0.03	0.61
Nueces nr Cinonia	2,150	7/15	9/25	9	9	1.26	0.04	0.35
Nueces at Asherton	4,082	10/40	9/62	23	0	1.68	0.02	0.56
West Nueces nr Brackettville (2)	700	10/40	9/62	17	6	4.60	0.00	0.67
Frio at Concan (3)	405	11/23	9/62	38	11	14.21	0.29	3.35
Frio nr Uvalde	661	9/52	9/62	10	1	1.92	0.00	0.40
Frio nr Derby	3,493	8/15	9/62	47	2	4.23	0.007	0.52
Dry Frio nr Reagan Wells	117	9/52	9/62	10	1	11.74	0.35	3.60
Sabinal nr Sabinal	206	10/42	9/62	20	0	11.39	0.05	2.47
Sabinal at Sabinal	247	9/52	9/62	10	1	7.45	0.02	1.46
Hondo nr Tarpley	101	9/52	9/62	10	1	16.66	0.06	4.24
Hondo nr Hondo	132	9/52	9/62	10	1	9.46	0.00	1.81
Hondo at King's Waterhole	142	10/61	9/62	1	0	-	-	-
Seco at Miller's Ranch	43	5/61	9/62	1	5	-	-	-
Seco nr Utopia	53	9/52	9/61	9	1	15.19	0.09	4.02
Seco nr D'Hanis	87	9/52	9/62	10	1	10.56	0.00	1.56
Seco nr Crook's Ranch	168	10/61	9/62	1	0	-	-	-
Leona nr Uvalde (4)	146	1/39	9/62	24	9	-	-	-
Atascosa at Pleasanton (5)	341	1/54	9/62	8	9	-	-	-

(1) Water year.
(2) Station discontinued September 30, 1950 and re-established March 29, 1956.
(3) Runoff for 1930 was estimated (USCE).
(4) Springflow only from Leona Springs.
(5) Staff gage established by USGS for the USCE. Gage used for high stages only.

TABLE 14

ANNUAL RUNOFF DATA (OBSERVED)

GUADALUPE AND SAN ANTONIO RIVER BASINS

Stream-gaging stations	Drainage area (sq.mi.)	Period of record				Annual runoff (inches)		
		From	Through	Length		Maximum (1)	Minimum (1)	Mean
				Years	Months			
Guadalupe nr Comfort (2)	762	1/18	9/32	13	6	6.75	0.91	2.37
Guadalupe at Comfort	836	6/39	9/62	23	4	5.81	0.24	2.36
Guadalupe nr Spring Branch	1,282	7/22	9/62	40	3	8.37	0.14	2.81
Guadalupe at Sattler	1,430	3/60	9/62	2	7	-	-	-
Guadalupe at New Braunfels	1,516	1/28	9/62	34	9	9.25	0.12	3.28
Guadalupe at New Braunfels (3)	1,635	2/15	12/27	12	11	13.07	2.85	6.39
Guadalupe at Gonzales (4)	3,452	9/04	9/62	58	1	-	-	-
Johnson Cr. nr Ingram (5)	115	10/42	9/62	19	2	3.76	0.56	1.68
Rebecca Cr. nr Spring Branch	11	2/60	9/62	2	7	-	-	-
Comal at New Braunfels (6)	117	1/28	9/62	34	9	-	-	-
San Marcos at San Marcos (6) (7)	84	7/15	9/62	11	7	-	-	-
San Marcos at Luling (8)	833	5/39	9/62	23	5	12.41	1.23	5.46
Blanco at Wimberley	353	7/28	9/62	33	6	13.69	0.25	4.67
Blanco nr Kyle	410	6/56	9/62	6	4	11.69	1.40	-
Plum Creek at Lockhart	113	5/59	9/62	3	5	-	-	-
Plum Creek nr Luling	356	4/30	9/62	32	6	10.08	0.28	3.51
San Antonio at San Antonio (9)	42	2/15	9/62	38	4	-	-	-
San Antonio nr Elmendorf	1,743	Installed September 1962				-	-	-
San Antonio nr Falls City (10)	2,113	5/25	9/62	37	5	-	-	-
Salado Creek at Upper San Antonio	137	9/60	9/62	2	1	-	-	-
Salado Creek at Lower San Antonio	189	9/60	9/62	2	1	-	-	-
Medina nr Pipe Creek (11)	474	10/22	9/62	23	6	10.70	0.15	3.09
Medina nr Rio Medina (12)	650	2/22	9/62	21	7	-	-	-
Medina nr San Antonio (13)	1,317	8/39	9/62	23	2	-	-	-
Red Bluff Creek nr Pipe Creek	56	4/56	9/62	6	6	6.28	0.009	-
Calaveras Creek nr Elmendorf (14)	7	1/57	9/62	5	9	-	-	-
Calaveras Creek nr Elmendorf (15)	77	9/54	9/62	8	1	-	-	-
Cibolo Creek nr Boerne	68	Installed March 1, 1962				-	-	-
Cibolo Creek nr Bulverde	198	5/46	9/62	16	5	3.15	0.00	0.61
Cibolo Creek at Selma	274	3/46	9/62	16	7	2.76	0.00	0.47
Cibolo Creek nr Falls City	827	10/30	9/62	32	0	5.20	0.17	1.81

(1) Water year. (2) Partial record 1/18 through 5/22. (3) Base flow includes springflow from Comal Springs. March 1898 to December 1899, gage heights and occasional discharge measurements; 1900-1902, occasional discharge measurements only; published in reports of Geological Survey. (4) U. S. Weather Bureau staff gage, stage only. (5) Gage discontinued November 30, 1959, re-established November 9, 1961. (6) Normal flow of river comes from springs, drainage area of stream not applicable. (7) Partial record 7/15 through 8/21; discontinued September 7, 1921, re-established May 26, 1956. (8) Base flow is mostly from large springs near San Marcos. (9) Normal flow of river formerly came from springs and in later years from release of pumpage from wells. The station was discontinued November 16, 1929; re-established February 15, 1939. (10) Flow partly regulated by Medina Lake and Olmos flood-control reservoir. (11) This gage discontinued September 30, 1934; re-established December 21, 1952. (12) All flow is seepage under and around Medina Dam except for occasional flow over spillway. This gage discontinued September 30, 1934; re-established January 29, 1953. Annual figures only are available for water years 1923-34. (13) 633 square miles controlled by Medina Reservoir. (14) Gage installed to measure contents of SCS reservoir. (15) 25.5 square miles are above 7 flood-control structures.

September 23-24, 1955. Isohyetal maps and typical mass curves of precipitation are shown on plates 6 through 12, and a description of these storms is given in the following paragraphs.

30. STORM OF MAY 25-30, 1929.- The center of this storm was in the Blanco River watershed about six miles north of the Cloptin Crossing Dam site. At the storm center rainfall of 15.0 inches was recorded for the storm period, of which about 12.0 inches fell in a 6-hour period. Other rainfall amounts in the area were as follows: Fischer's Store, 10.4 inches; San Marcos, 9.8 inches; Henly, 15.0 inches; Dripping Springs, 8.0 inches. The average depth of precipitation over the Blanco River watershed was about 10.7 inches. The depth of rainfall from the maximum depth-area curve for the 1929 storm is 13.7 inches for a drainage area of 428 square miles (equivalent to the drainage area above the mouth of the Blanco River). This storm produced the maximum stages on the Blanco River at Wimberley and Kyle since 1869 and 1882, respectively. The isohyetal map and typical mass curves of precipitation are shown on plate 6.

31. STORM OF JUNE 30-JULY 2, 1932.- This storm had several centers; however, the most intense center was located in the Upper Guadalupe River Basin at the State Fish Hatchery near Ingram. The State Fish Hatchery recorded 35.6 inches of rainfall. Another center was located in the Upper Sabinal Basin near the Humble Pump Station. The pump station recorded 33.5 inches of rainfall. Rio Frio recorded 24.0 inches of rainfall in the Frio River Basin. Other rainfall amounts in the area were as follows: Tarpley, 2 miles northwest, 22.0 inches; Uvalde, 20.2 inches; Rothe Ranch, 18.3 inches; Sabinal, 17.5 inches; Utopia, 14.0 inches. This was considered a 42-hour storm; however, the majority of the rainfall occurred in an 18-hour period. This storm produced the maximum stage since 1869 on the Frio River at Concan; the maximum stage since 1892 on the Sabinal River near Sabinal; and the maximum stage since 1900 on the Guadalupe River at Comfort. The isohyetal map and typical mass curves of precipitation are shown on plate 7.

32. STORM OF MAY 31, 1935.- The center of the storm was located in the Seco Creek watershed near Woodward's Ranch, about 17 miles north of D'Hanis. The Woodward Ranch reported 22.0 inches of rainfall during a 3-4 hour period on the morning of May 31. Lutz Ranch reported 12.5 inches of rainfall. D'Hanis and Hondo reported 12.0 and 9.2 inches, respectively. Sabinal reported 7.7 inches of rainfall. This storm produced the maximum stage since at least 1866 on Seco Creek near D'Hanis. The isohyetal map and typical mass curves of precipitation are shown on plate 8.

33. STORM OF JUNE 10-15, 1935.- The center of the storm was located slightly west of the Nueces River Basin approximately 15 miles south of Carta Valley. The amount of rainfall that was

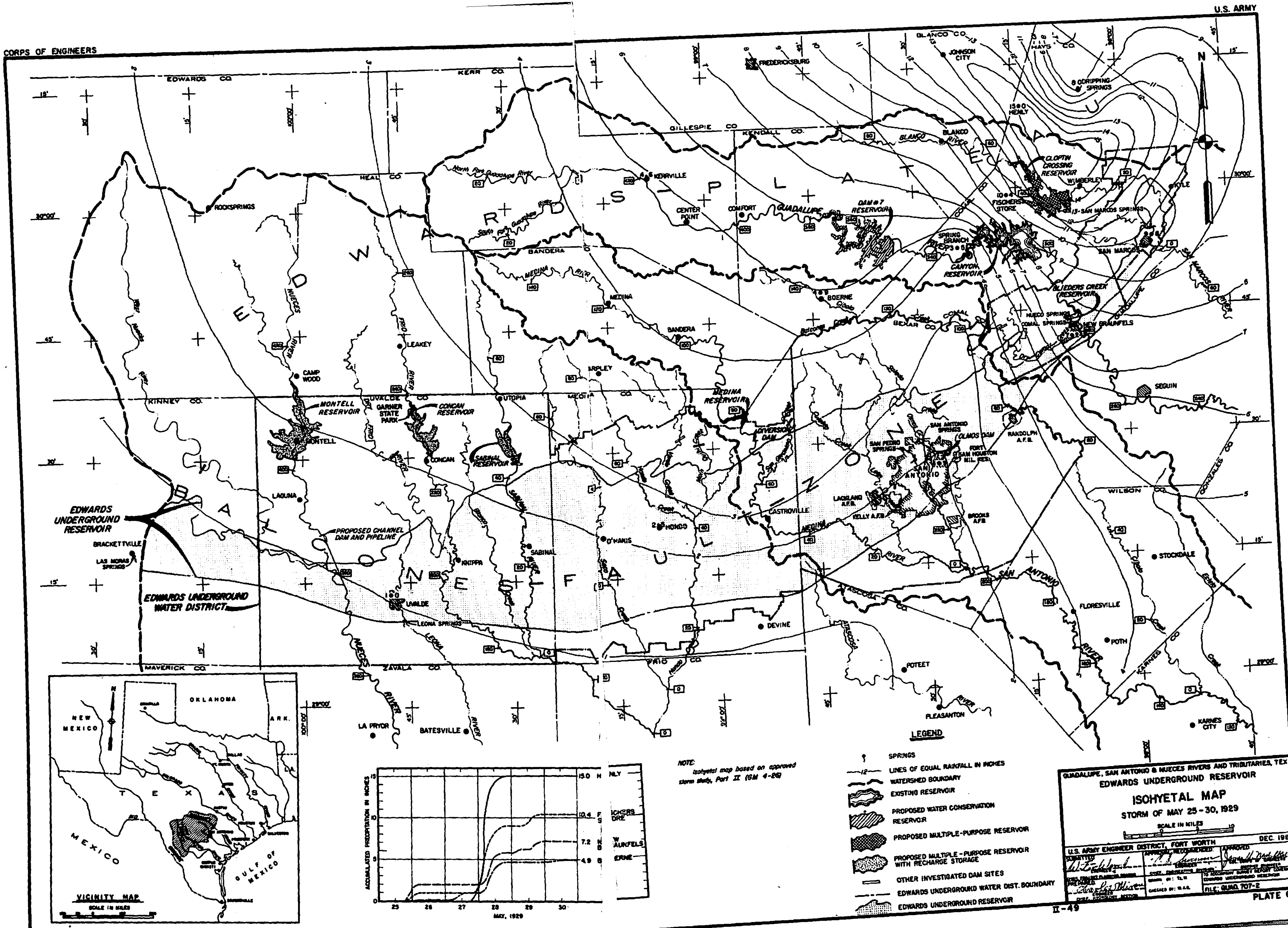
recorded at the storm center was 17.6 inches. Forty-two miles north of Brackettville 14.2 inches of rain was reported. Rocksprings and Montell reported 12.1 and 8.5 inches, respectively. This storm produced the maximum stage since at least 1879 on the West Nueces near Brackettville, and the maximum stage since at least 1836 on the Nueces River at Cotulla. The isohyetal map and typical mass curves of precipitation are shown on plate 9.

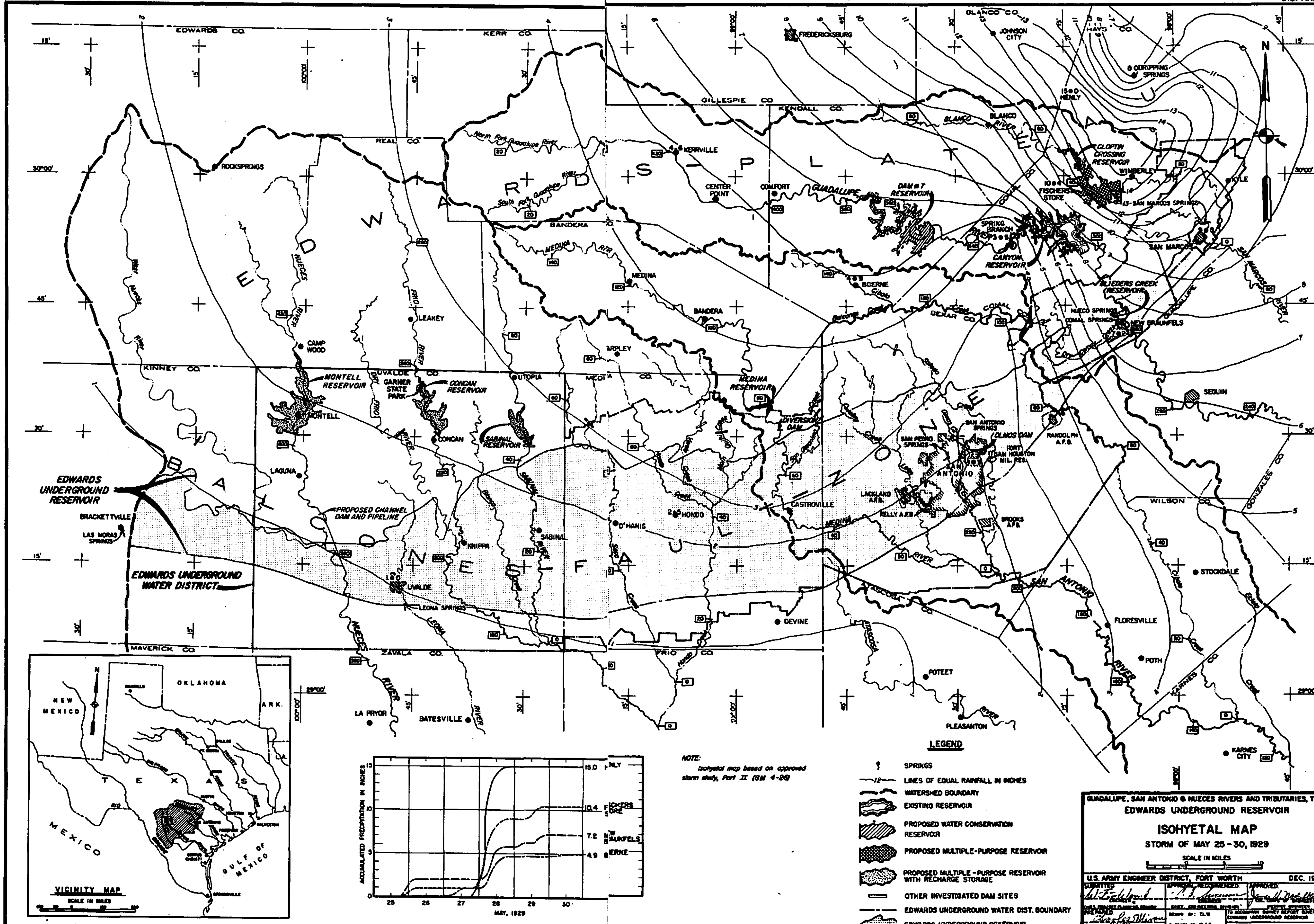
34. STORM OF SEPTEMBER 26-27, 1946.- The center of the storm was located 11 miles southeast of San Antonio at the State Apiculture Farm. The amount of rainfall that was recorded at the State Farm was 17.2 inches. Other rainfall amounts in the vicinity were as follows: San Antonio Nursery, 13.0 inches; San Antonio Airport, 6.9 inches; Kelly AFB, 5.8 inches. Most of the rainfall came within a six to eight hour period. This storm was particularly intense on Calaveras Creek at San Antonio. The isohyetal map and typical mass curves of precipitation are shown on plate 10.

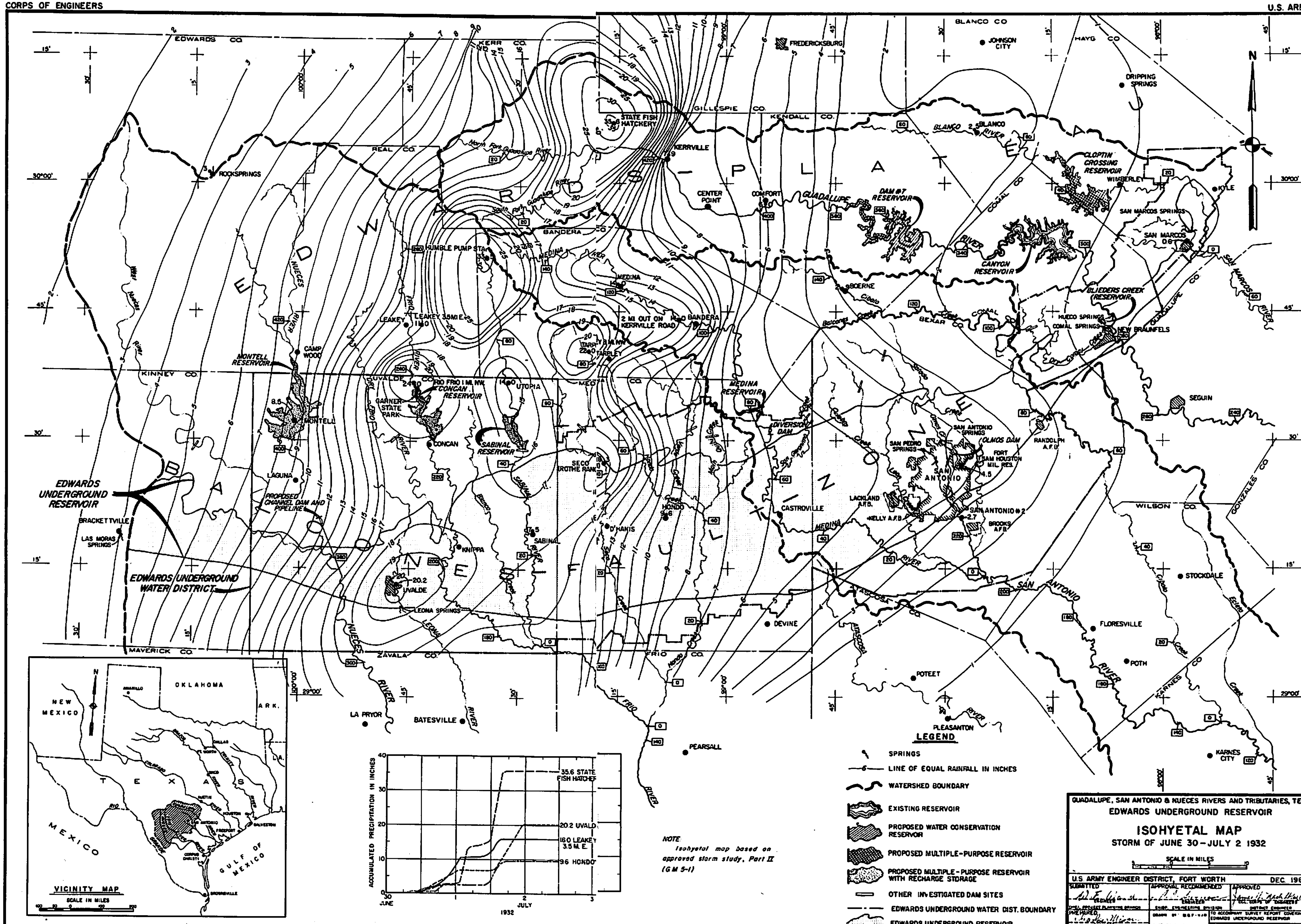
35. STORM OF SEPTEMBER 9-11, 1952.- The storm had two centers within the Edwards Plateau. One of the centers (GS-20) was located just inside the Blanco River watershed approximately four miles southeast of Hye. The amount of rainfall reported at the storm center was 28.8 inches. The other center (F-38) was located approximately seven miles northeast of Comfort. The amount of rainfall reported was 25.1 inches. Some of the other rainfall amounts in the area are as follows: Hye, 26.0 inches; Blanco, 21.1 inches; Boerne, 12.6 inches; San Marcos, 9.7 inches; Kerrville, 8.9 inches; New Braunfels, 8.8 inches. The isohyetal map and typical mass curves of precipitation are shown on plate 11.

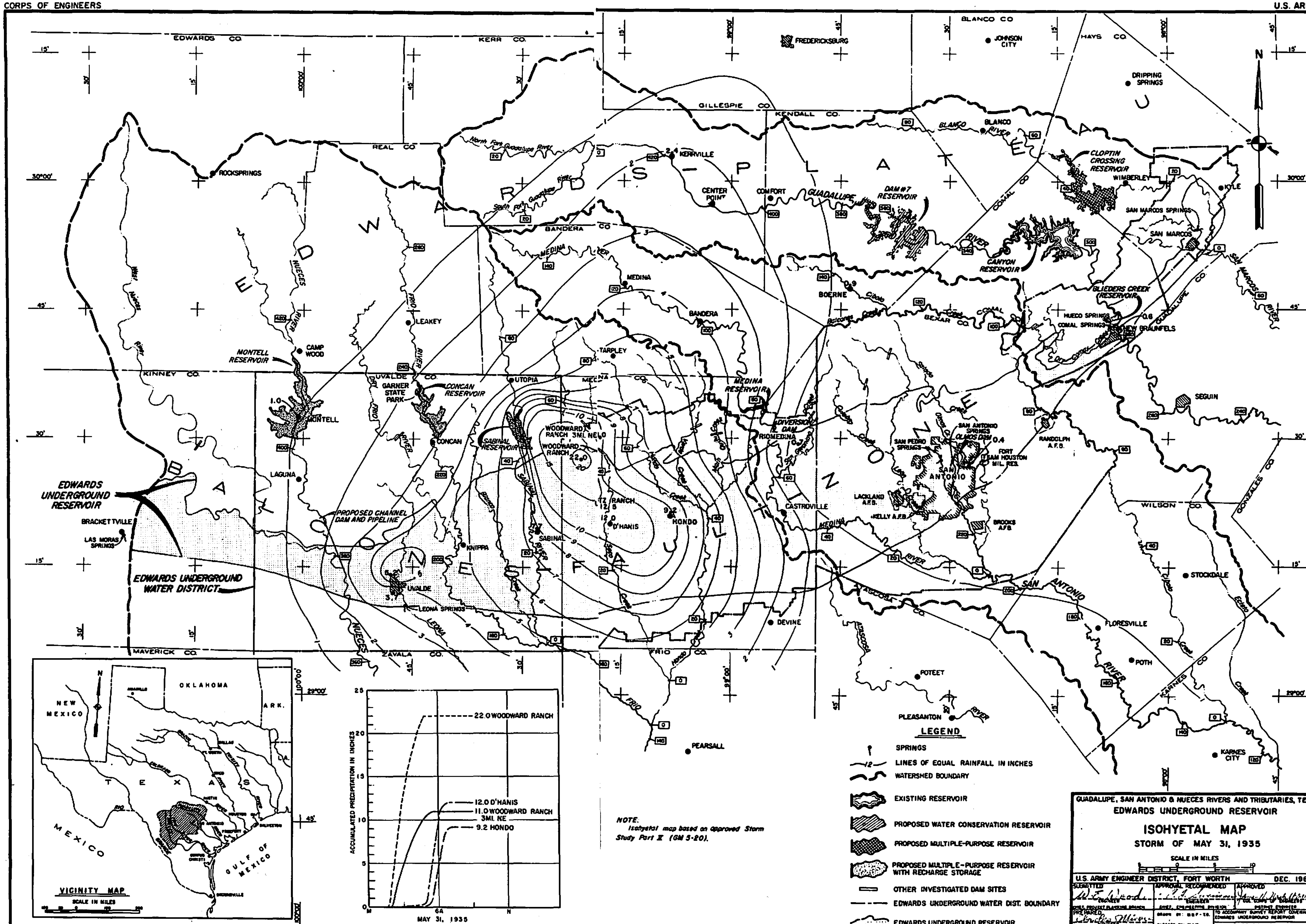
36. STORM OF SEPTEMBER 23-24, 1955.- This storm had three distinct centers. Only one of these severe centers was located within the area of study. A 24-inch center (C-1) on the Nueces River at the Edwards-Real County line southeast of Rocksprings, was the principal contributor to the Nueces River flood. Other rainfall amounts in the area are as follows: C-2, 22.0 inches; C-3, 12.0 inches; C-4, 12.0 inches; C-5, 10.2 inches; C-6, 10.0 inches; C-7, 9.0 inches; C-8, 8.0 inches; Crider's Ranch, 5.6 inches; Lynxhaven Ranch, 1.9 inches. This storm produced the maximum stage since at least 1866 on the Nueces River at Laguna. The volume of flow was decreased 82 percent at Three Rivers. Much of the loss occurred before the flood reached Uvalde due to the Balcones Fault Zone which crosses the Nueces River upstream from the Uvalde gage. The isohyetal map and typical mass curves of precipitation are shown on plate 12.

37. FLOODS.- In general, the flooding experienced along the Edwards Plateau is produced by intense storms with relatively limited areal coverage. The storm of June 30-July 2, 1932, was more general in character than any other major storm of record in the vicinity


GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
ISOHYETAL MAP
STORM OF MAY 25-30, 1929
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC. 1964
FILE: GUAD. 707-2
LEGEND
SPRINGS
LINES OF EQUAL RAINFALL IN INCHES
WATERSHED BOUNDARY
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR WITH RECHARGE STORAGE
OTHER INVESTIGATED DAM SITES
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
NOTE: Isohyetal map based on approved storm study, Part II (GM 4-26)
EDWARDS PLATEAU
BALCONES FAULT ZONE
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
MONTELL RESERVOIR
CONCAN RESERVOIR
SABINAL RESERVOIR
MEDINA RESERVOIR
DIVERSION DAM
CANYON RESERVOIR
CLOPTIN CROSSING RESERVOIR
DAM #7 RESERVOIR
BLIEDERS CREEK RESERVOIR
PROPOSED CHANNEL DAM AND PIPELINE
ACCUMULATED PRECIPITATION IN INCHES
MAY, 1929
VICINITY MAP
NEW MEXICO
OKLAHOMA
TEXAS
MEXICO
GULF OF MEXICO


EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
VICINITY MAP
SCALE IN MILES
ACCUMULATED PRECIPITATION IN INCHES
MAY, 1929
NOTE: Isohyetal map based on approved storm study, Part II (GM 4-26)
LEGEND
SPRINGS
LINES OF EQUAL RAINFALL IN INCHES
WATERSHED BOUNDARY
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR WITH RECHARGE STORAGE
OTHER INVESTIGATED DAM SITES
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
ISOHYETAL MAP
STORM OF MAY 25-30, 1929
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC. 1964
FILE: GUAD. 707-2


EDWARDS PLATEAU
BALCONES FAULT ZONE
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
EDWARDS CO.
KERR CO.
REAL CO.
BANDERA CO.
GILLESPIE CO.
KENDALL CO.
BLANCO CO.
HAYS CO.
COMAL CO.
BEXAR CO.
KINNEY CO.
UVALDE CO.
MEDINA CO.
MAVERICK CO.
ZAVALA CO.
FRIO CO.
ATASCOSA CO.
WILSON CO.
GONZALES CO.
KARNES CO.
GUADALUPE CO.
STATE FISH HATCHERY
KERRVILLE
ROCKSPRINGS
FREDERICKSBURG
JOHNSON CITY
DRIPPING SPRINGS
BLANCO
CLOPTIN CROSSING RESERVOIR
WIMBERLEY
KYLE
SAN MARCOS SPRINGS
SAN MARCOS
CENTER POINT
COMFORT
DAM #7 RESERVOIR
CANYON RESERVOIR
BLIEDERS CREEK RESERVOIR
HUECO SPRINGS
COMAL SPRINGS
NEW BRAUNFELS
BOERNE
HUMBLE PUMP STA.
MEDINA
2 MI OUT ON KERRVILLE ROAD
BANDERA
TARPLEY
LEAKEY
LEAKEY 3.5 MI E.
CAMP WOOD
MONTELL RESERVOIR
MONTELL
FRIO FRIO 1 MI NW.
CONCAN RESERVOIR
GARNER STATE PARK
CONCAN
UTOPIA
SABINAL RESERVOIR
SECO
ROTHE RANCH
MEDINA RESERVOIR
DIVERSION DAM
SEGUIN
SAN ANTONIO SPRINGS
OLMOS DAM
SAN PEDRO SPRINGS
FORT SAM HOUSTON MIL. RES.
SAN ANTONIO
RANDOLPH A.F.B.
LACKLAND A.F.B.
KELLY A.F.B.
SAN ANTONIO #2
BROOKS A.F.B.
CASTROVILLE
HONDO
D'HANIS
SABINAL
KNIPPA
UVALDE
LEONA SPRINGS
LAGUNA
PROPOSED CHANNEL DAM AND PIPELINE
BRACKETTVILLE
LAS MORAS SPRINGS
DEVINE
STOCKDALE
FLORESVILLE
POTH
POTEET
PLEASANTON
PEARSALL
LA PRYOR
BATESVILLE
KARNES CITY
VICINITY MAP
SCALE IN MILES
NEW MEXICO
OKLAHOMA
ARK.
LA.
TEXAS
MEXICO
GULF OF MEXICO
ACCUMULATED PRECIPITATION IN INCHES
35.6 STATE FISH HATCHERY
20.2 UVALDE
16.0 LEAKEY 3.5 M. E.
9.6 HONDO
30 JUNE
1
2 JULY
3
1932
NOTE
Isohyetal map based on approved storm study, Part II (G M 5-1)
LEGEND
SPRINGS
LINE OF EQUAL RAINFALL IN INCHES
WATERSHED BOUNDARY
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR WITH RECHARGE STORAGE
OTHER INVESTIGATED DAM SITES
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
ISOHYETAL MAP
STORM OF JUNE 30 – JULY 2 1932
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC. 1964
SUBMITTED
APPROVAL RECOMMENDED
APPROVED
PREPARED
TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
FILE: GUAD. 707-2


GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
ISOHYETAL MAP
STORM OF MAY 31, 1935
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC. 1964
FILE GUAD. 707-2
LEGEND
SPRINGS
LINES OF EQUAL RAINFALL IN INCHES
WATERSHED BOUNDARY
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR WITH RECHARGE STORAGE
OTHER INVESTIGATED DAM SITES
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
NOTE.
Isohyetal map based on approved Storm Study Part II (GM 5-20).
ACCUMULATED PRECIPITATION IN INCHES
22.0 WOODWARD RANCH
12.0 D'HANIS
11.0 WOODWARD RANCH 3MI. NE
9.2 HONDO
MAY 31, 1935
VICINITY MAP
SCALE IN MILES
NEW MEXICO
OKLAHOMA
ARK.
TEXAS
MEXICO
GULF OF MEXICO
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
PROPOSED CHANNEL DAM AND PIPELINE
EDWARDS PLATEAU
BALCONES FAULT ZONE
EDWARDS CO.
KERR CO.
BLANCO CO.
HAYS CO.
GILLESPIE CO.
KENDALL CO.
REAL CO.
BANDERA CO.
KINNEY CO.
UVALDE CO.
MEDINA CO.
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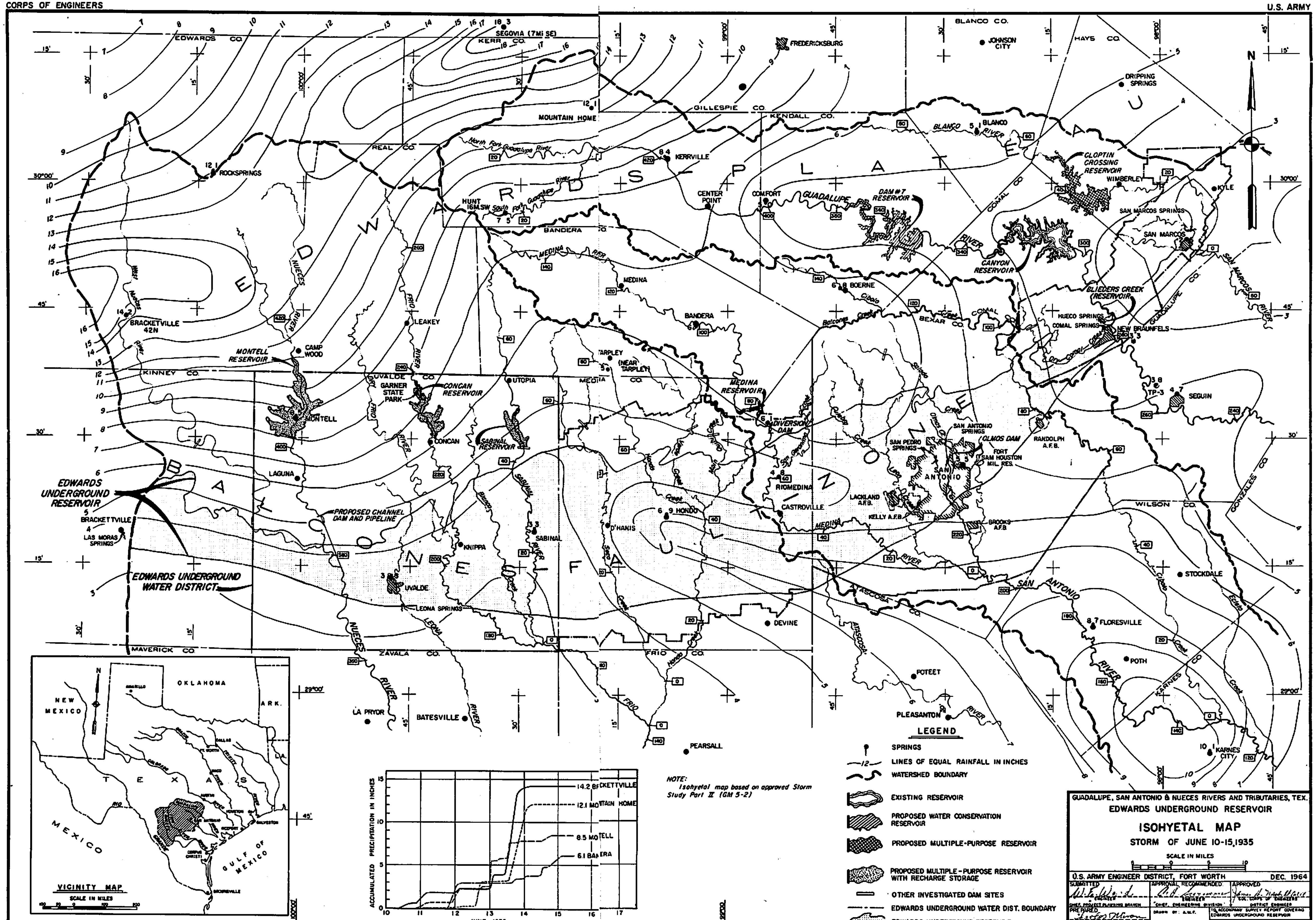
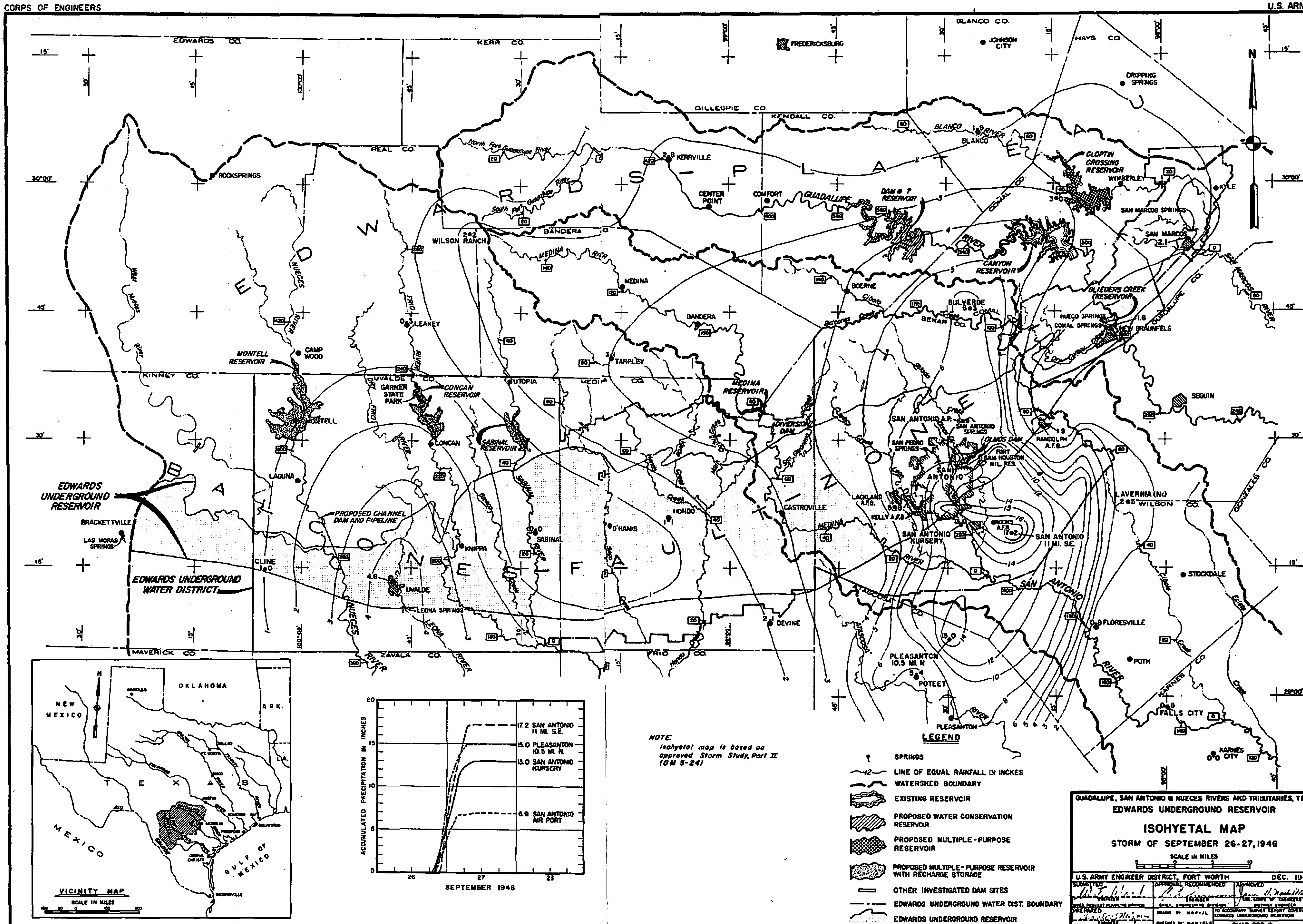
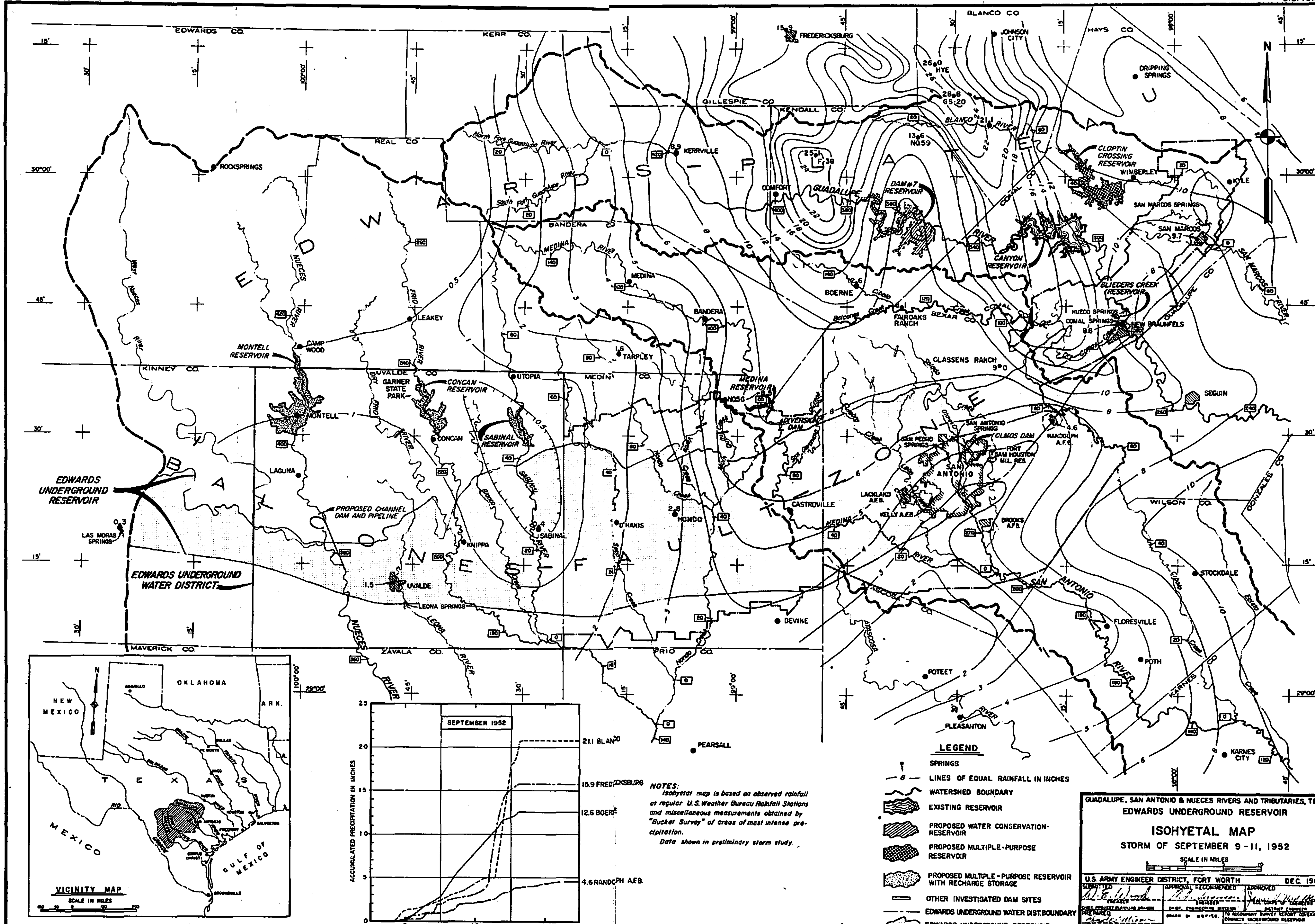
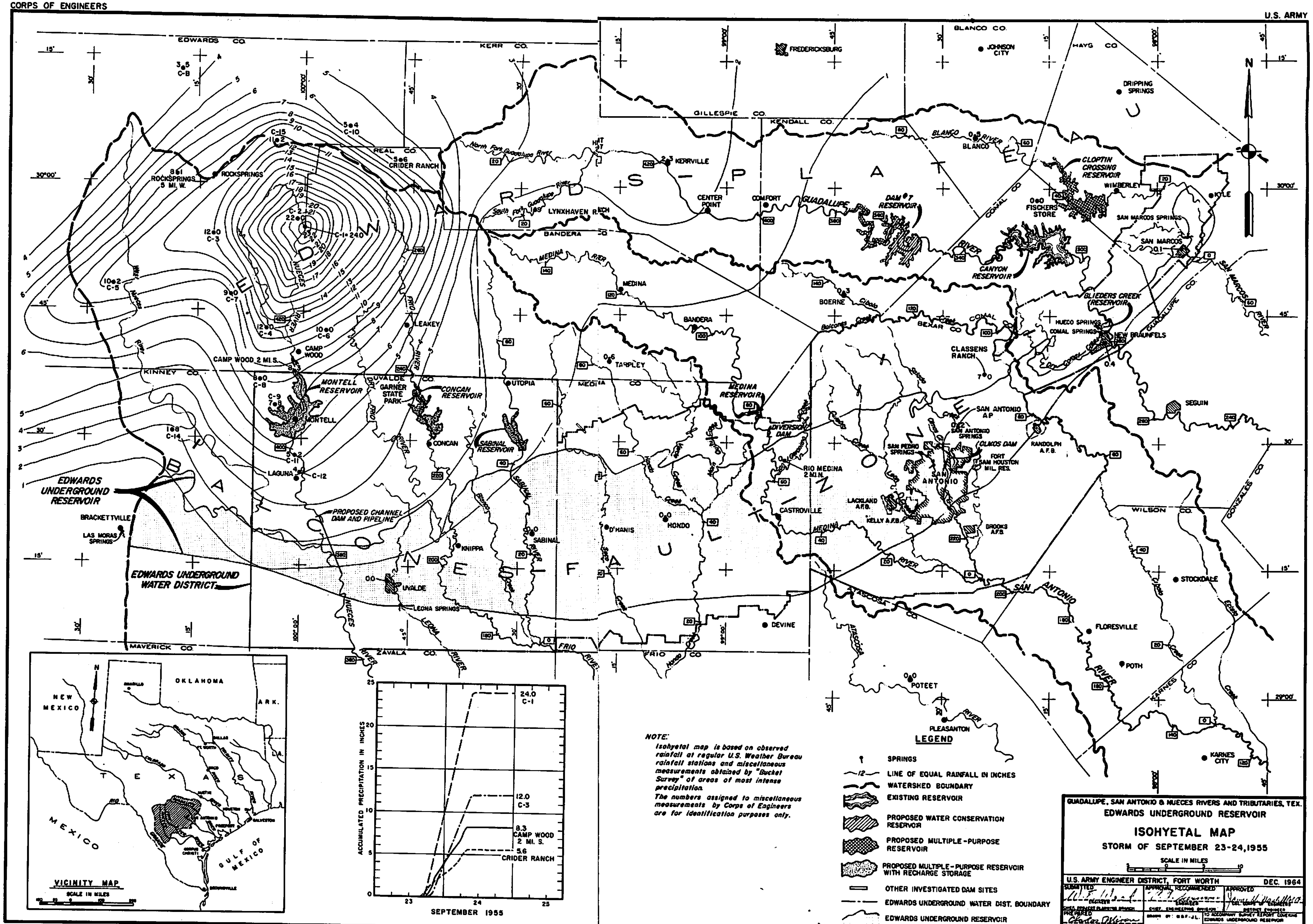
GUADALUPE CO.
WILSON CO.
GONZALES CO.
MAVERICK CO.
ZAVALA CO.
FRIO CO.
ATASCOSA CO.
KARNES CO.
FREDERICKSBURG
JOHNSON CITY
DRIPPING SPRINGS
KERRVILLE
CENTER POINT
COMFORT
BLANCO
WIMBERLEY
KYLE
SAN MARCOS SPRINGS
SAN MARCOS
ROCKSPRINGS
LEAKEY
CAMP WOOD
MONTELL RESERVOIR
MONTELL
GARNER STATE PARK
CONCAN RESERVOIR
CONCAN
UTOPIA
TARPLEY
MEDINA
BANDERA
BOERNE
MEDINA RESERVOIR
DIVERSION DAM
RIOMEDINA
CASTROVILLE
SABINAL RESERVOIR
SABINAL
WOODWARD RANCH
WOODWARD RANCH 3MI. NE
TZ RANCH
D'HANIS
HONDO
LAGUNA
BRACKETTVILLE
LAS MORAS SPRINGS
KNIPPA
UVALDE
LEONA SPRINGS
DEVINE
SAN ANTONIO
SAN ANTONIO SPRINGS
OLMOS DAM
SAN PEDRO SPRINGS
FORT SAM HOUSTON MIL. RES.
LACKLAND A.F.B.
KELLY A.F.B.
BROOKS A.F.B.
RANDOLPH A.F.B.
NEW BRAUNFELS
HUECO SPRINGS
COMAL SPRINGS
SEGUIN
CLOPTIN CROSSING RESERVOIR
DAM #7 RESERVOIR
CANYON RESERVOIR
CLIEDERS CREEK RESERVOIR
STOCKDALE
FLORESVILLE
POTH
POTEET
PLEASANTON
PEARSALL
KARNES CITY


GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
ISOHYETAL MAP
STORM OF JUNE 10-15, 1935
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC. 1964
SUBMITTED
APPROVAL RECOMMENDED
APPROVED
PREPARED
FILE: GUAD. 707-2
LEGEND
SPRINGS
LINES OF EQUAL RAINFALL IN INCHES
WATERSHED BOUNDARY
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR WITH RECHARGE STORAGE
OTHER INVESTIGATED DAM SITES
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
NOTE: Isohyetal map based on approved Storm Study Part II (GM 5-2)
ACCUMULATED PRECIPITATION IN INCHES
JUNE 1935
14.2 BRACKETTVILLE
12.1 MOUNTAIN HOME
8.5 MONTELL
6.1 BANDERA
VICINITY MAP
NEW MEXICO
OKLAHOMA
ARK.
LA.
TEXAS
MEXICO
GULF OF MEXICO
EDWARDS PLATEAU
BALCONES FAULT ZONE
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
PROPOSED CHANNEL DAM AND PIPELINE
SAN ANTONIO
NEW BRAUNFELS
SAN MARCOS
UVALDE
KERRVILLE
FREDERICKSBURG
SEGUIN
FLORESVILLE
KARNES CITY
PEARSALL
DEVINE
HONDO
CASTROVILLE
BANDERA
BOERNE
COMFORT
WIMBERLEY
KYLE
BLANCO
JOHNSON CITY
DRIPPING SPRINGS
ROCKSPRINGS
BRACKETTVILLE
CAMP WOOD
LEAKEY
UTOPIA
CONCAN
SABINAL
KNIPPA
LA PRYOR
BATESVILLE
POTEET
PLEASANTON
STOCKDALE
POTH
CANYON RESERVOIR
MEDINA RESERVOIR
DIVERSION DAM
OLMOS DAM
CLOPTIN CROSSING RESERVOIR
DAM #7 RESERVOIR
BLIEDERS CREEK RESERVOIR
MONTELL RESERVOIR
CONCAN RESERVOIR
SABINAL RESERVOIR


GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
ISOHYETAL MAP
STORM OF SEPTEMBER 26-27, 1946
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC. 1964
SUBMITTED
APPROVAL RECOMMENDED
APPROVED
PREPARED
FILE: GUAD. 707-2
NOTE:
Isohyetal map is based on approved Storm Study, Part II (GM 5-24)
LEGEND
SPRINGS
LINE OF EQUAL RAINFALL IN INCHES
WATERSHED BOUNDARY
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR WITH RECHARGE STORAGE
OTHER INVESTIGATED DAM SITES
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
ACCUMULATED PRECIPITATION IN INCHES
SEPTEMBER 1946
17.2 SAN ANTONIO 11 MI. S.E.
15.0 PLEASANTON 10.5 MI. N.
13.0 SAN ANTONIO NURSERY
6.9 SAN ANTONIO AIR PORT
VICINITY MAP
NEW MEXICO
OKLAHOMA
ARK.
TEXAS
MEXICO
GULF OF MEXICO
EDWARDS PLATEAU
BALCONES FAULT ZONE
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
PROPOSED CHANNEL DAM AND PIPELINE
MONTELL RESERVOIR
CONCAN RESERVOIR
SABINAL RESERVOIR
MEDINA RESERVOIR
DIVERSION DAM
CLOPTIN CROSSING RESERVOIR
DAM & 7 RESERVOIR
CANYON RESERVOIR
BLIEDERS CREEK RESERVOIR
SAN ANTONIO
SAN ANTONIO 11 MI. S.E.
SAN ANTONIO NURSERY
PLEASANTON 10.5 MI. N.
KERRVILLE
BANDERA
UVALDE
NEW BRAUNFELS
SAN MARCOS
SEGUIN
FLORESVILLE
PLEASANTON
DEVINE
HONDO
CASTROVILLE
BOERNE
COMFORT
WIMBERLEY
BRACKETTVILLE
ROCKSPRINGS
EDWARDS CO.
KERR CO.
REAL CO.
KINNEY CO.
UVALDE CO.
MEDINA CO.
BEXAR CO.
COMAL CO.
HAYS CO.
GUADALUPE CO.
WILSON CO.
ATASCOSA CO.
FRIO CO.
ZAVALA CO.
MAVERICK CO.
KARNES CO.
GONZALES CO.
KENDALL CO.
GILLESPIE CO.
BLANCO CO.
BANDERA CO.


EDWARDS CO.
KERR CO.
BLANCO CO
HAYS CO.
GILLESPIE CO
KENDALL CO.
REAL CO.
BANDERA CO.
KINNEY CO.
UVALDE CO.
MEDINA CO.
BEXAR CO.
COMAL CO.
GUADALUPE CO.
WILSON CO.
GONZALES CO.
MAVERICK CO.
ZAVALA CO.
FRIO CO.
ATASCOSA CO.
KARNES CO.
FREDERICKSBURG
JOHNSON CITY
HYE
DRIPPING SPRINGS
ROCKSPRINGS
KERRVILLE
COMFORT
CLOPTIN CROSSING RESERVOIR
WIMBERLEY
KYLE
SAN MARCOS SPRINGS
SAN MARCOS
DAM #7 RESERVOIR
CANYON RESERVOIR
BLIEDERS CREEK RESERVOIR
HUECO SPRINGS
COMAL SPRINGS
NEW BRAUNFELS
BOERNE
BANDERA
MEDINA
FAIROAKS RANCH
LEAKEY
CAMP WOOD
MONTELL RESERVOIR
TARPLEY
CLASSENS RANCH
SEGUIN
UTOPIA
GARNER STATE PARK
CONCAN RESERVOIR
MEDINA RESERVOIR
DIVERSION DAM
MONTELL
CONCAN
SABINAL RESERVOIR
SAN ANTONIO SPRINGS
SAN PEDRO SPRINGS
OLMOS DAM
FORT SAM HOUSTON MIL. RES.
RANDOLPH A.F.B.
SAN ANTONIO
LACKLAND A.F.B.
KELLY A.F.B.
BROOKS A.F.B.
LAGUNA
CASTROVILLE
EDWARDS UNDERGROUND RESERVOIR
PROPOSED CHANNEL DAM AND PIPELINE
LAS MORAS SPRINGS
KNIPPA
SABINAL
D'HANIS
HONDO
EDWARDS UNDERGROUND WATER DISTRICT
UVALDE
LEONA SPRINGS
DEVINE
STOCKDALE
FLORESVILLE
POTH
POTEET
PLEASANTON
PEARSALL
KARNES CITY
NUECES RIVER
FRIO RIVER
SABINAL RIVER
MEDINA RIVER
GUADALUPE RIVER
BLANCO RIVER
SAN ANTONIO RIVER
LEONA RIVER
EDWARDS PLATEAU
BALCONES FAULT ZONE
VICINITY MAP
SCALE IN MILES
NEW MEXICO
OKLAHOMA
ARK.
LA.
TEXAS
MEXICO
GULF OF MEXICO
SEPTEMBER 1952
ACCUMULATED PRECIPITATION IN INCHES
21.1 BLANCO
15.9 FREDERICKSBURG
12.6 BOERNE
4.6 RANDOLPH A.F.B.
NOTES:
Isohyetal map is based on observed rainfall at regular U.S. Weather Bureau Rainfall Stations and miscellaneous measurements obtained by "Bucket Survey" of areas of most intense precipitation.
Data shown in preliminary storm study.
LEGEND
SPRINGS
LINES OF EQUAL RAINFALL IN INCHES
WATERSHED BOUNDARY
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION-RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR WITH RECHARGE STORAGE
OTHER INVESTIGATED DAM SITES
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
ISOHYETAL MAP
STORM OF SEPTEMBER 9-11, 1952
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC. 1964
SUBMITTED
APPROVAL RECOMMENDED
APPROVED
PREPARED
FILE: GUAD. 707-2


NOTE:
Isohyetal map is based on observed rainfall at regular U.S. Weather Bureau rainfall stations and miscellaneous measurements obtained by "Bucket Survey" of areas of most intense precipitation.
The numbers assigned to miscellaneous measurements by Corps of Engineers are for identification purposes only.
LEGEND
SPRINGS
LINE OF EQUAL RAINFALL IN INCHES
WATERSHED BOUNDARY
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR WITH RECHARGE STORAGE
OTHER INVESTIGATED DAM SITES
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
ISOHYETAL MAP
STORM OF SEPTEMBER 23-24,1955
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC. 1964
FILE: GUAD. 707-2
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
VICINITY MAP
ACCUMULATED PRECIPITATION IN INCHES
SEPTEMBER 1955
24.0 C-1
12.0 C-3
8.3 CAMP WOOD 2 MI. S.
5.6 CRIDER RANCH

of the Edwards Plateau. Runoff from this storm produced the maximum known peak discharges in the upper part of the Frio, Sabinal, and Guadalupe River watersheds. Maximum peak discharges are as follows: Frio River at Concan, 162,000 second-feet; Guadalupe River near Comfort, 182,000 second-feet; Sabinal River near Sabinal, an estimated 86,000 second-feet. Several additional intense storms which covered smaller areas were: the storm of May 25-30, 1929 which produced the maximum known peak discharges of 113,000 and 139,000 second-feet on the Blanco River at Wimberley and Kyle, respectively; the storm of May 31, 1935 which produced the maximum known peak discharge of 230,000 second-feet on Seco Creek about 11 miles north of D'Hanis; the storm of June 10-15, 1935 which produced the maximum known peaks of 550,000 second-feet on the West Nueces River near Brackettville and 616,000 second-feet on the Nueces River near Uvalde; the storm of September 26-27, 1946 which produced the maximum known peak discharge of 58,000 second-feet on Calaveras Creek at San Antonio; the storm of September 9-11, 1952 which produced serious flooding on the Blanco River with a peak discharge of 95,000 second-feet at Wimberley; and the storm of September 23-24, 1955 which produced the maximum known peak discharge of 307,000 second-feet on the Nueces River at Laguna. The effect of the Balcones Fault on storms in the area is discussed in the following excerpt from a published report: 1/

> "The escarpment along the Balcones fault zone tends doubtless to increase the rainfall in its vicinity to some extent, because it forces warm moist air from the Gulf to rise, then to expand and cool, thus inducing heavy rainfall. The possible effect of the escarpment may be exaggerated, because whenever intense rains occur in that area, terrific floods are likely to follow, not because the rain was greater in volume or intensity than often occurs in the coastal area, but because of the steepness of the slopes, the shallowness and rocky character of the soil, and the narrow flood plains of the stream channels."

38. Table 15 gives peak discharges and flood volumes of some of the larger floods at selected gages in the upper watersheds of river basins in the vicinity of the Balcones Fault and in the study area.

39. HYPOTHETICAL FLOOD HYDROGRAPHS.- In connection with the determination of flood-control storage requirements, flood volume-duration-frequency studies were made for the reservoirs, based on gages throughout the area, in order to establish the degree of protection that would be afforded by varying amounts of flood-control storage in each project. These studies were developed in accordance with the method set forth in Section VI of "Statistical Methods in

1/ Dalrymple, Tate, and others, "Major Texas Floods of 1936." U. S. Geological Survey Water Supply Paper 816, page 10, Cause of floods.

"Hydrology" by Leo R. Beard, dated January 1962, and recommended for use in ER 1110-2-1450. Data obtained from the volume-duration-frequency curves were used to construct hypothetical hydrographs for floods of selected frequencies at each reservoir.

40. NATURAL RECHARGE CAPACITIES.

a. General.- Analyses of available data pertaining to natural recharge capacities have been made for all streams that cross the recharge zone of the Edwards Reservoir. The amount of data available varied considerably from one location to the next. It was possible to make more detailed analyses for some areas due to the presence of stream gaging records both above and below the outcrop. Most of these gages, however, have been in operation only a short time and the recorded losses are not necessarily indicative of the maximum recharge capacities. Estimates were made for streams without stream gaging records by comparison with the recharge rates for adjacent streams. In addition, use was made of published reports containing estimated recharge rates for certain streams within the Edwards Underground area. Preliminary analyses led to the elimination of some streams from further investigation into the possibilities of recharge reservoir construction. The major reasons for the eliminations were: (1) the estimated natural recharge of a number of the streams represents a large percentage of the runoff; hence, improvement could not increase the recharge significantly; (2) no suitable dam site was available in several areas. The locations of the investigated projects are shown on plate 4. The streams that were investigated in more detail are as follows: Nueces River, Frio River, Sabinal River, Medina River, Guadalupe River, and the Blanco River. Recharge characteristics of these streams are discussed in the following paragraphs.

(1) Nueces River.

(a) The investigation of the recharge capacity of the Nueces River is based on analyses of U. S. Geological Survey gage records. Stream gaging records are available on the Nueces River and the West Nueces River, a tributary to the Nueces River. The Laguna gage on the Nueces River, which is located above the recharge zone, has about 39 years of record. The Brackettville gage on the West Nueces River, which is above the recharge zone, was installed in October 1940, but was discontinued from October 1950 through March 1956. The Uvalde gage on the Nueces River is located below the recharge zone and is approximately 16 miles downstream from the confluence of the Nueces and West Nueces River. As indicated by the gage near Brackettville, Texas, there is seldom any flow in the West Nueces River except in periods of heavy rainfall. By taking into consideration the recorded or estimated flow of the West Nueces River, it is possible to estimate the recharge rate for the Nueces River downstream from the recommended dam site.

TABLE 15

FLOOD DATA

Date of flood	Peak discharge (cfs)	Date of peak	Flood volume passing gage (acre-feet)	Flood volume passing gage (inches)

West Nueces River near Brackettville - D.A. = 700 sq. mi.

June 1935	550,000(1)	June 14	-	-
June 16-19, 1958	104,000	June 17	104,400	2.80

(1) Measurement made by U. S. Geological Survey 10 miles above mouth.

Nueces River at Laguna - D.A. = 764 sq. mi.

June 13-18, 1935	213,000	June 14	277,900	6.82
September 15-19, 1936	114,000	September 16	111,890	2.74
July 13-15, 1939	222,000	July 13	89,000	2.18
September 24-27, 1955	307,000	September 24	153,810	3.77

Nueces River below Uvalde - D.A. = 1,947 sq. mi.

September 1-4, 1932	207,000	September 1	280,000	2.72(1)
June 13-18, 1935	616,000	June 14	461,700	4.48(1)
July 13-15, 1939	89,000	July 13	57,480	0.55
September 24-27, 1955	189,000	September 24	143,900	1.39
June 17-20, 1958	146,000	June 17	191,100	1.84

(1) Measurement was made at the gage near Uvalde-D.A. = 1,930 sq. mi.

Frio River at Concan - D.A. = 405 sq. mi.

July 1-6, 1932	162,000	July 1	150,620	6.97
June 13-18, 1935	106,000	June 14	115,140	5.33
September 15-19, 1936	119,000	September 16	44,230	2.05

Frio River near Derby - D.A. = 3,493 sq. mi.

July 2-8, 1932	230,000	July 4	528,080	2.83
May 29-June 8, 1935	68,300	June 2	261,600	1.40
June 13-22, 1935	50,500	June 16	251,660	1.35

Sabinal River near Sabinal - D.A. = 206 sq. mi.

May 24-25, 1954	15,800	May 24	5,460	0.50
June 17-19, 1958	55,200	June 17	29,850	2.72
June 25-28, 1959	11,900	June 25	10,950	1.00

Sabinal River at Sabinal-D.A. = 247 sq. mi. (1)

May 24-26, 1954	15,900	May 24	8,050	0.61
June 17-20, 1958	73,300	June 17	42,230	3.19
June 26-29, 1959	15,900	June 26	11,250	0.85

(1) Gage is located below Balcones fault zone.

Hondo Creek near Tarpley - D.A. = 101 sq. mi.

May 24-26, 1954	18,600	May 24	2,080	0.39
September 22-24, 1957	25,300	September 22	6,900	1.28
June 17-20, 1958	69,800	June 17	26,400	4.90

Hondo Creek near Hondo - D.A. = 132 sq. mi. (1)

May 24-26, 1954	13,700	May 24	2,600	0.37
September 22-24, 1957	20,500	September 22	6,810	0.97
June 17-20, 1958	71,700	June 17	22,980	3.26

(1) Gage is located below Balcones fault zone.

Seco Creek near Utopia - D.A. = 53 sq. mi.

September 22-25, 1957	12,100	September 22	3,340	1.18
June 17-20, 1958	52,600	June 17	13,770	4.87

Seco Creek near D'Hanis - D.A. = 87 sq. mi. (1)

May, 1935	230,000(2)	May 31	-	-
September 22-24, 1957	12,400	September 22	3,750	0.81
June 17-19, 1958	72,000	June 17	20,020	4.32

(1) Gage located below Balcones fault zone.
(2) Measurement made by U. S. Geological Survey 11 miles above D'Hanis)

Medina River near Pipe Creek - D.A. = 474 sq. mi.

July 1-5, 1932	64,000	July 1	81,880	3.24
July 24, 1935	40,400(1)	July 24	-	-
June 17-19, 1958	37,100	June 17	30,660	1.21

(1) Station abandoned July 25.

Guadalupe River at Comfort - D.A. = 836 sq. mi.

July 1-3, 1932	182,000	July 1	136,070	3.35(1)
May 25-28, 1944	59,400	May 26	49,030	1.10
September 10-12, 1952	38,600	September 10	19,840	0.44
October 4-7, 1959	93,200	October 4	56,900	1.28

(1) Measurement was made at gage near Comfort - D.A. = 762 sq. mi.
Note: Gage was not operating during 1935 flood.

Guadalupe River near Spring Branch - D.A. = 1,282 sq. mi.

July 2-4, 1932	121,000	July 3	194,580	2.85
June 13-17, 1935	114,000	June 15	179,520	2.63
May 25-29, 1944	28,000	May 27	62,940	0.92
September 10-13, 1952	66,900	September 11	119,190	1.74
October 4-8, 1959	42,500	October 5	68,270	1.00

Blanco River at Wimberley - D.A. = 353 sq. mi.

May 28-31, 1929	113,000	May 28	84,630	4.50
September 11-14, 1952	95,000	September 11	77,840	4.13
April 24-25, 1957	62,600	April 24	27,990	1.49
May 2-5, 1958	96,400	May 2	43,700	2.36

(b) During a 5-day period from August 31 to September 5, 1942, the average daily infiltration rate varied from over 300 second-feet to over 1600 second-feet. On October 20, 1962, the average daily flow at the Laguna gage was 901 second-feet, with a peak discharge of 3210 second-feet. All of this flow was lost to the underground reservoir in crossing the recharge zone. The above recharge values are examples of the infiltration that has been experienced in the Nueces River channel below the recommended dam site.

(2) Frio River.

(a) Stream gaging records are available on the Frio River and Dry Frio River, above the recharge zone. The Concan gage on the Frio River, which is located above this zone, has about 39 years of record. The Reagan Wells gage on the Dry Frio River, however, was not installed until September 1952. The Dry Frio River enters the Frio River a short distance downstream from the lower edge of the recharge zone. Approximately five miles downstream from the confluence of the Dry Frio with the Frio River the Geological Survey installed a stream gage on the Frio River near Uvalde. By use of these gages it was possible to estimate the recharge rate for the Frio River.

(b) On July 17, 1955, the average daily flow at the Concan gage was 447 second-feet, with a peak discharge of 2670 second-feet; all of this flow was lost to the Udwards Underground Reservoir. An average daily flow of 728 second-feet, having a peak of 3500 second-feet, was lost to the underground on October 20, 1962. The above losses are the only examples of high rates of recharge since the gage has been installed below the recharge zone on the Frio River.

(3) Sabinal River.

(a) Stream gaging records are available above the recharge zone since October 1942, and below the recharge zone since September 1952. There are no large tributaries entering the Sabinal River between the gages; therefore, the recharge was estimated to be the difference in the amount of flow passing the two gages.

(b) The losses on the Sabinal River varied from 500 second-feet to 300 second-feet for a five day period from July 16 through July 20, 1960. On May 6, 1963, the average daily flow was 406 second-feet, having a peak of 1010 second-feet; all of this flow was lost to the underground. The recommended dam site is located within the loss area; therefore, it is expected that the recharge rate will increase due to the large area of exposed limestone that is within the reservoir storage limits.

(4) Medina River.

(a) The two major loss areas in the Medina River Basin are the Medina Reservoir, and the small diversion dam that is located approximately four miles downstream from the main reservoir. As stated in a published report: 1/

"The two components which make up this loss have different characteristics. The loss on the main reservoir would be expected to vary with the stage of the water in the reservoir, whereas the loss from the diversion reservoir is more or less a constant, continuing whenever the reservor is being used, because it operates with very little variation in head. . . .

"On a falling stage the combined losses in the two reservoirs vary from about 50 second-feet (whenever there is more than 30,000 acre-feet in storage) to something in excess of 120 second-feet when the reservoir is full. When the stage is rising the losses vary from about 90 second-feet to more than 165 second-feet.

"As indicated above, the losses from the diversion reservoir and the channel downstream are independent of stage in the main reservoir, and are more or less constant as long as water is being supplied to the canal. Without additional information it was assumed that this loss would be a constant . . . and would amount to about 25 second-feet."

(b) It is noted that the above data and conclusions were reviewed and adopted by Guyton in a report dated 1958. 2/ In the 1958 report, several additional years of record were evaluated, and found to generally substantiate the original findings. This office also reviewed the original computations, examined the latest available records and found Lowry's original computations to be satisfactory.

(5) Guadalupe River.

"The Guadalupe River, in contrast to most of the other streams crossing the Balcones fault zone, apparently does not lose significant quantities of water to the Edwards limestone. . . . Investigations to determine seepage losses have

1/ Lowry, R. L., 1953 "Hydrologic Report Medina River Above the Applewhite Dam Site." Consulting Engineer's Report to San Antonio City Water Board.

2/ William T. Guyton and Associates, March 1958, "Leakage from Medina Lake, Medina County, Texas."

"failed to disclose losses greater than those that might be expected from evapo-transpiration. However, there are minor losses and gains in various reaches of the river . . . ." 3/

(6) Blanco River.

"Records of the discharge of the Blanco River at Wimberley, which is above the outcrop of the Edwards, are available for the period since June 1928. No continuous records of discharge are available below the outcrop. Discharge measurements to determine seepage losses or gains indicate that, with discharge up to approximately 200 cfs at the gage, the loss in crossing the outcrop of the Edwards limestone is about 15 cfs. Therefore, the limit of infiltration in this section has been set at 15 cfs regardless of flow above 200 cfs at the gage. All flows up to 15 cfs are assumed to be recharge to the ground water reservoir. . . ." 3/

b. Recommended Releases for Recharge.- The reservoirs considered for the improvement of the recharge of the underground are Montell, Concan, and Sabinal Reservoirs. The storage requirements for these reservoirs were determined based on various release rates covering reasonable ranges indicated by the gage records. It was found that regardless of the release rate selected, there was only a small difference in the storage requirements. This was due primarily to the normally short duration of the surface runoff in this area. The release rates which have been adopted for this study are values which approach the maximum average daily losses that have been experienced. The recommended rates for Montell, Concan, and Sabinal Reservoirs are 1,000 second-feet, 750 second-feet and 500 second-feet, respectively. It is possible that these rates may have to be adjusted after experience gained from the operation of the reservoirs indicates more closely the actual recharge rates.

41. CHANNEL CAPACITIES.- Minimum channel capacities downstream from the Montell, Concan, Sabinal, and Cloptin Crossing Reservoirs are shown on table 16.

3/ Petitt, B. M., Jr., and George, W. O., 1956 U. S. Geological Survey, "Ground Water Resources of the San Antonio Area, Texas, A Progress Report on Current Studies," Texas Board of Water Engineers Bulletin 5608, Volume I.

TABLE 16

CHANNEL CAPACITIES

Stream	Location	Minimum channel capacities (cfs)
	NUECES RIVER BASIN	
Nueces	Laguna	5,000
	Nr Uvalde	64,000
	Nr Cinonia (discontinued gage-above mouth of Turkey Creek)	15,000
	Nr Asherton	20,000
	Cotulla	5,000
	Nr Tilden	5,000
Frio	Concan	7,000
Sabinal	Nr Sabinal	3,000
Frio	Derby	7,000
	Calliham	10,000
Nueces	Nr Three Rivers	5,000
	GUADALUPE RIVER BASIN	
Blanco	Wimberley	15,000(1)
	Nr Kyle	15,000(2)
San Marcos	Luling	14,000
	Ottine	12,000
Guadalupe	Gonzales	15,000
	Nr Cuero	20,000
	Victoria	12,000

(1) Channel capacity is restricted to approximately 5,000 second-feet by low water crossings on County roads.

(2) Channel capacity is restricted to approximately 6,000 second-feet by low water crossings on County roads.

SURFACE RESERVOIRS

42. EXISTING AND AUTHORIZED FEDERAL PROJECTS.- The existing and authorized Federal projects in the study area are those of the Corps of Engineers and the Soil Conservation Service. These projects are discussed in paragraph 8 and located on plate 13.

43. EXISTING NON-FEDERAL RESERVOIRS.- The existing non-Federal reservoirs in the study area are discussed in paragraph 9 and located on plate 13.

44. RECOMMENDED PLAN.- The recommended plan will provide controlled recharge storage for the underground reservoir, additional water supply storage and recreation facilities for the people of the Edwards Reservoir area, and flood protection for the downstream areas of the Nueces and Guadalupe River Basins. The storage allocations for the reservoirs are given in table 17. Location of the recommended reservoirs is shown on plate 13. Reservoirs recommended in the plan of improvement are as follows:

a. For authorization and construction by the Federal Government:

(1) Montell Reservoir on the Nueces River for flood-control, water supply, recharge, and for recreation and fish and wildlife purposes, including a channel dam and a pipeline for water supply to downstream areas of the Nueces River Basin. Detailed pertinent data are shown in table 18.

(2) Concan Reservoir on the Frio River for flood-control, recharge, and recreation purposes. Detailed pertinent data are shown in table 19.

(3) Sabinal Reservoir on the Sabinal River for flood-control, recharge, and recreation purposes. Detailed pertinent data are shown in table 20.

(4) Cloptin Crossing Reservoir on the Blanco River for flood-control, water conservation, recreation, and fish and wildlife purposes. Detailed pertinent data are shown in table 21.

b. For construction by local interests.- Dam No. 7 Reservoir on the Guadalupe River for water conservation.

45. AREA AND CAPACITY OF THE RESERVOIRS.- The area and capacity of the reservoirs investigated for this study were determined from available topographic maps of the reservoir sites. The topographic maps were planimetered and the area at and below each mapped contour was plotted versus elevation to form area-elevation curves. Areas were

picked from these curves at 1-foot intervals and capacities were computed therefrom by the average-end area method. Tabulations of initial areas and capacities are given in tables 22 through 26 for Montell, Concan, Sabinal, Dam No. 7, and Cloptin Crossing Reservoirs.

46. DETERMINATION OF RESERVOIR INFLOWS.- Monthly flows were determined at the existing and investigated reservoir sites in the Edwards Reservoir area for periods including a reasonably representative cycle of floods and runoff deficiency in the vicinity of the reservoirs. The monthly flows were based on: (1) existing conditions of runoff, generally determined from observed records at stream-gaging stations, and (2) runoff under 2025 conditions of watershed development. Because of the small consumptive use of surface water in the area and because total surface reservoir capacity in the basin was very small prior to 1962, it was considered that historical runoff was the same as runoff under existing conditions of watershed development. It was, however, necessary to adjust existing flows to 2025 conditions for water supply studies. The United States Study Commission - Texas had previously determined 2010 flows at the Canyon Dam site on the Guadalupe River and at the Wimberley Dam site (approximately 10 miles downstream from Cloptin Crossing) on the Blanco River for the period 1941-1957. The factors adopted by the USSC-T for the conversion of existing to 2010 conditions runoff were based upon thorough studies of future watershed development. The methods and procedures used were examined, found to be acceptable, and the factors adopted for use in this report. Since the U. S. Study Commission assumed that the watershed development for these basins would be substantially complete by 2010, these conversion factors, relating natural to 2010 runoff, also relate natural to 2025 runoff. Because of the proximity of the dam sites, the factors developed for Canyon and Wimberley Dam sites were considered applicable to Dam No. 7 and Cloptin Crossing Dam sites. Factors for the conversion of natural to 2025 flow for the period prior to 1941 and subsequent to 1957 were determined in a manner similar to that for the 1941-1957 period.

47. The report of the U. S. Study Commission - Texas did not recommend construction of reservoirs above the Balcones Fault Zone in the Nueces River Basin and consequently studies for the report did not determine whether anticipated watershed development would reduce future runoff appreciably from that area. The studies of future conditions depletion of runoff were accomplished for the U. S. Study Commission - Texas by the U. S. Bureau of Reclamation and were based upon procedures which that agency had developed in connection with its report on "Gulf Basins Project, Texas."

48. These procedures and a discussion of them is presented in Annex (C-8) of the above report titled "Land Treatment, Pond and Minor Reservoir and Floodwater Retarding Structure Depletions," dated August 1958. According to the introduction to Annex (C-8),

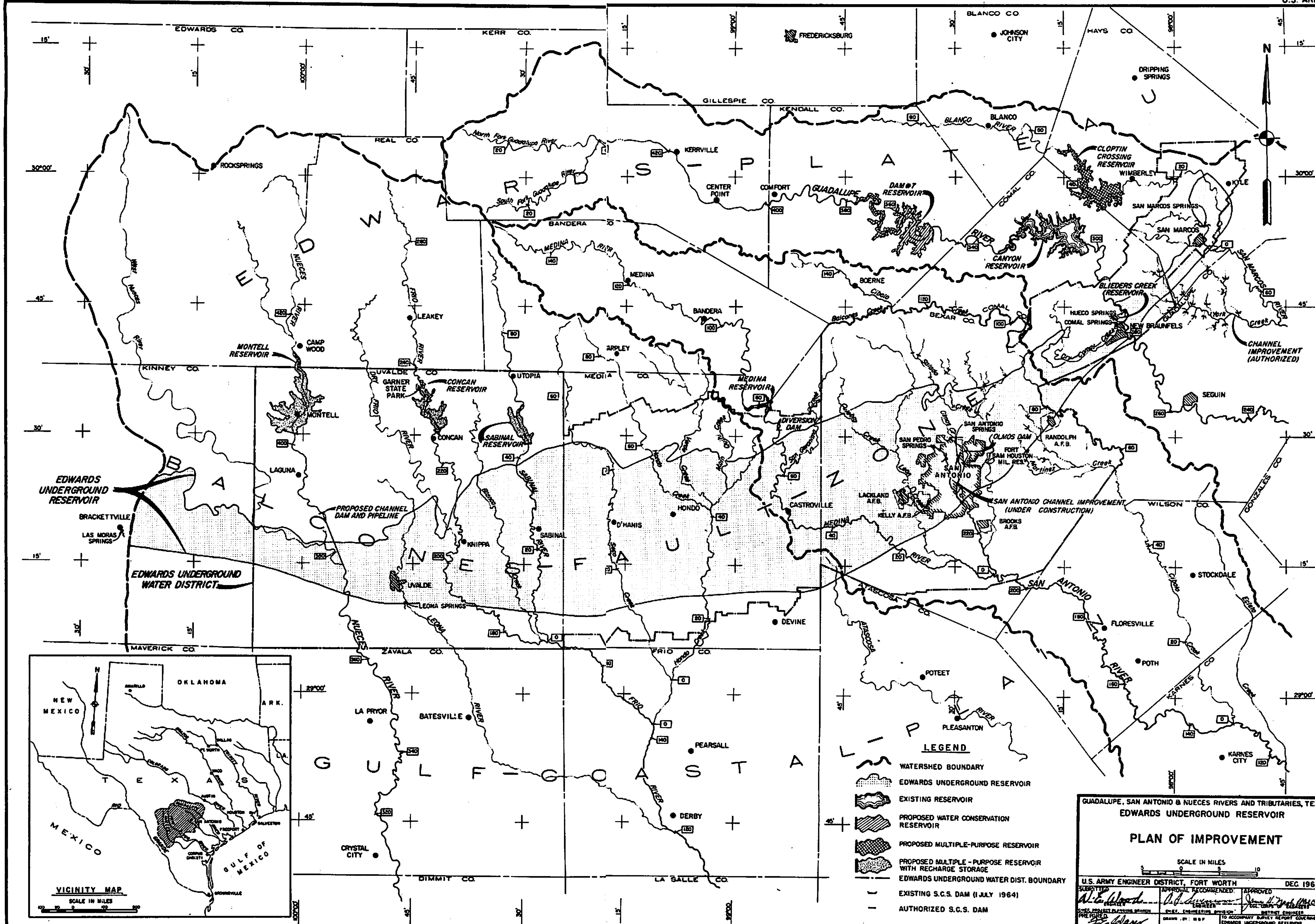

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.
EDWARDS UNDERGROUND RESERVOIR
PLAN OF IMPROVEMENT
SCALE IN MILES
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
DEC 1964
FILE: GUAD. 707-2
LEGEND
WATERSHED BOUNDARY
EDWARDS UNDERGROUND RESERVOIR
EXISTING RESERVOIR
PROPOSED WATER CONSERVATION RESERVOIR
PROPOSED MULTIPLE-PURPOSE RESERVOIR
PROPOSED MULTIPLE - PURPOSE RESERVOIR WITH RECHARGE STORAGE
EDWARDS UNDERGROUND WATER DIST. BOUNDARY
EXISTING S.C.S. DAM (1 JULY 1964)
AUTHORIZED S.C.S. DAM
EDWARDS PLATEAU
BALCONES FAULT ZONE
GULF-COASTAL PLAIN
EDWARDS UNDERGROUND RESERVOIR
EDWARDS UNDERGROUND WATER DISTRICT
MONTELL RESERVOIR
CONCAN RESERVOIR
SABINAL RESERVOIR
MEDINA RESERVOIR
DIVERSION DAM
DAM #7 RESERVOIR
CANYON RESERVOIR
CLOPTIN CROSSING RESERVOIR
BLIEDERS CREEK RESERVOIR
CHANNEL IMPROVEMENT (AUTHORIZED)
SAN ANTONIO CHANNEL IMPROVEMENT (UNDER CONSTRUCTION)
PROPOSED CHANNEL DAM AND PIPELINE
OLMOS DAM
EDWARDS CO.
KERR CO.
REAL CO.
BANDERA CO.
KENDALL CO.
GILLESPIE CO.
BLANCO CO.
HAYS CO.
COMAL CO.
BEXAR CO.
GUADALUPE CO.
KINNEY CO.
UVALDE CO.
MEDINA CO.
WILSON CO.
GONZALES CO.
MAVERICK CO.
ZAVALA CO.
FRIO CO.
ATASCOSA CO.
KARNES CO.
DIMMIT CO.
LA SALLE CO.
FREDERICKSBURG
JOHNSON CITY
DRIPPING SPRINGS
ROCKSPRINGS
KERRVILLE
CENTER POINT
COMFORT
BLANCO
WIMBERLEY
KYLE
SAN MARCOS SPRINGS
SAN MARCOS
BOERNE
MEDINA
BANDERA
LEAKEY
CAMP WOOD
PIPE CREEK
UTOPIA
GARNER STATE PARK
CONCAN
MONTELL
LAGUNA
BRACKETTVILLE
LAS MORAS SPRINGS
KNIPPA
UVALDE
LEONA SPRINGS
SABINAL
D'HANIS
HONDO
CASTROVILLE
DEVINE
LACKLAND A.F.B.
KELLY A.F.B.
BROOKS A.F.B.
SAN ANTONIO
SAN PEDRO SPRINGS
SAN ANTONIO SPRINGS
FORT SAM HOUSTON MIL. RES.
RANDOLPH A.F.B.
HUECO SPRINGS
COMAL SPRINGS
NEW BRAUNFELS
SEGUIN
STOCKDALE
FLORESVILLE
POTH
POTEET
PLEASANTON
KARNES CITY
PEARSALL
DERBY
LA PRYOR
BATESVILLE
CRYSTAL CITY
NUECES RIVER
FRIO RIVER
SABINAL RIVER
MEDINA RIVER
GUADALUPE RIVER
BLANCO RIVER
SAN MARCOS RIVER
SAN ANTONIO RIVER
ATASCOSA RIVER
LEONA RIVER
North Fork Guadalupe River
South Fork Guadalupe River
Cibolo Creek
Hondo Creek
Seco Creek
Dry Frio River
West Nueces River
VICINITY MAP
NEW MEXICO
OKLAHOMA
ARK.
LA.
TEXAS
MEXICO
GULF OF MEXICO
SCALE IN MILES

TABLE 17

EXISTING AND RECOMMENDED RESERVOIRS - EDWARDS UNDERGROUND RESERVOIR AREA

Reservoir	Stream	River mile	Contributing drainage area (sq. mi.)	Storage capacity (acre-feet) Sediment	Conservation	F-C	Total	2025 Yield (cfs)
				FEDERAL PROJECTS				
Montell	Nueces	401.6	707	12,000	1,000	239,300(1)	252,300	6
Concan	Frio	226.2	391	7,800	0	141,200(1)	149,000	0
Sabinal	Sabinal	42.3	210	4,200	0	89,100(1)	93,300	0
Canyon	Guadalupe	303.0	1,425	28,100	366,400	346,400	740,900	133
Canyon w/Dam 7	Guadalupe	303.0	301(2)	10,300	378,900	351,700	740,900	67
Cloptin Crossing	Blanco	32.5	307	9,200	274,900	119,900	404,000	59
				LOCAL INTERESTS PROJECTS				
Dam 7	Guadalupe	351.3	1,124	17,500	640,500	-	658,000	130

(1) Dual-purpose storage (flood control and recharge).

(2) Local area below Dam 7.

TABLE 18

MONTELL RESERVOIR
(RECOMMENDED)

LOCATION:
R.M. 401.6 on Nueces River in Uvalde County, and about 2.5 mi. south of Montell; about 11.5 mi. south of Camp Wood, Texas

DRAINAGE AREA: 707 sq. mi.

DAM:

Type:	Rock fill w/spwy near left abutment
Length:	7,360 ft.
Max. height:	158 ft.
Top width:	30 ft.

SPILLWAY:

Crest:	1331.0 ft. msl
Length:	960.0 ft.
Type:	Broadcrested
Control:	None

INFLOW:

Spillway design flood peak, cfs	893,900
Spillway design flood volume, ac-ft	821,300
Spillway design flood runoff, inches	21.78

OUTFLOW: (El. 1366.0)

Total routed peak outflow, cfs	581,000
Spillway	570,600
Outlet works	10,400

OUTLET WORKS:

Type:	1 gate controlled conduit
Dimension:	15' diameter
Control:	3 - 5'8" x 12'0" tractor-type gates
Invert:	1216.0 ft. msl

POWER FEATURES:
None

RESERVOIR DATA

Features	Elev feet msl	Reservoir area (acres)	Reservoir capacity: Accumulative (ac-ft)	Runoff (inches)	Incremental (ac-ft)	Spillway capacity (cfs)	Outlet works capacity (cfs)
Top of dam	1371.0						
Maximum water surface	1366.0	10,180	533,100	14.14		570,600	10,400(2)
Flood control pool	1331.0	6,200	252,300	6.69	239,300	0	10,350
Spillway crest	1331.0	6,200	252,300	6.69		0	10,350
Conservation pool	1237.0	260	2,200	0.06	1,000	0	3,400
Sediment reserve					12,000(1)		
Total storage					252,300		
Maximum tailwater	1257.4						
Streambed	1216.0						

(1) Sediment distributed as follows:
1,200 ac-ft below el. 1237.0
10,800 ac-ft between el. 1237.0 and 1331.0

(2) O/W submerged by tailwater

TABLE 19

CONCAN RESERVOIR
(RECOMMENDED)

LOCATION:
R.M. 226.2 on Frio River in Uvalde County, and about 1.0 mi. northeast of Concan, Tex.

DRAINAGE AREA: 391.0 sq. mi.

DAM:

Type:	Rock fill w/spwy near right abutment
Length:	2,955 ft.
Max. height:	164.0 ft.
Top width:	30 ft.

SPILLWAY:

Crest:	1366.5 ft msl
Length:	1030 ft.
Type:	Broadcrested
Control:	None

INFLOW:

Spillway design flood peak, cfs	592,500
Spillway design flood volume, ac-ft	489,400
Spillway design flood runoff, inches	23.47

OUTFLOW: (El. 1394.2)

Total routed peak outflow, cfs	433,000
Spillway	425,300
Outlet works	7,700

OUTLET WORKS:

Type:	1 gate-controlled conduit
Dimension:	13' diameter
Control:	2 - 6' x 13'Tractor-type gates
Invert:	1240.0 ft. msl

POWER FEATURES:
None

RESERVOIR DATA

Features	Elev feet msl	Reservoir area (acres)	Reservoir capacity: Accumulative (ac-ft)	Runoff (inches)	Incremental (ac-ft)	Spillway capacity (cfs)	Outlet works capacity (cfs)
Top of dam	1399.5						
Maximum water surface	1394.2	5,670	280,600	13.46		425,300	7,700(1)
Flood control pool	1366.5	3,830	149,000	7.15	141,200	0	8,000
Spillway crest	1366.5	3,830	149,000	7.15		0	8,000
Sediment reserve					7,800		
Total storage					149,000		
Maximum tailwater	1283.3						
Streambed	1240.0						

(1) O/W submerged by tailwater.

TABLE 20

SABINAL RESERVOIR
(RECOMMENDED)

LOCATION:
R.M. 42.3 on Sabinal River in Uvalde County and about 11.0 mi. north of Sabinal, Texas

DRAINAGE AREA: 210 sq. mi.

DAM:
- Type: Rock fill w/gated spwy in river channel
- Length: 2,150 ft.
- Max. height: 114 ft.
- Top width: 30 ft.

SPILLWAY:
- Crest: 1196.5 ft. msl
- Length: 240 ft. net @ crest
- Type: Ogee
- Control: 6 - 40' x 30' tainter gates

INFLOW:

Spillway design flood peak, cfs	381,800
Spillway design flood volume, ac-ft	249,000
Spillway design flood runoff, inches	22.23

OUTFLOW: (El. 1238.8)

Total routed peak outflow, cfs	270,600
Spillway	270,600
Outlet works	0

OUTLET WORKS:
- Type: 2 sluices
- Dimension: 3' x 6'
- Control: 2 - 3' x 6' slide gates
- Invert: 1130.0 ft. msl

POWER FEATURES:
None

RESERVOIR DATA

Features	Elev feet msl	Reservoir area (acres)	Reservoir capacity: Accumulative (ac-ft)	Reservoir capacity: Runoff (inches)	Reservoir capacity: Incremental (ac-ft)	Spillway capacity (cfs)	Outlet works capacity (cfs)
Top of dam	1244.0						
Maximum water surface	1238.8	3,860	135,200	12.07		270,600	0(1)
Flood control pool(2)	1226.5	2,990	93,300	8.33	89,100	156,200	1,730
Spillway crest	1196.5	1,320	30,100	2.69		0	1,420
Sediment reserve					4,200		
Total storage					93,300		
Maximum tailwater	1179.0						
Streambed	1130.0						

(1) Outlet works inoperative during routing of spillway design flood
(2) Also top of gates

TABLE 22

EDWARDS UNDERGROUND RESERVOIR
NUECES RIVER
MONTELL RESERVOIR
R. M. 401.6
AREA AND CAPACITY DATA

AREA - ACRES

El	0	1	2	3	4	5	6	7	8	9
1210							0	2	5	9
1220	13	20	30	42	54	68	84	102	117	134
1230	153	168	183	196	212	226	241	256	273	292
1240	314	342	370	400	429	462	494	526	559	591
1250	623	656	687	720	752	785	818	853	887	924
1260	962	1,004	1,049	1,097	1,147	1,200	1,253	1,308	1,364	1,419
1270	1,476	1,528	1,588	1,649	1,712	1,774	1,842	1,908	1,973	2,042
1280	2,109	2,176	2,246	2,314	2,386	2,456	2,526	2,598	2,672	2,746
1290	2,819	2,892	2,964	3,038	3,114	3,190	3,266	3,344	3,422	3,502
1300	3,578	3,653	3,728	3,803	3,877	3,953	4,029	4,106	4,184	4,263
1310	4,343	4,427	4,513	4,603	4,694	4,788	4,886	4,982	5,076	5,164
1320	5,251	5,338	5,422	5,504	5,586	5,670	5,756	5,842	5,927	6,014
1330	6,098	6,196	6,292	6,392	6,492	6,593	6,693	6,794	6,898	7,004
1340	7,108	7,206	7,300	7,396	7,488	7,580	7,674	7,770	7,866	7,973
1350	8,083	8,186	8,298	8,416	8,536	8,658	8,784	8,914	9,044	9,174
1360	9,323	9,454	9,595	9,737	9,885	10,032	10,180	10,330	10,475	10,616
1370	10,762	10,904	11,045	11,186	11,325	11,457	11,593	11,731	11,869	12,007
1380	12,154	12,296	12,440	12,584	12,728	12,868	13,008	13,150	13,298	13,451
1390	13,608	13,778	13,954	14,127	14,306	14,488	14,670	14,852	15,034	15,216
1400	15,398	15,600	15,790	15,980	16,180	16,380	16,590	16,800	17,010	17,[illegible]
1410	17,420	17,640	17,860	18,080	18,300	18,530	18,750	18,980	19,210	19,440
1420	19,670	19,910	20,150	20,390	20,640	20,890	21,150	21,420	21,700	21,980
1430	22,260	22,540	22,830	23,120	23,420	23,710	24,010	24,310	24,610	24,910
1440	25,197									

CAPACITY - ACRE-FEET

El	0	1	2	3	4	5	6	7	8	9
1210							0	1	5	12
1220	23	39	64	100	148	209	285	378	488	614
1230	758	918	1,094	1,284	1,488	1,707	1,941	2,189	2,453	2,735
1240	3,038	3,366	3,722	4,107	4,521	4,967	5,445	5,955	6,497	7,072
1250	7,679	8,319	8,991	9,695	10,431	11,199	12,001	12,837	13,707	14,613
1260	15,556	16,539	17,565	18,638	19,760	20,934	22,160	23,440	24,776	26,168
1270	27,616	29,118	30,676	32,294	33,974	35,717	37,525	39,400	41,340	43,348
1280	45,424	47,566	49,777	52,057	54,407	56,828	59,319	61,881	64,516	67,225
1290	70,007	72,803	75,791	78,792	81,868	85,020	88,248	91,553	94,936	98,398
1300	101,938	105,554	109,244	113,010	116,850	120,765	124,756	128,824	132,969	137,193
1310	141,496	145,881	150,351	154,909	159,557	164,298	169,135	174,069	179,098	184,218
1320	189,426	194,720	200,100	205,563	211,108	216,736	222,449	228,248	234,132	240,102
1330	246,158	252,305	258,549	264,891	271,333	277,875	284,518	291,262	298,108	305,059
1340	312,115	319,272	326,525	333,873	341,315	348,849	356,476	364,198	372,016	379,936
1350	387,964	396,098	404,340	412,697	421,173	429,770	438,491	447,340	456,319	465,428
1360	474,676	484,064	493,588	503,254	513,065	523,023	533,129	543,384	553,786	564,332
1370	575,021	585,854	596,828	607,944	619,200	630,591	642,116	653,778	665,578	677,516
1380	689,596	701,821	714,189	726,701	739,357	752,155	765,093	778,172	791,396	804,770
1390	818,299	831,992	845,858	859,898	874,114	888,511	903,090	917,851	932,794	947,919
1400	963,226	978,725	994,420	1,010,305	1,026,385	1,042,665	1,059,150	1,075,845	1,092,750	1,109,865
1410	1,127,185	1,144,715	1,162,465	1,180,435	1,198,625	1,217,040	1,235,680	1,254,545	1,273,640	1,292,965
1420	1,312,520	1,332,310	1,352,340	1,372,610	1,393,125	1,413,890	1,434,910	1,456,195	1,477,755	1,499,595
1430	1,521,715	1,544,115	1,566,800	1,589,775	1,613,045	1,636,610	1,660,470	1,684,630	1,709,090	1,733,850
1440	1,758,904									

D.A. = 707 sq. mi., determined by subtracting area between Laguna Gage and Montell Dam Site from D. A. at Laguna Gage. (Delineated on Quads. Barksdale, Davenport Hill, Turkey Mountain, and York Hollow; scale 1:62,500).

TABLE 23

EDWARDS UNDERGROUND RESERVOIR
CONCAN RESERVOIR
R.M. 226.2 - Frio River
DRAINAGE AREA 391 SQ. MI.
AREA AND CAPACITY CURVES

AREA (ACRES)

Elev.	0	1	2	3	4	5	6	7	8	9
1240	0	1	2	4	6	8	10	15	18	19
1250	20	23	25	30	36	37	40	42	45	50
1260	57	60	70	80	90	100	110	125	140	150
1270	165	175	185	203	216	228	243	265	271	283
1280	302	312	328	345	358	374	392	408	426	444
1290	463	482	501	522	544	564	586	608	630	654
1300	675	705	732	762	790	821	852	883	914	945
1310	976	1,010	1,040	1,073	1,108	1,141	1,176	1,210	1,245	1,278
1320	1,315	1,355	1,400	1,441	1,486	1,530	1,580	1,626	1,678	1,727
1330	1,780	1,827	1,878	1,927	1,980	2,031	2,082	2,136	2,187	2,240
1340	2,290	2,350	2,400	2,452	2,508	2,558	2,614	2,672	2,726	2,781
1350	2,836	2,890	2,948	3,004	3,062	3,120	3,177	3,236	3,294	3,355
1360	3,414	3,474	3,540	3,603	3,671	3,736	3,798	3,860	3,928	3,993
1370	4,060	4,120	4,190	4,259	4,324	4,393	4,463	4,532	4,600	4,668
1380	4,740	4,803	4,866	4,930	4,994	5,060	5,125	5,190	5,258	5,325
1390	5,393	5,460	5,526	5,593	5,653	5,730	5,800	5,868	5,938	6,008
1400	6,083	6,150	6,223	6,300	6,380	6,461	6,543	6,625	6,710	6,797
1410	6,880	6,970	7,054	7,142	7,228	7,320	7,412	7,500	7,592	7,684
1420	7,747	7,825	7,900	7,975	8,050	8,125	8,205	8,285	8,365	8,445
1430	8,525	8,605	8,690	8,775	8,855	8,940	9,025	9,115	9,205	9,295
1440	9,384	9,475	9,570	9,665	9,755	9,845	9,935	10,030	10,125	10,215
1450	10,305	10,395	10,485	10,575	10,670	10,760	10,850	10,945	11,035	11,125
1460	11,218									

CAPACITY (ACRE-FEET)

Elev.	0	1	2	3	4	5	6	7	8	9
1240	0	1	3	6	11	18	27	40	57	76
1250	96	118	142	170	203	240	279	320	364	412
1260	466	525	590	665	750	845	950	1,068	1,201	1,346
1270	1,504	1,674	1,854	2,048	2,258	2,480	2,716	2,970	3,238	3,515
1280	3,808	4,115	4,435	4,772	5,124	5,490	5,873	6,273	6,690	7,125
1290	7,579	8,052	8,544	9,056	9,589	10,143	10,718	11,315	11,934	12,576
1300	13,241	13,931	14,650	15,397	16,173	16,979	17,816	18,684	19,583	20,513
1310	21,474	22,467	23,492	24,549	25,640	26,765	27,924	29,117	30,345	31,607
1320	32,904	34,239	35,617	37,038	38,502	40,010	41,565	43,168	44,820	46,523
1330	48,277	50,081	51,934	53,837	55,791	57,797	59,854	61,963	64,125	66,339
1340	68,604	70,924	73,299	75,725	78,205	80,738	83,324	85,967	88,666	91,420
1350	94,229	97,092	100,011	102,987	106,020	109,111	112,260	115,467	118,732	122,057
1360	125,442	128,886	132,393	135,965	139,602	143,306	147,073	150,902	154,796	158,757
1370	162,784	166,874	171,029	175,254	179,546	183,905	188,333	192,831	197,397	202,031
1380	206,735	211,507	216,342	221,240	226,202	231,229	236,322	241,480	246,704	251,996
1390	257,355	262,782	268,275	273,835	279,458	285,150	290,915	296,749	302,652	308,625
1400	314,671	320,788	326,975	333,237	339,577	345,998	352,500	359,084	365,752	372,506
1410	379,345	386,270	393,282	400,380	407,565	414,839	422,205	429,661	437,207	444,845
1420	452,561	460,347	468,209	476,147	484,159	492,247	500,412	508,657	516,982	525,387
1430	533,872	542,437	551,085	559,817	568,632	577,530	586,512	595,582	604,742	613,992
1440	623,332	632,762	642,284	651,902	661,612	671,412	681,302	691,284	701,362	711,532
1450	721,791	732,141	742,581	753,111	763,733	774,448	785,253	796,151	807,141	818,221
1460	829,393									

D.A. = 391 sq. mi., determined by subtracting D.A. between site at R.M. 225.0 and site at R.M. 226.2 from area determined by U.S.G.S. for site at R.M. 225.0. Reservoir area determined from A.M.S. Quadrangle "Magers Crossing, Texas," scale 1:24,000.

TABLE 24

EDWARDS UNDERGROUND RESERVOIR
SABINAL DAM SITE
Sabinal R. M. 42.3
AREA AND CAPACITY CURVES

Area - Acres

Elev. (ft):	0	1	2	3	4	5	6	7	8	9
1130	0	7	14	21	28	35	42	49	56	63
1140	70	78	86	94	102	110	119	128	137	146
1150	155	165	176	188	201	215	230	246	263	281
1160	300	319	338	357	376	395	414	433	452	471
1170	490	510	530	552	574	596	620	644	668	694
1180	720	748	778	810	844	878	914	950	986	1,022
1190	1,060	1,098	1,136	1,176	1,216	1,256	1,298	1,340	1,384	1,428
1200	1,473	1,520	1,568	1,618	1,668	1,720	1,774	1,830	1,886	1,942
1210	2,000	2,058	2,116	2,174	2,232	2,290	2,350	2,410	2,470	2,530
1220	2,590	2,650	2,710	2,770	2,832	2,894	2,956	3,018	3,082	3,146
1230	3,210	3,278	3,346	3,416	3,488	3,562	3,638	3,716	3,794	3,872
1240	3,950	4,028	4,106	4,184	4,262	4,340	4,419	4,499	4,579	4,659
1250	4,739	4,822	4,906	4,992	5,080	5,168	5,256	5,346	5,436	5,528
1260	5,620	5,712	5,804	5,898	5,992	6,086	6,182	6,278	6,374	6,472
1270	6,570	6,668	6,766	6,864	6,962	7,060	7,160	7,260	7,360	7,460
1280	7,560	7,660	7,760	7,860	7,962	8,064	8,166	8,268	8,372	8,476
1290	8,580	8,684	8,788	8,892	8,998	9,104	9,210	9,318	9,426	9,534
1300	9,644	9,740	9,840	9,940	10,040	10,140	10,240	10,340	10,440	10,540
1310	10,640	10,742	10,844	10,948	11,052	11,160	11,268	11,376	11,484	11,592
1320	11,700	11,808	11,916	12,024	12,132	12,240	12,348	12,456	12,564	12,672
1330	12,780	12,890	13,000	13,110	13,222	13,334	13,446	13,558	13,672	13,786
1340	13,900	14,014	14,130	14,246	14,362	14,480	14,598	14,716	14,834	14,954
1350	15,074									

Capacity - Acre-feet

Elev. (ft):	0	1	2	3	4	5	6	7	8	9
1130	0	3	14	31	56	87	126	171	224	283
1140	350	424	506	596	694	800	914	1,038	1,170	1,312
1150	1,462	1,622	1,792	1,974	2,169	2,377	2,599	2,837	3,091	3,363
1160	3,654	3,963	4,292	4,639	5,006	5,391	5,796	6,219	6,661	7,123
1170	7,604	8,104	8,624	9,165	9,728	10,313	10,921	11,553	12,209	12,890
1180	13,597	14,331	15,094	15,888	16,715	17,576	18,472	19,404	20,372	21,376
1190	22,417	23,496	24,613	25,769	26,965	28,201	29,478	30,797	32,159	33,565
1200	35,015	36,511	38,055	39,648	41,291	42,985	44,732	46,534	48,392	50,306
1210	52,277	54,306	56,393	58,538	60,741	63,002	65,322	67,702	70,142	72,642
1220	75,202	77,822	80,502	83,242	86,043	88,906	91,831	94,818	97,868	100,982
1230	104,160	107,404	110,716	114,097	117,549	121,074	124,674	128,351	132,106	135,939
1240	139,850	143,839	147,906	152,051	156,274	160,575	164,954	169,413	173,952	178,571
1250	183,270	188,050	192,914	197,863	202,899	208,023	213,235	218,536	223,927	229,409
1260	234,983	240,649	246,407	252,258	258,203	264,242	270,376	276,606	282,932	289,355
1270	295,876	302,495	309,212	316,027	322,940	329,951	337,061	344,271	351,581	358,991
1280	366,501	374,111	381,821	389,631	397,542	405,555	413,670	421,887	430,207	438,631
1290	447,159	455,791	464,527	473,367	482,312	491,363	500,520	509,784	519,156	528,636
1300	538,225	547,917	557,707	567,597	577,587	587,677	597,867	608,157	618,547	629,037
1310	639,627	650,318	661,111	672,007	683,007	694,113	705,327	716,649	728,079	739,617
1320	751,263	763,017	774,879	786,849	798,927	811,113	823,407	835,809	848,319	860,937
1330	873,663	886,498	899,443	912,498	925,664	938,942	952,332	965,834	979,449	993,178
1340	1,007,021	1,020,978	1,035,050	1,049,238	1,063,542	1,077,963	1,092,502	1,107,159	1,121,934	1,136,828
1350	1,151,842									

Drainage Area = 210 sq. mi., determined by adding the drainage area between original site and site at R.M. 42.3 to the drainage area at the original site as determined by the USSC-T. Reservoir areas determined from A.M.S. map "SAN ANTONIO, TEXAS", scale 1:250,000.

TABLE 25

EDWARDS UNDERGROUND RESERVOIR
DAM #7 RESERVOIR
R.M. 351.3 Guadalupe River
AREA AND CAPACITY CURVES

Area - Acres

Elev. (ft)	0	1	2	3	4	5	6	7	8	9
1050			0	1	3	4	6	8	10	12
1060	15	18	21	23	26	29	32	36	40	44
1070	49	53	57	61	66	71	76	82	88	94
1080	101	108	117	126	135	144	153	163	173	183
1090	193	204	214	224	235	246	257	268	279	291
1100	303	315	327	340	353	367	381	395	409	423
1110	438	454	470	487	504	522	542	563	585	608
1120	631	655	680	706	733	761	789	818	846	875
1130	904	933	964	995	1,026	1,057	1,088	1,120	1,151	1,183
1140	1,215	1,252	1,291	1,330	1,370	1,410	1,450	1,490	1,531	1,572
1150	1,614	1,657	1,700	1,743	1,787	1,833	1,880	1,928	1,976	2,023
1160	2,070	2,124	2,180	2,240	2,302	2,367	2,436	2,507	2,580	2,656
1170	2,732	2,808	2,885	2,963	3,043	3,124	3,205	3,286	3,368	3,451
1180	3,534	3,632	3,730	3,828	3,925	4,020	4,120	4,220	4,326	4,430
1190	4,538	4,645	4,750	4,855	4,960	5,070	5,175	5,285	5,400	5,520
1200	5,638	5,770	5,910	6,050	6,195	6,350	6,500	6,655	6,815	6,975
1210	7,145	7,310	7,475	7,645	7,815	7,985	8,155	8,325	8,500	8,670
1220	8,844	9,015	9,190	9,360	9,535	9,710	9,890	10,070	10,245	10,425
1230	10,605	10,785	10,965	11,145	11,325	11,510	11,695	11,880	12,060	12,245
1240	12,431	12,615	12,800	12,985	13,170	13,355	13,545	13,735	13,925	14,115
1250	14,310	14,505	14,700	14,895	15,090	15,290	15,495	15,705	15,915	16,130
1260	16,346	16,560	16,780	17,000	17,216	17,460	17,700	17,930	18,170	18,410
1270	18,660	18,930	19,210	19,490	19,790	20,100	20,420	20,760	21,130	21,550
1280	22,030									

Capacity - Acre-feet

Elev. (ft)	0	1	2	3	4	5	6	7	8	9
1050			0	0	2	6	11	18	27	38
1060	52	68	88	110	134	162	192	226	264	306
1070	352	403	458	517	581	649	723	802	887	978
1080	1,076	1,180	1,292	1,414	1,544	1,684	1,832	1,990	2,158	2,336
1090	2,524	2,722	2,931	3,150	3,380	3,620	3,872	4,134	4,408	4,693
1100	4,990	5,299	5,620	5,954	6,300	6,660	7,034	7,422	7,824	8,240
1110	8,670	9,116	9,578	10,056	10,552	11,065	11,597	12,149	12,723	13,319
1120	13,939	14,582	15,250	15,943	16,663	17,410	18,185	18,989	19,821	20,681
1130	21,571	22,489	23,437	24,417	25,427	26,469	27,541	28,645	29,781	30,948
1140	32,147	33,381	34,653	35,963	37,313	38,703	40,133	41,603	43,113	44,665
1150	46,258	47,894	49,572	51,294	53,059	54,869	56,725	58,629	60,581	62,581
1160	64,627	66,724	68,876	71,086	73,357	75,691	78,093	80,565	83,109	85,727
1170	88,421	91,191	94,037	96,961	99,964	103,048	106,212	109,458	112,785	116,195
1180	119,687	123,270	126,951	130,730	134,606	138,578	142,648	146,818	151,091	155,469
1190	159,953	164,545	169,243	174,045	178,953	183,968	189,090	194,320	199,662	205,122
1200	210,701	216,405	222,245	228,225	234,347	240,619	247,044	253,622	260,357	267,252
1210	274,312	281,540	288,932	296,492	304,222	312,122	320,192	328,432	336,844	345,429
1220	354,186	363,116	372,218	381,493	390,941	400,563	410,363	420,343	430,501	440,836
1230	451,351	462,046	472,921	483,976	495,211	506,629	518,231	530,017	541,987	554,139
1240	566,477	579,000	591,708	604,600	617,678	630,940	644,390	658,030	671,860	685,880
1250	700,092	714,500	729,102	743,900	758,892	774,082	789,474	805,074	820,884	836,906
1260	853,144	869,597	886,267	903,157	920,265	937,603	955,183	972,998	991,048	1,009,338
1270	1,027,873	1,046,668	1,065,738	1,085,088	1,104,728	1,124,673	1,144,933	1,165,523	1,186,468	1,207,808
1280	1,229,598									

Drainage Area = 1,124 sq. mi., as determined by USSC-T and Consulting Engineer for Guadalupe-Blanco River Authority. Reservoir area determined from A.M.S. Quadrangle, "Boerne, Texas", scale 1:62,500.

TABLE 26

EDWARDS UNDERGROUND RESERVOIR
CLOPTIN CROSSING RESERVOIR
BLANCO RIVER - Mile 32.5
AREA AND CAPACITY CURVES

Elev.	0	1	2	3	4	5	6	7	8	9
					AREA (ACRES)					
820				0	10	12	15	17	20	22
830	25	27	28	29	30	32	34	35	36	38
840	40	42	47	50	56	60	66	70	76	82
850	84	86	90	99	104	112	121	124	131	134
860	145	158	168	180	195	209	224	240	250	258
870	263	275	287	299	312	326	341	356	372	391
880	410	431	454	477	501	527	552	578	605	632
890	659	687	715	744	773	803	833	864	897	932
900	970	1,013	1,057	1,102	1,147	1,194	1,242	1,290	1,340	1,391
910	1,440	1,491	1,542	1,592	1,644	1,697	1,752	1,807	1,862	1,915
920	1,967	2,018	2,071	2,122	2,174	2,225	2,275	2,325	2,376	2,428
930	2,480	2,554	2,625	2,693	2,762	2,826	2,890	2,954	3,018	3,082
940	3,146	3,211	3,277	3,341	3,403	3,465	3,524	3,583	3,642	3,704
950	3,770	3,838	3,909	3,980	4,051	4,122	4,193	4,264	4,336	4,407
960	4,478	4,546	4,614	4,684	4,755	4,827	4,900	4,972	5,045	5,119
970	5,196	5,272	5,350	5,430	5,510	5,589	5,672	5,757	5,839	5,924
980	6,013	6,110	6,203	6,297	6,392	6,486	6,581	6,675	6,770	6,865
990	6,960	7,057	7,152	7,248	7,343	7,439	7,536	7,632	7,728	7,824
1000	7,920	8,016	8,112	8,208	8,304	8,400	8,496	8,592	8,688	8,784
1010	8,880	8,976	9,072	9,168	9,264	9,360	9,456	9,552	9,648	9,744
1020	9,840									

Elev.	0	1	2	3	4	5	6	7	8	9
					CAPACITY (ACRE-FEET)					
820				0	2	17	36	56	78	101
830	125	151	179	207	236	267	300	334	370	407
840	446	487	532	580	633	691	754	821	894	973
850	1,056	1,141	1,229	1,323	1,425	1,533	1,649	1,771	1,899	2,032
860	2,171	2,323	2,483	2,665	2,843	3,045	3,263	3,494	3,739	3,996
870	4,255	4,525	4,806	5,099	5,404	5,723	6,056	6,405	6,769	7,151
880	7,551	7,972	8,414	8,879	9,368	9,883	10,422	10,987	11,578	12,197
890	12,843	13,516	14,217	14,946	15,704	16,493	17,310	18,159	19,039	19,954
900	20,905	21,896	22,931	24,011	25,136	26,306	27,524	28,790	30,105	31,471
910	32,886	34,352	35,868	37,435	39,053	40,723	42,448	44,228	46,062	47,951
920	49,892	51,884	53,929	56,025	58,173	60,372	62,623	64,922	67,273	69,675
930	72,129	74,646	77,235	79,894	82,622	85,416	88,274	91,196	94,182	97,232
940	100,346	103,525	106,768	110,077	113,450	116,883	120,378	123,932	127,544	131,217
950	134,954	138,758	142,631	146,576	150,592	154,678	158,835	163,064	167,364	171,736
960	176,178	180,690	185,270	189,919	194,639	199,430	204,293	209,229	214,237	219,320
970	224,477	229,711	235,022	240,412	245,882	251,431	257,062	262,776	268,575	274,456
980	280,424	286,486	292,643	298,892	305,237	311,676	318,209	324,837	331,560	338,377
990	345,290	352,299	359,404	366,604	373,900	381,291	388,778	396,362	404,042	411,818
1,000	419,690	427,658	435,722	443,682	452,138	460,490	468,938	477,482	486,122	494,858
1,010	503,690	512,618	521,642	530,762	539,978	549,290	558,698	568,202	577,802	587,498
1,020	597,290									

D.A. = 307 sq. mi., determined from A.M.S. maps "SAN ANTONIO, TEXAS" and "LLANO, TEXAS", scale 1:250,000.
Reservoir area determined from Corps of Engineers, FWD, field survey topography map.

". . . The runoff reductions were computed by reasonable methods from available data. However, as will be apparent from later exposition, available data are inadequate to permit an accurate estimate of either past or future effects of land use, land treatment, and minor reservoirs upon runoff. Consequently, the computed depletions should be viewed as a generous allowance for depletions which available data indicates might happen or might have happened rather than as a precise determination of what will happen, or has happened. Future evaluation procedures may indicate smaller depletions."

Annex (C-8) indicates considerable coordination with the Soil Conservation Service, the Agricultural Stabilization and Conservation Service, and the Texas Forest Service. The 1954 census of agriculture published by the Department of Agriculture was also used extensively as were data collected at the Agricultural Experiment Station at Riesel and Spur, Texas, and at Guthrie, Oklahoma.

49. Although Annex (C-8) does not estimate future depletions for the area in the upper Nueces River Basin, the procedures it presents allow the estimation of such future depletions for the drainage area above Montell, Concan, and Sabinal Reservoirs. Our interpretation of these procedures and their application results in the finding that only very small reductions in future runoff will take place, and that for all practical purposes, existing conditions data, historical data and future (2025) conditions data may be regarded as the same for these three reservoirs. Monthly and annual values of estimated 2025 inflow for Montell, Concan, Sabinal, Dam No. 7, and Cloptin Crossing Reservoirs are given in tables 27 through 31.

50. SEDIMENT CONTRIBUTING AREA.- All of the reservoir sites studied for this report are located in the Edwards Plateau area above the Balcones Fault zone. The following description of the area is quoted from Bulletin 5912: 1/

"The Edwards Plateau is a high limestone plain in southwest Texas covering an area of about 22,000,000 acres. On the northwest it merges with slightly higher areas of the High Plains, and on the northeast joins the lower lying Rolling Plains in a series of rock escarpments. On the east, it merges with the Grand Prairie with little change in elevation. On the southeast and south the plateau terminates in steep rock slopes of the Balcones Escarpment, descending to the level of the Blackland Prairies and Rio Grande Plain. Annual

1/ "Inventory and use of Sedimentation Data in Texas," prepared by the Soil Conservation Service, USDA, for the Texas Board of Water Engineers (now the Texas Water Commission) January 1959.

"rainfall decreases from 32 inches in the eastern section to 16 inches in the western section. Elevation ranges from 2,000 to 4,000 feet above mean sea level. Locally there are some nearly level divides and smooth valleys, but generally the area is made up of hilly, broken, and rough lands. Limestone sinks are a feature of the nearly level divides, and these areas are noncontributing so far as sediment is concerned. The Edwards Plateau is dominantly range land and is used almost exclusively for the raising of livestock. Some cultivation is found on the nearly level divides where deeper soils have developed in the eastern one-third of the area, but less than 5 percent of the total area is in cultivation."

Over almost the entire area the surface consists of thin limestone based soil. In places it is open prairie but most of the surface is covered with a medium to thick growth of cedar, small oak, and mesquite with a varying growth of prickly pear and a consistent range of grass and weeds.

51. SEDIMENT PRODUCTION RATES.- Annual sedimentation production rates are generally considered to be low in the Edwards Plateau area. Many of the streams are springfed and clear flowing except in times of flood when flood plain scour and streambank erosion occurs. Estimates based on Bulletin 5912 indicate that the average annual rate of sediment production in the Edwards Plateau area varies from 0.065 to 0.038 acre-foot per square mile for drainage areas from 100 to 10,000 square miles, respectively. Due to the paucity of general sedimentation data for this area and the lack of suspended samples during extremely high flash floods, the rates recommended in Bulletin 5912 have been increased. The 100-year sediment volumes and the estimated distribution of the sediment in the reservoirs studied are shown in table 32.

52. STORAGE REQUIREMENTS.

a. General.

(1) To determine the most effective and efficient means of recharge to the underground reservoir several plans of operation were tested. Of the several investigated plans the immediate recharge of stored flood water was determined to be the most effective in areas of high natural recharge to the Edwards Reservoir. Under this plan, releases from the reservoirs were limited to the estimated recharge rates for the streams below the proposed dam sites. The estimated recharge rates for the Nueces, Frio, and Sabinal Rivers are 1,000 second-feet, 750 second-feet, and 500 second-feet, respectively. It is noted that the recommended releases are considerably less than the minimum downstream channel capacities shown in table 16. Under this plan, the surface reservoirs would be empty approximately 95 percent of the time;

TABLE 27

ESTIMATED MONTHLY AND ANNUAL FLOWS IN 1000 ACRE-FEET AT MONTELL DAM SITE - 2025 CONDITIONS

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
1924	8.4	6.3	7.2	7.8	5.1	4.1	2.2	0.9	0.7	0.8	1.0	1.4	45.9
1925	1.8	2.2	2.3	1.8	36.4	13.1	4.5	2.1	2.3	14.1	8.9	5.2	94.7
1926	3.9	3.4	3.8	4.1	6.1	2.6	30.2	7.3	2.7	1.7	2.1	3.2	71.1
1927	3.5	8.4	6.8	7.8	3.4	3.9	3.8	1.6	0.8	13.8	3.0	2.5	59.3
1928	2.5	2.5	2.3	2.1	3.7	9.5	1.5	3.3	1.0	3.1	2.4	2.1	36.0
1929	1.8	1.6	1.7	1.6	16.5	6.3	6.3	2.0	1.8	1.1	1.0	2.0	43.7
1930	2.1	2.0	1.9	1.5	2.1	48.8	4.7	1.4	1.1	33.7	6.8	5.8	111.9
1931	5.9	11.2	9.1	9.9	24.5	8.8	14.7	9.7	4.8	3.6	3.5	3.8	109.5
1932	3.7	3.2	4.7	4.5	5.6	2.9	45.3	13.9	111.0	21.0	11.6	8.4	235.8
1933	7.3	5.8	5.5	4.3	3.6	2.9	1.6	1.0	1.1	1.3	1.3	1.7	37.4
1934	1.8	1.8	2.1	2.6	3.2	1.5	0.9	0.6	0.5	0.5	0.5	0.6	16.6
1935	0.8	1.0	1.2	1.3	49.4	297.7	22.3	12.8	21.1	9.3	6.6	6.7	430.2
1936	5.7	4.6	5.0	4.3	4.6	7.1	8.5	3.7	124.2	22.6	15.3	10.1	215.7
1937	7.2	5.2	6.5	5.3	3.7	4.5	2.8	1.9	1.3	1.6	2.2	15.2	57.4
1938	12.6	7.1	5.6	6.9	7.2	3.8	8.8	5.0	2.8	2.7	2.3	2.4	67.2
1939	3.1	2.6	2.7	2.3	2.0	1.5	89.9	8.1	4.2	21.4	4.3	4.5	146.6
1940	3.9	4.1	3.9	4.9	9.6	5.7	3.9	3.0	2.4	1.9	2.2	3.3	48.8
1941	3.2	3.3	4.2	6.9	13.7	7.2	8.0	4.6	4.5	13.6	6.3	4.8	80.3
1942	3.9	3.0	3.0	3.1	5.4	3.0	2.3	3.3	22.8	22.7	9.6	6.6	88.7
1943	4.5	3.5	3.7	4.3	3.9	6.5	3.0	1.9	1.7	2.0	2.2	2.9	40.1
1944	4.5	4.8	7.0	5.9	4.5	3.7	2.1	1.8	11.7	5.6	3.5	3.8	58.9
1945	7.8	5.2	5.0	5.0	3.1	1.8	1.3	1.1	0.8	4.7	3.3	3.0	42.1
1946	3.1	2.9	2.6	2.3	4.0	7.4	3.2	1.3	1.5	22.3	6.5	4.5	61.6
1947	7.5	7.3	6.5	4.9	7.0	8.5	7.8	3.6	2.2	1.8	1.7	2.1	60.9
1948	2.3	2.5	2.6	2.3	2.2	2.7	14.3	1.9	1.2	1.4	1.5	1.6	36.5
1949	1.9	59.6	18.3	9.7	11.0	7.0	4.5	26.0	10.7	8.3	6.8	5.8	169.6
1950	5.4	4.7	4.3	3.4	4.2	5.0	3.8	2.8	2.6	2.7	2.3	2.6	43.8
1951	2.3	2.0	2.5	2.7	2.1	1.7	1.2	0.9	0.6	0.5	0.6	0.8	17.9
1952	1.0	1.1	1.4	4.4	6.2	2.4	1.2	0.8	0.6	0.4	0.4	0.5	20.4
1953	0.8	1.1	1.6	1.7	1.0	0.7	0.5	0.4	6.4	2.8	2.1	1.7	20.8
1954	1.5	1.3	1.2	2.0	10.1	20.5	9.5	2.9	1.5	1.6	1.3	1.3	54.7
1955	1.5	1.5	1.8	1.4	1.2	1.0	3.4	1.9	146.8	9.9	5.8	3.6	179.8
1956	2.8	2.3	2.2	1.7	1.5	1.0	0.8	0.5	0.5	0.6	0.3	0.3	14.5
1957	0.3	0.3	0.4	4.4	9.8	15.7	3.7	1.8	1.8	6.5	6.6	6.5	57.8
1958	6.7	9.6	16.2	8.2	8.8	60.1	17.9	8.5	50.2	28.5	23.2	14.5	252.4
1959	9.6	7.6	7.1	5.8	7.4	23.9	22.0	11.1	11.2	26.2	9.2	7.9	149.0
1960	7.8	8.0	7.6	6.0	5.2	3.4	5.7	16.5	8.2	13.3	15.2	11.7	108.6
1961	10.8	11.8	9.8	7.3	5.6	10.7	18.8	12.8	7.8	11.3	9.6	7.4	123.7
1962	6.0	4.7	4.6	4.2	3.3	5.2	2.4	1.5	1.3	--	--	--	(33.2)
Total	171.2	221.1	185.9	170.6	307.9	623.8	389.3	186.2	580.4	340.9	193.0	172.8	3,543.1
Average	4.4	5.7	4.8	4.4	7.9	16.0	10.0	4.8	14.9	9.0	5.0	4.5	91.4

TABLE 28

ESTIMATED MONTHLY AND ANNUAL FLOWS IN 1000 ACRE-FEET AT CONCAN DAM SITE - 2025 CONDITIONS

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
1924	7.0	5.3	7.4	8.3	9.4	6.0	2.7	1.3	1.5	1.5	1.6	1.7	53.7
1925	1.7	1.9	2.0	1.8	4.7	2.6	1.2	1.1	1.6	4.3	3.1	2.8	28.8
1926	2.7	2.3	2.7	3.2	2.7	2.0	26.4	5.2	3.1	3.2	2.3	3.1	58.9
1927	2.9	8.8	9.2	6.6	4.7	3.7	3.2	2.1	1.5	2.5	1.8	1.9	48.9
1928	1.9	1.9	2.0	1.8	2.2	1.9	0.9	2.5	1.4	2.1	1.4	1.5	21.5
1929	1.5	1.1	1.2	1.0	4.0	2.7	3.9	1.1	1.3	1.2	1.0	2.1	22.1
1930	2.2	2.1	1.9	1.6	2.2	32.7	4.9	1.5	1.2	30.2	5.7	5.0	91.2
1931	6.5	10.6	9.6	12.5	25.1	8.9	25.8	8.7	4.5	7.6	4.1	4.4	128.3
1932	4.6	5.1	7.5	5.6	7.5	4.4	168.0	12.1	65.9	21.5	10.2	7.9	320.3
1933	8.0	5.8	5.5	4.4	4.2	3.4	2.3	2.1	2.2	1.9	2.0	2.1	43.9
1934	2.5	2.1	2.3	3.7	3.9	1.4	1.0	0.9	0.6	0.6	0.7	1.2	20.9
1935	1.5	1.5	1.5	1.8	61.8	141.8	33.6	14.3	28.2	10.2	6.8	7.6	310.6
1936	6.7	5.4	5.2	5.2	5.7	5.5	5.3	3.4	76.6	23.5	15.5	9.8	167.8
1937	7.6	5.9	7.0	5.3	4.0	5.0	3.0	2.0	1.7	2.1	2.5	6.0	52.1
1938	8.0	6.2	5.9	5.5	6.3	4.1	3.1	2.4	1.8	1.7	1.4	1.8	48.2
1939	2.5	2.3	2.3	1.8	1.4	1.1	22.2	5.4	2.4	3.8	2.9	2.7	50.8
1940	2.5	2.8	2.7	4.3	6.7	5.3	6.4	2.8	2.1	1.8	2.4	3.9	43.7
1941	3.5	4.1	5.2	14.5	20.0	8.6	5.8	9.2	11.2	13.0	9.2	6.7	111.0
1942	5.0	4.0	3.8	5.5	7.1	3.8	3.3	3.3	9.6	8.7	6.3	4.8	65.2
1943	4.0	3.0	3.2	3.4	2.9	3.3	2.4	1.3	1.5	1.8	1.7	2.4	30.9
1944	3.0	2.9	5.4	4.5	6.2	7.1	3.6	4.4	5.4	4.5	3.2	3.9	54.1
1945	8.1	6.4	6.1	6.8	5.7	3.1	2.0	1.2	0.9	3.6	2.7	3.1	49.7
1946	2.7	2.6	2.4	2.2	3.0	2.1	1.7	0.8	1.6	16.6	6.1	4.1	45.9
1947	6.3	5.4	5.0	5.0	5.9	9.4	6.4	3.3	2.2	1.9	2.1	2.6	55.5
1948	2.4	2.4	2.4	1.9	1.7	1.8	1.7	0.8	0.8	1.1	1.2	1.4	19.6
1949	1.7	26.8	10.6	7.9	6.8	4.9	3.1	3.0	3.2	3.6	3.1	3.2	77.9
1950	3.3	3.1	3.3	2.8	2.9	2.5	1.7	1.4	1.3	1.4	1.1	1.5	26.3
1951	1.2	1.4	2.2	2.2	7.3	2.5	0.8	0.4	2.2	7.0	0.9	1.2	29.3
1952	1.2	1.1	1.4	1.8	2.5	1.6	0.7	0.2	0.1	0.1	0.4	1.2	12.3
1953	1.7	1.3	1.2	0.9	0.4	0.1	0.1	0.2	0.8	1.2	1.2	1.2	10.3
1954	1.0	0.8	0.7	0.6	10.3	3.4	2.6	1.1	0.5	0.3	0.4	0.5	22.2
1955	0.8	0.9	1.0	0.6	2.5	0.8	2.2	0.8	1.9	1.1	0.9	0.9	14.4
1956	0.8	0.7	0.7	0.5	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	3.2
1957	0.1	0.4	1.6	10.2	5.4	8.1	1.9	0.7	1.3	6.5	5.9	4.9	47.0
1958	5.5	8.3	12.5	6.4	5.5	30.2	12.4	8.2	44.0	23.9	22.5	11.7	191.1
1959	7.9	5.5	5.0	4.9	5.2	22.2	14.1	7.4	5.6	15.0	7.7	6.3	106.8
1960	6.2	5.8	5.7	4.9	4.2	2.8	5.4	12.6	7.0	7.6	10.1	11.7	84.0
1961	10.1	12.6	10.7	7.4	5.4	12.6	10.7	8.7	5.6	6.2	5.3	4.7	100.0
1962	4.2	3.3	3.1	3.3	3.1	5.0	1.7	0.8	0.8	--	--	--	(25.3)
Total	151.0	173.9	169.1	172.6	270.8	368.5	398.3	138.7	305.1	244.8	157.4	143.5	2,693.7
Average	3.9	4.5	4.3	4.4	6.9	9.5	10.2	3.6	7.8	6.4	4.2	3.8	69.5

TABLE 29

ESTIMATED MONTHLY AND ANNUAL FLOWS IN 1000 ACRE-FEET AT SABINAL DAM SITE - 2025 CONDITIONS

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
1934	0.8	0.7	0.7	1.1	1.2	0.4	0.3	0.3	0.2	0.2	0.2	0.4	6.5
1935	1.1	1.2	1.1	1.4	46.8	107.3	25.4	10.8	21.3	7.7	5.1	5.8	235.0
1936	4.7	3.8	3.7	3.7	4.0	3.8	3.8	2.3	54.3	16.6	11.0	7.0	118.7
1937	3.6	2.8	3.3	2.5	1.9	2.4	1.4	1.0	0.8	1.0	1.2	2.8	24.7
1938	3.6	2.8	2.7	2.5	2.9	1.9	1.4	1.1	0.8	0.8	0.7	0.8	22.0
1939	1.2	1.1	1.1	0.9	0.7	0.5	10.5	2.6	1.1	1.8	1.4	1.3	24.2
1940	1.1	1.2	1.2	1.8	2.8	2.3	2.7	1.2	0.9	0.7	1.0	1.7	18.6
1941	2.3	2.6	3.4	9.5	13.0	5.6	3.8	5.9	7.3	8.4	6.0	4.3	72.1
1942	2.7	2.3	2.1	3.0	3.9	2.2	1.8	1.8	5.2	5.1	2.5	1.8	34.4
1943	1.3	0.9	1.0	1.8	0.9	2.2	1.7	0.4	0.2	0.2	0.2	0.3	11.1
1944	0.8	1.3	4.4	2.8	2.8	3.8	1.7	2.5	1.3	1.0	0.8	1.6	24.8
1945	6.1	3.6	5.2	6.3	3.4	1.7	0.8	0.3	0.6	1.0	0.7	1.0	30.7
1946	0.7	0.7	0.6	1.0	1.2	0.7	0.3	0.0	1.9	4.9	2.8	1.7	16.5
1947	2.2	2.0	1.8	1.7	1.9	4.0	1.6	0.7	0.3	0.1	0.1	0.2	16.6
1948	0.3	0.4	0.4	0.2	0.0	0.3	0.1	0.0	0.3	0.3	0.0	0.1	2.4
1949	0.3	5.4	3.8	5.5	4.9	2.9	1.5	1.4	1.3	1.8	1.3	1.1	31.2
1950	1.3	1.5	1.6	1.2	1.2	1.8	0.9	0.2	0.1	0.0	0.0	0.1	9.9
1951	0.1	0.1	0.2	0.3	5.0	1.3	0.2	0.0	0.0	0.0	0.0	0.0	7.2
1952	0.0	0.0	0.0	0.3	1.5	1.2	0.2	0.0	0.0	0.0	0.0	0.0	3.2
1953	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.3	1.2	0.6	0.5	3.0
1954	0.2	0.1	0.0	0.0	5.7	1.0	0.6	0.1	0.0	0.0	0.0	0.0	7.7
1955	0.0	0.0	0.0	0.0	0.3	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.5
1956	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	1.1
1957	0.0	0.0	1.4	6.1	2.6	5.6	0.5	0.0	5.2	4.0	4.1	3.7	33.2
1958	5.9	8.8	15.7	6.0	5.7	42.6	9.5	3.7	15.3	18.4	19.1	8.0	158.7
1959	4.5	2.8	2.2	2.6	2.0	13.1	9.2	3.8	2.2	7.6	4.9	4.0	58.9
1960	4.1	3.6	3.0	2.5	2.7	1.0	5.9	11.8	3.7	5.4	5.6	6.4	55.7
1961	5.8	9.9	7.5	4.0	2.7	9.7	5.4	3.6	1.6	2.2	1.2	1.2	54.8
1962	1.0	0.7	0.5	0.7	0.5	0.4	0.0	0.0	0.0	--	--	--	(3.8)
Total	55.8	60.5	68.7	69.4	122.2	219.7	92.5	55.5	126.2	90.4	70.5	55.8	1087.2
Average	1.9	2.1	2.4	2.4	4.2	7.6	3.2	1.9	4.3	3.2	2.5	2.0	37.7

TABLE 30

ESTIMATED MONTHLY AND ANNUAL FLOWS IN 1000 ACRE-FEET AT DAM NO. 7 SITE - 2025 CONDITIONS

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
1924	21.8	22.0	33.5	28.6	41.7	24.4	8.7	4.2	5.9	4.1	4.4	5.0	204.3
1925	4.6	3.7	3.5	3.0	3.7	1.6	1.1	1.5	2.2	15.2	9.4	4.2	53.7
1926	4.6	3.4	7.6	38.4	20.3	8.2	11.8	4.5	2.7	3.5	5.5	6.8	117.3
1927	4.8	14.0	21.6	18.0	10.0	20.3	5.4	2.4	2.5	5.5	2.9	3.5	110.9
1928	3.7	4.4	7.2	3.0	3.6	6.0	1.4	1.0	1.5	2.0	1.8	2.2	37.8
1929	2.3	2.2	3.0	4.2	61.1	12.0	22.9	2.7	2.1	1.7	2.4	3.6	120.2
1930	3.0	3.0	2.9	2.3	21.3	20.1	3.6	1.1	0.9	45.0	8.6	7.8	119.6
1931	15.6	26.2	24.6	35.5	48.0	13.9	13.4	6.7	3.3	3.0	4.2	5.3	199.7
1932	8.3	8.0	18.2	12.0	13.5	5.3	197.6	10.8	32.2	13.7	9.0	10.8	339.4
1933	18.1	10.9	11.9	9.2	12.0	6.0	3.4	2.6	2.7	2.5	2.7	3.2	85.2
1934	5.9	4.1	6.3	11.3	5.0	1.8	4.0	1.1	1.2	1.0	1.5	2.1	45.3
1935	2.1	4.1	2.7	2.9	49.8	206.5	22.7	8.7	50.8	18.0	12.3	18.7	399.3
1936	13.9	10.0	10.6	7.7	37.9	48.8	64.7	11.5	209.4	60.4	34.2	28.3	537.4
1937	23.7	17.7	20.9	14.5	9.5	31.4	7.5	3.7	3.9	4.8	4.5	11.8	153.9
1938	25.3	14.7	11.9	20.5	19.2	8.3	4.7	2.7	3.0	2.5	2.7	2.9	118.5
1939	5.2	3.4	3.4	3.2	3.8	1.1	7.7	2.8	1.1	11.7	3.2	3.4	50.0
1940	3.5	4.7	7.7	18.6	13.7	16.5	9.0	4.3	2.5	3.6	10.8	33.4	128.3
1941	12.2	60.8	54.8	77.0	96.2	29.8	20.0	9.5	13.8	21.8	11.2	9.7	416.8
1942	7.8	6.6	6.4	32.6	43.3	11.9	7.4	5.4	19.0	25.0	14.2	12.0	191.6
1943	10.6	7.6	8.2	9.2	6.4	14.6	7.2	2.4	4.4	3.7	3.2	4.6	82.1
1944	7.8	12.0	26.4	15.0	87.8	32.6	10.0	15.0	16.0	13.6	9.0	25.4	270.6
1945	38.8	36.4	50.6	37.2	16.0	9.6	8.0	5.0	12.6	17.4	8.0	20.2	259.8
1946	12.4	14.6	16.2	12.4	25.6	11.8	4.6	2.8	11.8	20.4	38.4	23.4	194.4
1947	50.4	28.6	22.6	21.0	18.0	22.4	8.8	4.8	3.0	2.9	3.8	4.8	191.1
1948	4.4	4.6	4.6	4.4	3.8	8.2	4.6	1.8	1.9	3.0	2.2	2.6	46.1
1949	3.6	17.6	11.2	20.2	15.4	8.6	4.0	6.6	5.6	4.0	3.6	4.2	104.6
1950	4.4	5.0	4.2	5.6	9.5	5.2	4.2	1.6	2.1	1.7	1.7	2.4	47.6
1951	2.4	2.4	3.8	3.2	9.4	5.8	0.6	0.1	0.1	0.4	1.0	1.8	31.0
1952	1.7	1.5	2.1	5.6	17.4	7.8	1.8	0.4	107.2	4.0	4.0	9.8	163.3
1953	8.6	5.0	5.7	4.2	2.4	0.5	0.8	0.8	12.6	4.4	3.1	3.2	51.3
1954	3.0	2.2	1.9	1.2	6.0	0.6	0.0	0.0	0.0	1.4	1.0	1.0	18.3
1955	2.0	3.6	1.5	0.8	7.2	1.9	7.2	1.9	0.8	0.7	0.7	1.1	29.4
1956	1.2	1.4	0.8	0.4	1.0	0.0	0.0	0.3	0.4	0.4	0.6	0.3	6.8
1957	0.6	1.6	14.0	76.4	39.5	31.8	3.5	1.4	14.2	74.2	38.4	25.8	321.4
1958	40.4	53.0	57.4	26.8	90.6	35.0	14.2	6.2	34.8	20.0	25.2	16.2	419.8
1959	12.0	10.8	9.4	15.6	11.4	31.4	12.9	6.3	4.2	73.0	10.4	11.2	208.6
1960	14.0	16.8	14.6	12.7	8.0	4.2	7.2	41.2	9.4	68.6	29.2	41.8	267.7
1961	36.0	69.5	37.4	20.9	13.1	23.5	13.7	8.0	6.0	5.4	6.2	5.9	245.6
1962	5.4	4.9	4.9	6.0	4.9	7.6	1.8	0.6	2.4	--	--	--	(38.5)
Total	446.1	523.0	556.2	641.3	907.0	737.0	532.1	194.4	610.3	564.2	335.2	380.4	6,427.2
Average	11.4	13.4	14.3	16.4	23.3	18.9	13.6	5.0	15.6	14.5	8.6	9.8	164.8

TABLE 31

ESTIMATED MONTHLY AND ANNUAL FLOWS IN 1000 ACRE-FEET AT CLOPTIN CROSSING DAM SITE - 2025 CONDITIONS

YEAR	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	TOTAL
1928	--	--	--	--	--	--	0.6	0.7	0.3	0.4	0.5	0.8	(3.3)
1929	1.2	0.6	0.7	4.9	77.0	15.8	15.4	2.8	1.7	1.0	1.4	1.3	123.8
1930	1.0	0.9	0.9	0.8	14.0	5.3	2.3	0.9	0.7	4.0	1.9	3.5	36.2
1931	8.2	18.9	18.6	17.3	16.1	5.2	10.5	2.6	1.6	1.3	1.2	1.5	103.0
1932	3.3	3.3	8.0	3.3	2.5	1.6	1.6	1.7	1.5	1.0	0.9	0.9	29.6
1933	1.4	1.3	1.7	1.5	1.5	0.9	0.9	1.3	0.9	0.7	0.5	0.6	13.2
1934	2.6	2.8	6.7	13.2	3.4	1.4	1.1	0.8	0.4	0.6	1.7	0.9	35.6
1935	0.8	1.8	0.8	0.7	21.7	36.6	5.4	2.1	6.2	3.1	2.1	2.8	84.1
1936	2.4	1.6	2.0	1.5	10.8	16.0	30.5	4.9	23.0	7.3	5.6	5.2	110.8
1937	7.6	6.6	12.1	6.6	3.0	4.2	2.8	1.2	1.4	4.7	1.1	5.2	56.5
1938	17.8	11.5	7.2	24.4	19.3	6.9	3.7	1.7	1.2	1.1	0.8	1.1	96.7
1939	1.2	0.9	0.8	1.8	0.7	0.5	1.5	0.5	0.4	0.7	0.6	0.6	10.2
1940	0.5	0.7	1.2	2.9	0.8	3.5	2.4	0.9	0.8	0.3	6.3	20.9	41.2
1941	6.7	24.6	29.4	28.7	39.0	30.6	9.3	3.0	2.1	5.3	2.3	1.8	182.8
1942	1.5	1.4	1.5	10.6	3.9	2.2	1.4	3.2	18.9	13.2	8.1	5.5	71.4
1943	4.2	2.9	3.5	4.6	2.9	2.2	3.2	1.2	2.3	1.2	1.0	0.9	30.1
1944	4.5	11.9	18.4	10.0	16.5	11.4	4.4	7.3	9.0	2.4	2.5	13.2	111.5
1945	17.4	18.9	25.6	14.1	6.5	4.8	3.2	1.7	1.7	2.7	1.7	5.1	103.4
1946	5.2	9.2	13.9	7.1	6.3	4.3	2.4	1.7	2.9	4.0	25.5	17.1	99.6
1947	20.4	11.2	7.9	5.7	4.2	2.8	1.7	1.4	1.1	1.1	1.1	1.1	59.7
1948	0.9	0.9	0.8	0.8	3.1	1.1	1.0	0.5	0.5	1.5	0.6	0.6	12.3
1949	0.8	2.1	2.5	14.4	9.1	2.8	1.6	1.1	0.7	0.8	0.7	0.8	37.4
1950	0.7	1.3	0.9	2.1	3.1	2.0	1.2	0.8	0.7	0.6	0.5	0.5	14.4
1951	0.5	0.5	0.7	0.7	0.9	2.5	0.4	0.3	0.6	0.3	0.4	0.4	8.2
1952	0.4	0.4	0.5	2.1	5.3	4.0	1.3	0.6	71.6	3.2	2.4	4.1	95.9
1953	6.4	3.3	3.1	4.4	2.7	1.3	1.0	3.0	10.8	3.2	3.2	3.8	46.2
1954	2.3	1.7	1.4	1.1	0.8	0.5	0.4	0.4	0.3	0.5	0.4	0.5	10.3
1955	0.6	0.7	0.5	0.4	4.6	0.8	0.5	0.5	0.4	0.3	0.3	0.4	10.0
1956	0.3	0.4	0.3	0.2	0.6	0.2	0.1	0.1	0.4	1.7	1.4	1.3	7.0
1957	0.5	1.2	9.9	48.8	17.7	18.9	3.1	1.5	12.2	25.1	20.3	13.3	172.5
1958	12.2	23.4	24.2	12.0	5.6	15.8	5.4	2.8	8.1	8.2	11.9	5.7	135.3
1959	4.2	5.7	5.5	10.8	6.1	5.7	3.2	3.1	2.1	19.3	3.8	5.1	74.6
1960	8.4	10.8	8.1	7.2	5.0	3.3	4.8	5.0	2.7	40.0	16.3	23.5	135.1
1961	20.3	44.8	16.9	7.3	4.5	20.2	8.2	4.6	3.7	3.3	3.0	2.9	139.7
1962	2.5	2.0	2.1	2.2	2.1	8.2	2.4	1.3	2.0	--	--	--	(24.8)
Total	168.9	230.2	238.3	274.2	321.3	243.5	138.9	67.2	194.9	164.1	132.0	152.9	2,326.4
Average	5.0	6.8	7.0	7.1	9.4	7.2	4.0	1.9	5.6	4.8	3.9	4.5	67.2

TABLE 32

SEDIMENT STORAGE - EDWARDS UNDERGROUND RESERVOIR AREA

Reservoir	Contributing drainage area (sq. mi.)	Sediment storage (acre-feet)
Montell	707	12,000 (1)
Concan	391	7,800
Sabinal	210	4,200
Dam No. 7	1,124	17,500
Canyon w/Dam No. 7	301	10,300 (2)
Cloptin Crossing	307	9,200 (3)

(1) 1,200 acre-feet would be deposited in the conservation pool and 10,800 acre-feet in the dual purpose pool.

(2) 8,800 acre-feet would be deposited in the conservation pool and 1,500 acre-feet in the flood control pool.

(3) 8,500 acre-feet would be deposited in the conservation pool and 700 acre-feet in the flood control pool.

therefore, the storage required for recharge can also be used as flood-control storage. In this appendix the joint storage space reserved for recharge and flood-control purposes is referred to as dual-purpose storage.

(2) Those watersheds having little or no natural recharge capacity were investigated for potential surface water supply and flood-control reservoirs. Releases from the flood-control storage were limited to minimum downstream channel capacities as shown in table 16.

(3) The areas that are protected below the recommended reservoirs are predominantly agricultural. It is considered desirable to provide at least 50-year protection for these areas if the storage can be justified economically. The storage requirements for each recommended reservoir are discussed under the appropriate heading in the following paragraphs.

b. Dual-Purpose Storage.

(1) Montell Reservoir.

(a) A continuous daily routing was made for Montell Reservoir for the period 1924 through 1962, with releases being made at the estimated recharge rate of 1,000 second-feet. The results of this routing are shown graphically on plates 14 and 15. It was determined from this routing that the June 1935 flood required 259,200 acre-feet or 6.87 inches of storage, more than any other flood during the period of record, although the September 1955 flood produced the greatest peak discharge since at least 1854 according to historical data. The storages utilized for individual floods during the period of record routing were the basis for a storage-frequency analysis made in accordance with the method set forth in Section VI of "Statistical Methods in Hydrology" by Leo R. Beard, dated January 1962 and recommended for use in ER 1110-2-1450. From this analysis it was determined that the June 1935 flood had a frequency of recurrence of less than once in 50 years. The dual-purpose storage, having an average frequency of recurrence of once in 50 years, is 235,300 acre-feet, or 6.24 inches. An additional 4,000 acre-feet of storage is recommended so that releases may be withheld for up to two days or reduced for a somewhat longer period, depending upon the local runoff downstream from the damsite. This period of withholding or reducing releases will allow a greater percentage of the local runoff to infiltrate into the aquifer. A total storage of 239,300 acre-feet, or 6.35 inches, is, therefore, recommended for inclusion in the Montell Reservoir. It is noted that the flood of June 1935, when routed through the recommended reservoir, produces a maximum spill slightly less than the minimum downstream channel capacity.

(b) The possibility that a major flood could occur prior to the emptying of some antecedent flood volume was also considered. Examination of the period of record routing shows that the major floods generally occur in June and September, with a normal lag of 60-90 days between major floods. A conservative lag of 30 days between the end of the first flood period and the beginning of the second was, however, selected in constructing a flood series composed of the hypothetical 25-year flood followed by the hypothetical 50-year flood. It is noted that this results in a lag of about 40 days between peaks. The routing of this flood series indicated that 248,900 acre-feet or 6.60 inches of storage would be required for its complete control. However, the recommended storage would control the flood series to non-damaging release rates, with the maximum outflow approximately 4,800 second-feet. Results of this routing are shown graphically on plate 16.

(2) Concan Reservoir.

(a) A continuous daily routing was made for Concan Reservoir for the period 1924 through 1962, with releases being made at the estimated recharge rate of 750 second-feet. Results of this routing are shown graphically on plates 17 and 18. It was determined from this routing that the July 1932 flood, largest flood of record, required 137,600 acre-feet or 6.60 inches of storage. The July 1932 flood was not only the largest flood in volume but it produced the highest stage at the Concan gage since at least 1869 according to historical data. The storages utilized for individual floods during the period of record routing were the basis for a storage-frequency analysis made in accordance with the method set forth in Section VI "Statistical Methods In Hydrology" by Leo R. Beard, dated January 1962, and recommended for use in EM 1110-2-1405. From this analysis it was determined that the storage required for the July 1932 flood was in close agreement with the recommended dual-purpose storage. The dual-purpose storage having an average frequency of recurrence of once in 50 years is 138,200 acre-feet or 6.63 inches. An additional 3,000 acre-feet of storage is recommended so that releases may be withheld for up to two days or reduced for a somewhat longer period. This period of withholding or reducing releases will allow a greater percentage of runoff from the uncontrolled area downstream to infiltrate into the aquifer. A total storage of 141,200 acre-feet or 6.77 inches has, therefore, been adopted for inclusion in the recommended Concan Reservoir.

(b) The possibility of a major flood occurring prior to the emptying of an antecedent flood was checked in a manner similar to that discussed in paragraph (b) for Montell Reservoir. The normal lag time between major floods was found to be from 60 to 90 days. A conservative lag of 30 days between the end of the first flood period and the beginning of the second was, however, selected in constructing a flood series composed of the hypothetical 25-year flood

NOTE:
For notes see Sheet 2.

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
MONTELL RESERVOIR

STORAGE REQUIREMENTS FOR PERIOD OF RECORD

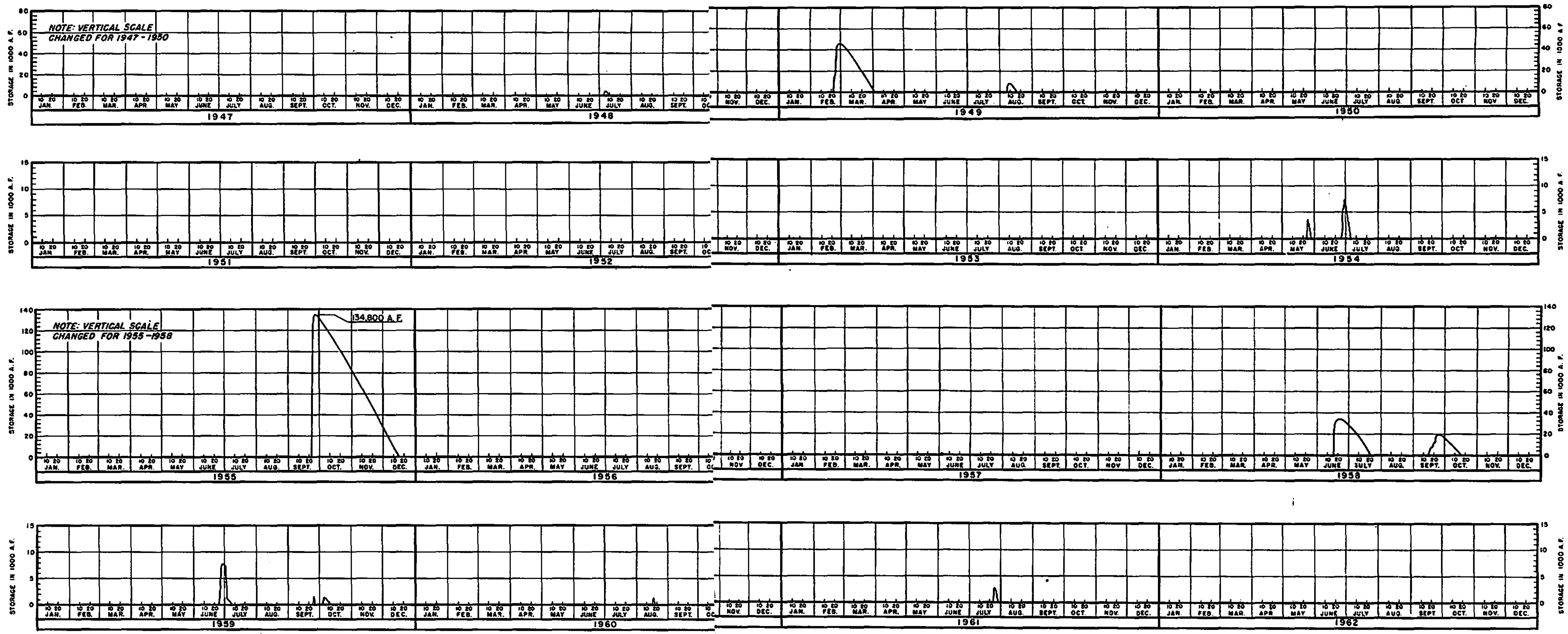
(DUAL PURPOSE OPERATION)

IN 2 SHEETS SHEET NO. 1

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC. 1964

SUBMITTED: W. E. Wood, Engineer, Chief, Planning & Reports Branch
APPROVAL RECOMMENDED: Engineer, Chief, Engineering Division
APPROVED: District Engineer
PREPARED: Chief, Hydrology Section
DRAWN BY: A.M.F.
CHECKED BY: T L.B./B.J.S.
TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
FILE: GUAD. 707-2



NOTES:

1. *Accumulated storage based on constant release rate of 1,000 c.f.s. (2,000 acre feet/day) when available from inflow or storage. Outflow equals inflow for remainder of time.*
2. *Dual purpose operation refers to simultaneous operation for flood control and recharge.*
3. *Flows for Montell Reservoir based on records at U.S.G.S. gage on Nueces River at Laguna, Texas.*

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
MONTELL RESERVOIR

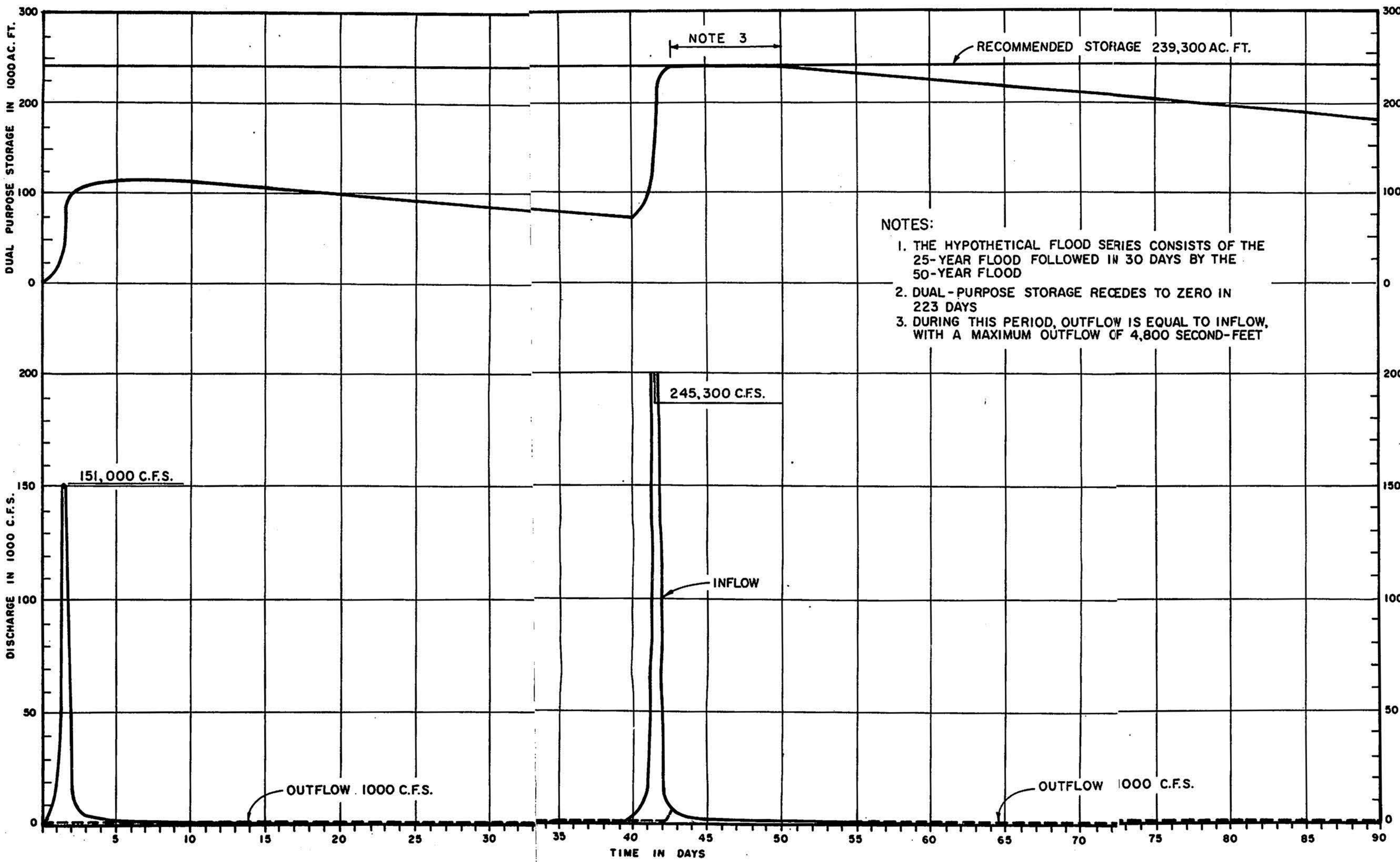
STORAGE REQUIREMENTS FOR PERIOD OF RECORD

(DUAL PURPOSE OPERATION)

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

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
W. E. Wood, Chief, Project Planning Branch	Chief, Engineering Division	District Engineer
PREPARED: Chief, Hydrology Section	DRAWN BY: B.G.S. / CHECKED BY: T.L.R./W.J.B.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR — FILE GUAD. 707-2

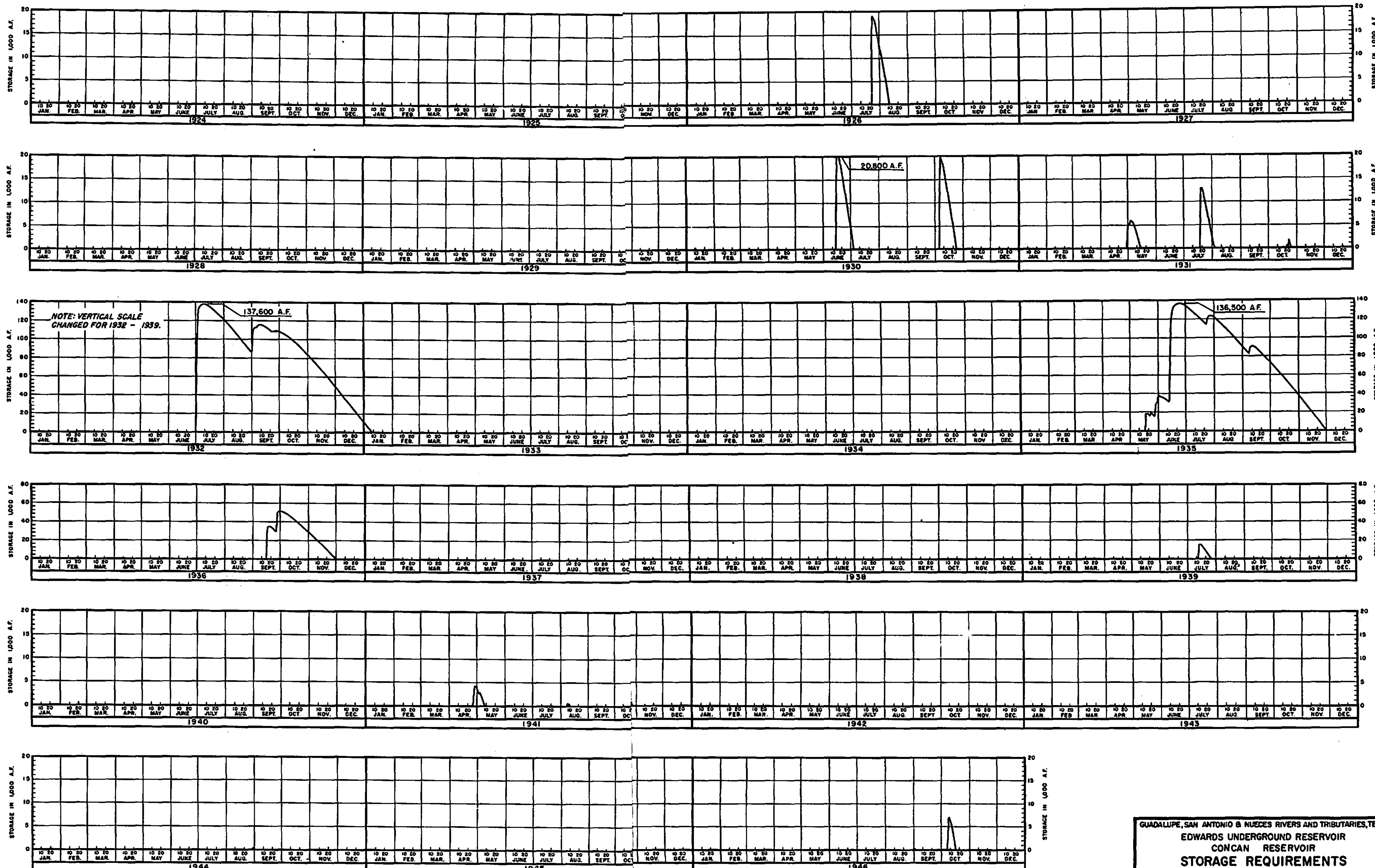


EDWARDS UNDERGROUND RESERVOIR

MONTELL RESERVOIR
HYPOTHETICAL FLOOD SERIES

DEC. 1964 PLATE 16

 A.M.F.



NOTE:
For notes see Sheet 2.

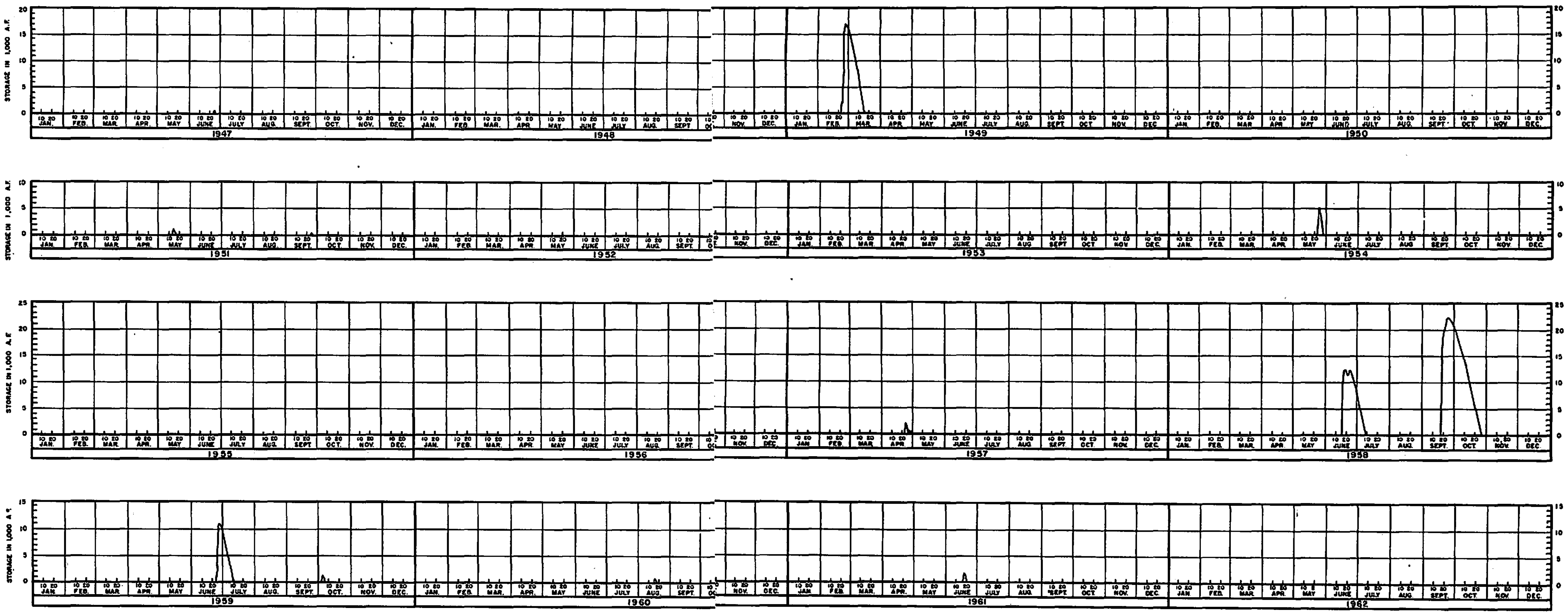
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
CONCAN RESERVOIR

STORAGE REQUIREMENTS FOR PERIOD OF RECORD
(DUAL PURPOSE OPERATION)

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

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED: CHIEF, PROJECT PLANNING BRANCH
APPROVAL RECOMMENDED: CHIEF, ENGINEERING DIVISION
APPROVED: COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
DESIGNED: CHIEF, HYDROLOGY SECTION
DRAWN BY: B.G.S.
CHECKED BY: T.L.N./M.J.E.
TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
FILE GUAD. 707-2



NOTES:

1. *Accumulated storage based on constant release rate of 750 C.F.S./Day (1500 A.F./Day) when available from inflow or storage. Outflow equals inflow for remainder of time.*
2. *Dual purpose operation refers to simultaneous operation for flood control and recharge.*
3. *Flows for Concan Reservoir based on records at U.S.G.S. gage on Frio River at Concan, Texas.*

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

EDWARDS UNDERGROUND RESERVOIR
CONCAN RESERVOIR

STORAGE REQUIREMENTS FOR PERIOD OF RECORD

(DUAL PURPOSE OPERATION)

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

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
W. E. Wood, ENGINEER, CHIEF, PROJECT PLANNING BRANCH	C. J. [illegible], ENGINEER, CHIEF, ENGINEERING DIVISION	[illegible], LTC, CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: [illegible], ENGINEER, CHIEF, HYDROLOGY SECTION	DRAWN BY: TLaM G. CHECKED BY: TLR/WJS	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR. FILE: GUAD 707-2

followed by the hypothetical 50-year flood. It is noted that this results in a lag of about 40 days between peaks. The routing of this flood series indicated that 139,600 acre-feet of storage was required which is 1,600 acre-feet less than the recommended size. Results of this routing are shown graphically on plate 19.

(3) Sabinal Reservoir.- The length of stream gage record in the vicinity of the Sabinal Reservoir is less than half that available for analysis for the Montell and Concan Reservoirs and was not considered adequate for the establishment of storage requirements. A regional storage relationship was determined in the following manner: Continuous daily operations were made at the Montell and Concan Dam sites for each of four different release rates. The storages utilized for the individual floods during the entire period of record for each of the four release rates were the basis for storage-frequency analyses as recommended in EM 1110-2-1405. A correlation was developed relating the 50-year storage from these analyses and the coresponding release rates. Examination of these correlation curves for Concan and Montell Reservoirs indicated that for any given release rate, a direct drainage area relationship existed between the required 50-year storages at the two projects. This relationship apparently exists because the areas are adjacent, with similar topography, soils, land use and climatic conditions. Pending the collection of additional runoff data, it has been assumed for this report that a similar relationship exists between the Concan and Sabinal Dam sites since they, too, are located on adjacent watersheds. This is the basis for the selection of the recommended dual-purpose storage for Sabinal Reservoir. This storage, having an average frequency of 50 years, is 87,100 acre-feet, or 7.78 inches. An additional 2,000 acre-feet of storage is recommended so that releases may be withheld for up to two days or reduced for a somewhat longer period. The period of withholding, or of reduced releases, will allow a greater percentage of the local runoff to infiltrate into the aquifer. A total storage of 89,100 acre-feet (7.96 inches) is, therefore, recommended for inclusion in the Sabinal Reservoir.

(4) Because of the short record available, hypothetical 25-, 50-, and 100-year floods were not developed for the Sabinal Reservoir for test routing purposes. However, the location of the dam axis within the recharge zone of the Sabinal River will tend to assure the adequacy of the storage by producing a higher rate of recharge than the 500 second-feet estimated for the streambed below the dam site. It is anticipated that some water will infiltrate into the Edwards Reservoir directly from the bottom and sides of the reservoir. The Medina Reservoir on the Medina River is located on the fault zone and loses a considerable quantity of water to the Edwards Reservoir in this way. It should be noted that though the Medina Reservoir has been constructed since 1913, sedimentation has produced no apparent effect on its recharge capacity.

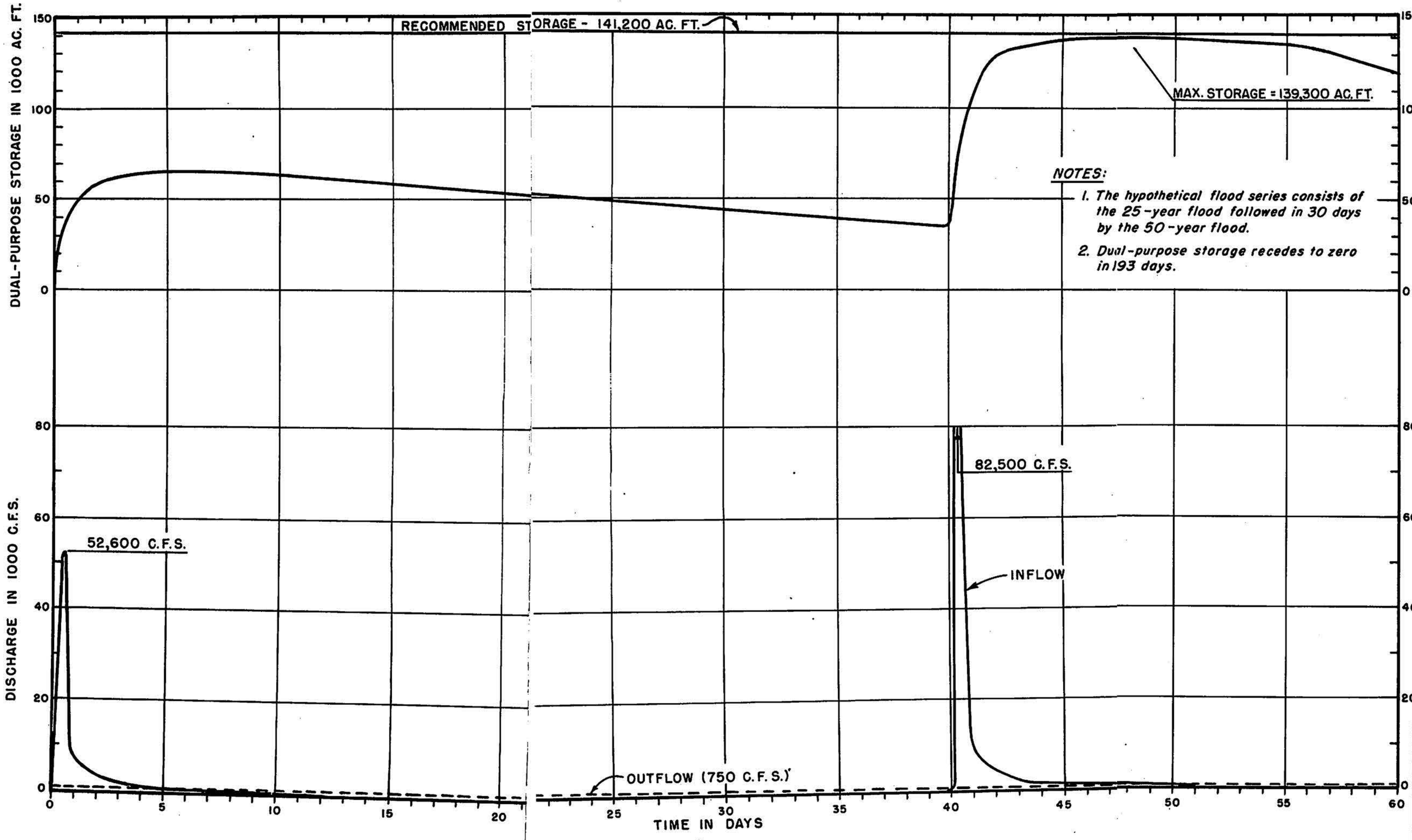
(5) There exists no means of estimating the magnitude of the recharge which will occur directly from the pool; therefore, all analyses of modified recharge were based on that which it is estimated will take place downstream from the project.

c. Flood Control Storage - Cloptin Crossing Reservoir.

(1) Routings of the major floods of record were made for Cloptin Crossing Reservoir to determine the flood-control storage requirements. These routings assumed a full conservation pool at the project and releases were made to control the non-damaging discharges at selected downstream control points. In addition, hypothetical flood hydrographs for varying frequencies, developed as discussed in paragraph 39, were routed through the reservoir on a full conservation pool. The floods were routed in accordance with the adopted regulating criteria, assuming the coincident occurrence of floods of approximately equivalent frequency on the uncontrolled area downstream from the project. Data obtained from the routings of hypothetical floods were used to establish a relationship between flood-frequency and flood-control storage requirements for Cloptin Crossing Reservoir.

(2) The May 1929 flood when routed through the Cloptin Crossing Reservoir in accordance with the procedure presented in the above paragraph utilized 76,200 acre-feet or 4.65 inches of flood-control storage. Historical data for the Wimberley gage on the Blanco River show the flood of May 1929 to be the maximum since 1869. However, historical data for the San Marcos gage on the San Marcos River indicate that the maximum stage at San Marcos, since at least 1913, occurred in September 1921 and was produced by backwater from the Blanco River. Also, according to historical data, the flood of May 1929 was exceeded by the flood of 1869 or 1870 on the San Marcos River at Luling and by the flood of December 1913 on the San Marcos River at Ottine, with a large flood also occurring at the latter location in 1869 or 1870. From the above data covering a period of about 100 years, it is concluded that at least three historical floods in the San Marcos River watershed have approached or exceeded the flood of May 1929. It is also evident from an examination of the isohyetal patterns of the May 1929 and September 1952 storms on plates 6 and 11, that a transposition of either storm pattern involving a displacement of only 15 miles in the storm center would produce heavier rainfall and resulting runoff on the area above Cloptin Crossing Reservoir.

(3) The storage required to control the hypothetical 50-year flood, whose derivation was discussed in paragraph 39, was 106,400 acre-feet or 6.50 inches. Also, it was concluded that the flood-control storage of 4.65 inches utilized in routing the flood of May 1929 (maximum of record) is equivalent to that required for the control of a hypothetical flood of only 25-year frequency. It is further concluded from the historical data and representative storm



EDWARDS UNDERGROUND RESERVOIR

CONCAN RESERVOIR
HYPOTHETICAL FLOOD SERIES

DEC. 1964 PLATE 19

patterns previously discussed that the maximum flood of record is not truly representative of the flood potential of the watershed. An analysis of the relationship between cost and benefit for projects containing flood-control storage of varying frequencies led to adoption of a project containing 119,900 acre-feet, or 7.30 inches of flood control storage, having an average frequency of recurrence of once in 75 years.

d. Conservation Storage.

(1) General.- At the present time the municipal and rural water demand of the area is being met by ground water, but projected future demands indicate a need for supplementing the present supply. One of the purposes of this study is to determine the benefits associated with the provision of surface storage on streams within the Edwards Underground area. The reservoirs recommended in connection with this study, the maximum or recommended conservation storage and its associated dependable yield under 2025 conditions of watershed development, are shown in table 17.

(2) Montell Reservoir.- The Montell Reservoir is the only reservoir in the recommended plan to have both dual-purpose and conservation storage. The reservoir is primarily a recharge project; however, 1,000 acre-feet of conservation storage space has been provided in Montell Reservoir in lieu of construction of Tom Nunn Hill Reservoir. The conservation storage in Montell Reservoir has a dependable yield of 4,300 acre-feet per year (6 second-feet). This was the only point that was developed, consequently, no storage-yield curve is presented for this project. Aspects of the conservation storage in Montell Reservoir are discussed in more detail in paragraph 80.

(3) Dam No. 7 Reservoir.- Economic evaluations indicated that additional flood-control storage for the Guadalupe River Basin could not be economically provided in Dam No. 7 Reservoir; however, because of the need for full development of the area's resources, the reservoir is recommmended for construction by local interests. Dam No. 7 Reservoir is designed to operate in conjunction with Canyon Reservoir to develop to the fullest extent feasible the total resources upstream from Canyon Dam. The provision of 640,500 acre-feet of conservation storage in Dam No. 7 Reservoir would produce a dependable yield for the Canyon-Dam No. 7 system of 142,700 acre-feet per year (197 second-feet). This is an increase of 46,400 acre-feet per year (64 second-feet) over the yield determined for the Canyon Reservoir without upstream development. A curve relating the conservation storage and dependable yield for Dam No. 7 Reservoir is shown on plate 20. This curve was developed from monthly water supply routings based on the runoff in table 30 and evaporation data developed from that presented in table 12.

(4) Cloptin Crossing.- A multiple-purpose reservoir for flood-control, water conservation, recreation, and fish and wildlife is recommended for Federal construction on the Blanco River at the Cloptin Crossing site. The recommended conservation storage of 274,900 acre-feet would fully develop the resources of the Blanco River watershed upstream from the damsite based on refilling the conservation storage after the critical period. The above storage would provide a dependable yield of 42,700 acre-feet per year (59 second-feet) from Cloptin Crossing Reservoir. A curve relating the conservation storage and dependable yield for Cloptin Crossing Reservoir is shown on plate 21. This curve was developed from monthly water-supply routings based on the runoff in table 31 and evaporation data developed from that presented in table 12.

53. FLOOD-CONTROL EFFECTS.- In order to evaluate the flood-control effects of the reservoirs investigated in this study, the peak discharges for the damaging floods of record were determined at the principal gaging stations within the affected areas with and without the reservoirs in operation. The procedures involved the use of observed and estimated reservoir inflows, streamflow records and routing procedures. The floods of record were routed through the reservoirs in accordance with the regulating criteria set forth in paragraph 52, STORAGE REQUIREMENTS. The floods were routed through Montell, Concan, Sabinal and Cloptin Crossing Reservoirs starting with empty flood-control pools. The larger floods of the upper Nueces River Basin which were routed through Montell Reservoir were the June 1935, June 1939, and September 1955 storms; the larger floods of the upper Frio River Basin which were routed through Concan Reservoir were the June-July 1932, June 1935, and September 1936 storms; the June 1958 flood was among the larger floods which were routed through Sabinal Reservoir; and the May-June 1929 and September 1952 storms were among the larger floods in the Blanco-San Marcos River Basin which were routed through Cloptin Crossing Reservoir. The results of these flood routings are summarized in table 33. The reservoir regulation during these flood periods is shown graphically on plates 22 through 28.

54. MINIMUM INFILTRATION INDICES.- Infiltration indices were computed for the Nueces River watershed above the Laguna gage; for the Frio River watershed above the Concan gage; for the Sabinal River watershed above the Sabinal gage; and for the Blanco River watershed above the Wimberley and Kyle gages, using the method described in EM 1110-2-1405, "Flood Hydrograph Analyses and Computations." Initial losses in the watersheds ranged from a minimum of 0.25 inch to a maximum of 3.00 inches. The range in infiltration indices was from 0.09 inch per hour to 0.82 inch per hour, and the runoff varied from 11.2 percent to 80.5 percent of the rainfall. The results of these computations are given in tables 34 and 35. Based upon these studies an initial loss of 1.00 inch and an infiltration rate of 0.15 inch per hour was adopted for the upper Nueces and Frio River watersheds. The

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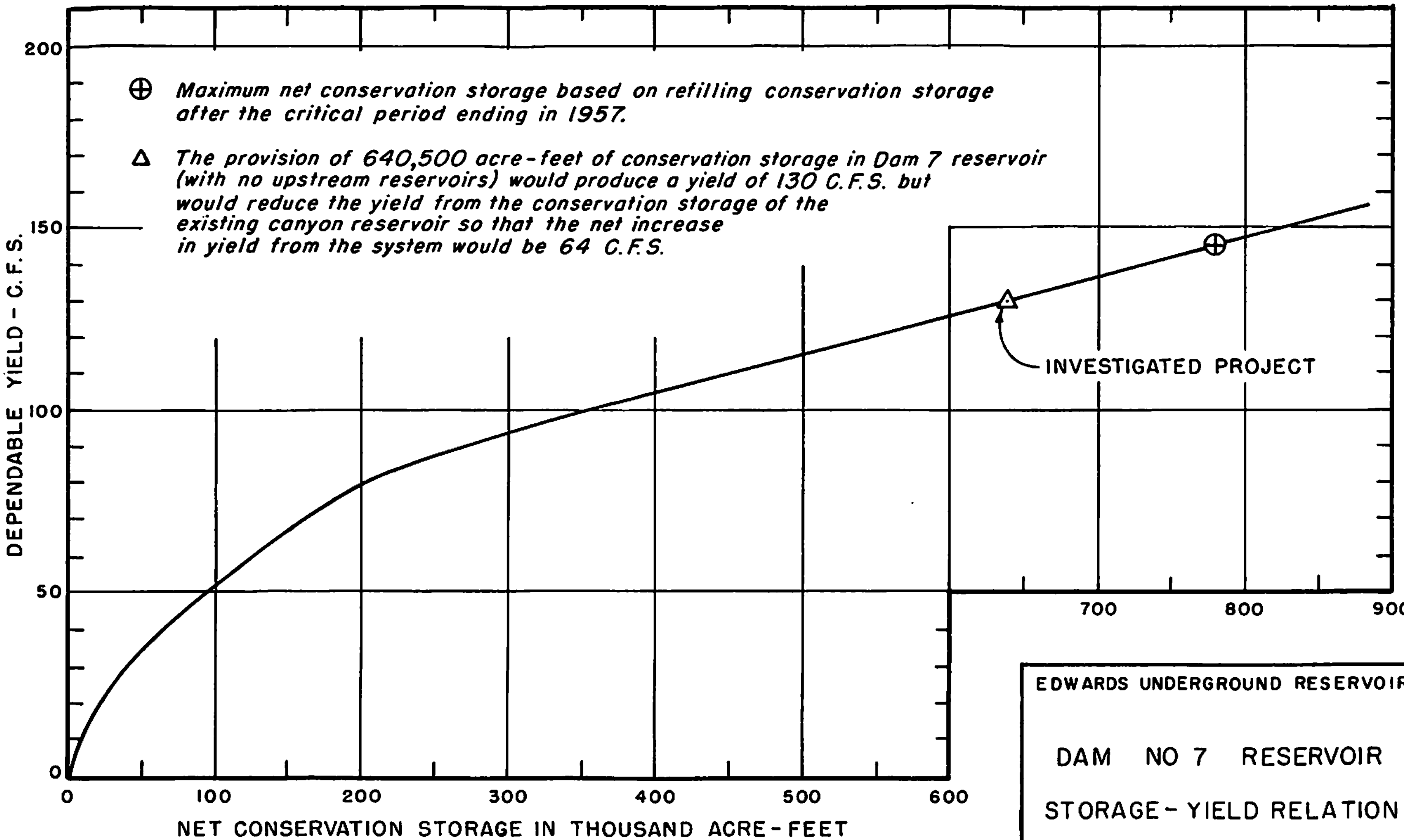
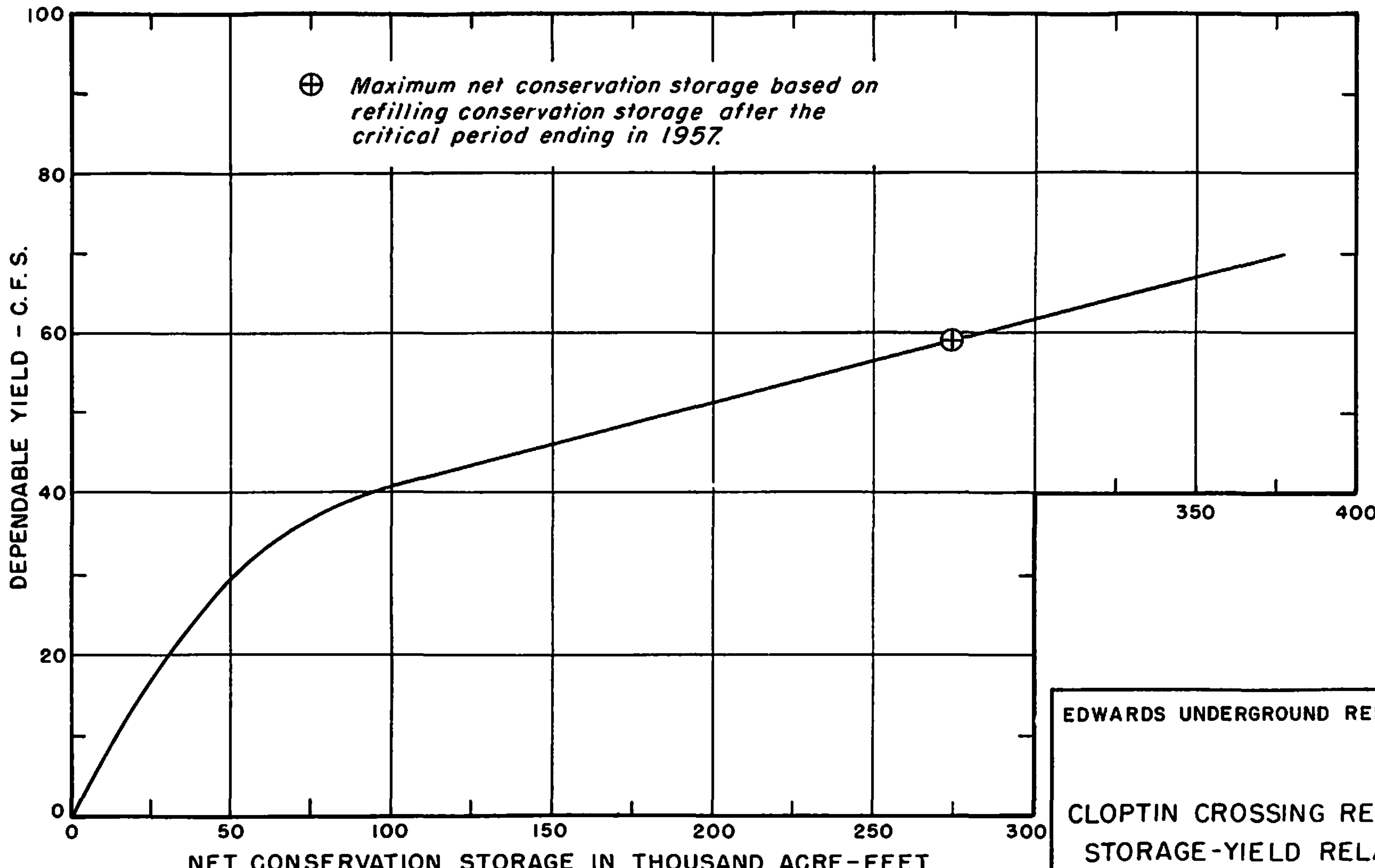


EDWARDS UNDERGROUND RESERVOIR

DAM NO 7 RESERVOIR

STORAGE-YIELD RELATION

DEC. 1964 PLATE 20



EDWARDS UNDERGROUND RESERVOIR

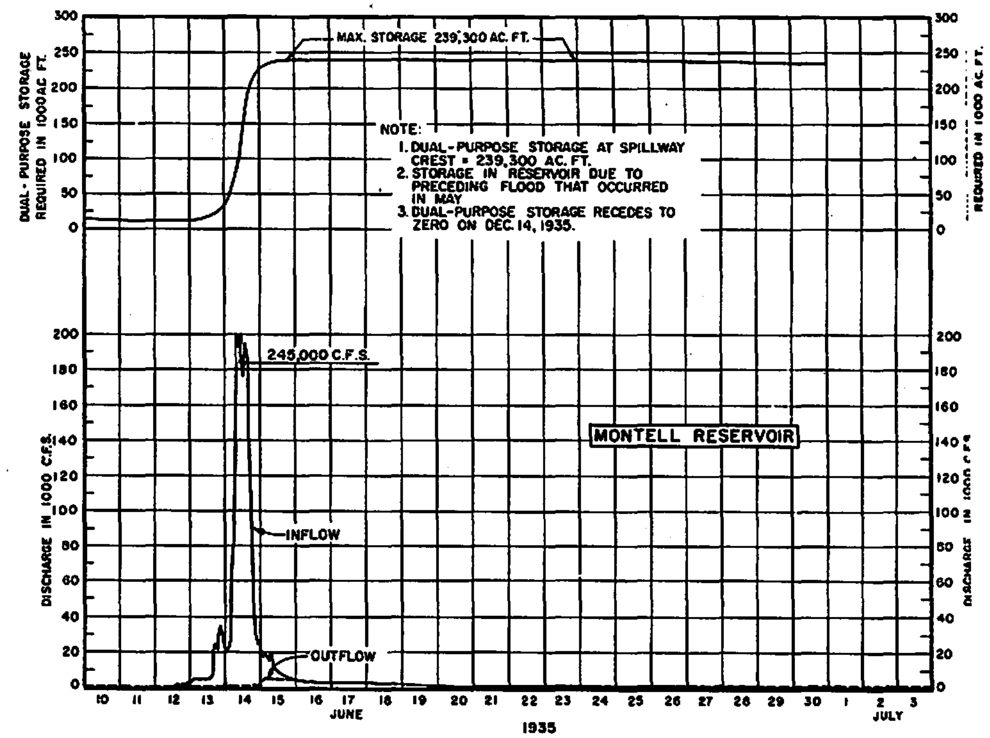
CLOPTIN CROSSING RESERVOIR
STORAGE-YIELD RELATION

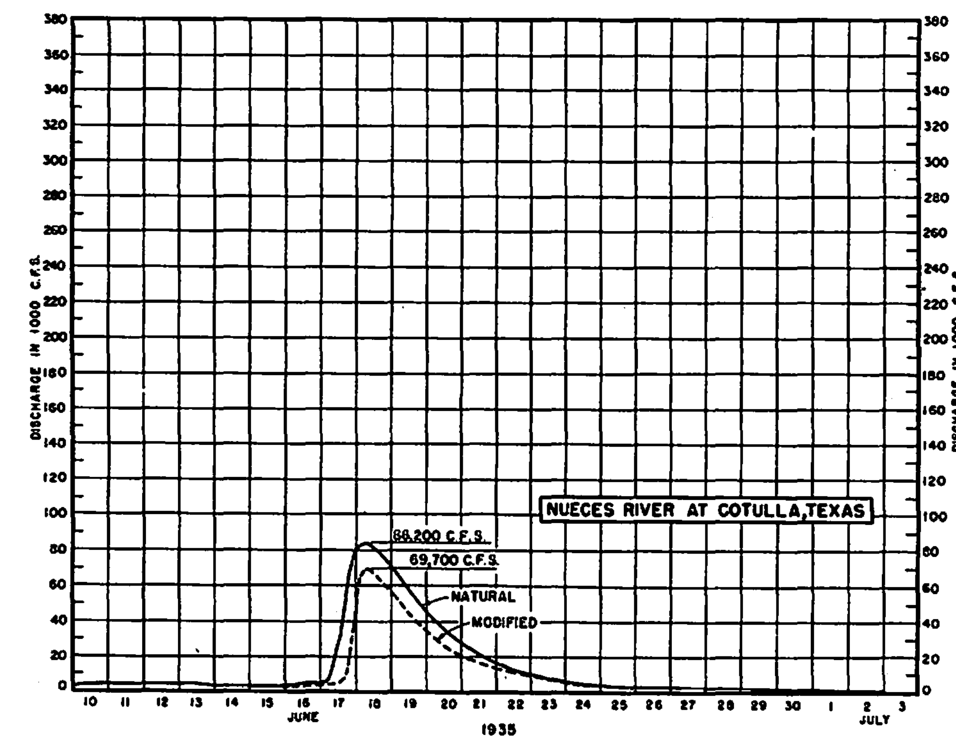
DEC. 1964 PLATE 21

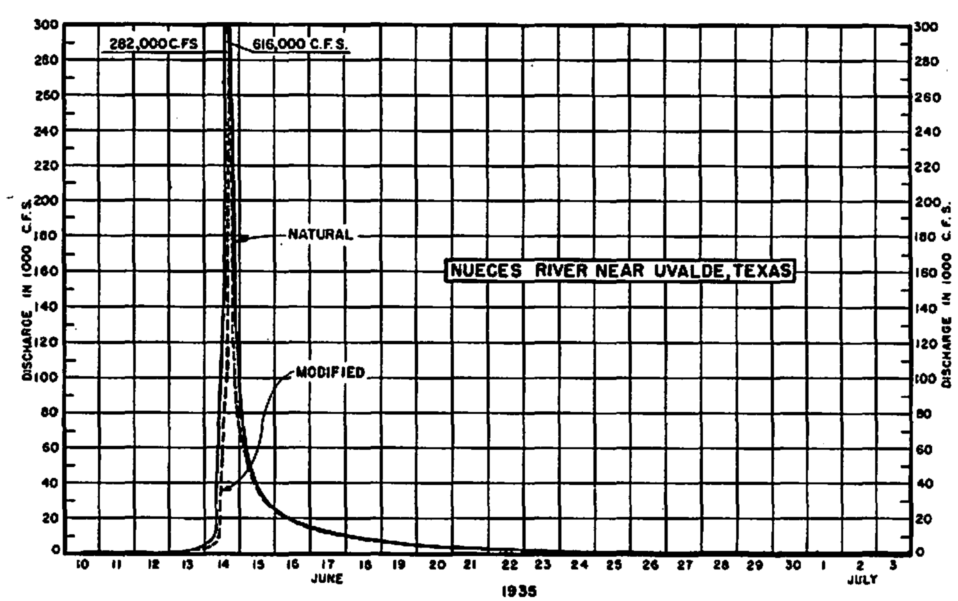
TABLE 33

HYPOTHETICAL RESERVOIR REGULATION

Flood	Peak inflow (c.f.s.)	Peak outflow (c.f.s.)	Storage required (acre feet)
		MONTEIL RESERVOIR D.A. = 707 sq.mi.	
June 1935	245,000	5,000	239,300
July 1939	205,400	1,000	76,400
September 1955	295,300	1,000	134,700
		CONCAN RESERVOIR D.A. = 391 sq.mi.	
July 1932	159,200	750	137,600
June 1935	104,200	750	136,500
September 1936	119,000	750	51,300
		SABINAL RESERVOIR D.A. = 210 sq.mi.	
June 1958	55,200	500	28,500
		CLOPTIN CROSSING RESERVOIR D.A. = 307 sq. mi.	
May-June 1929	105,400	5,000	76,200
September 1952	88,600	5,000	61,100







GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
NUECES RIVER

RESERVOIR REGULATION
FLOOD OF JUNE 1935

SCALE AS SHOWN

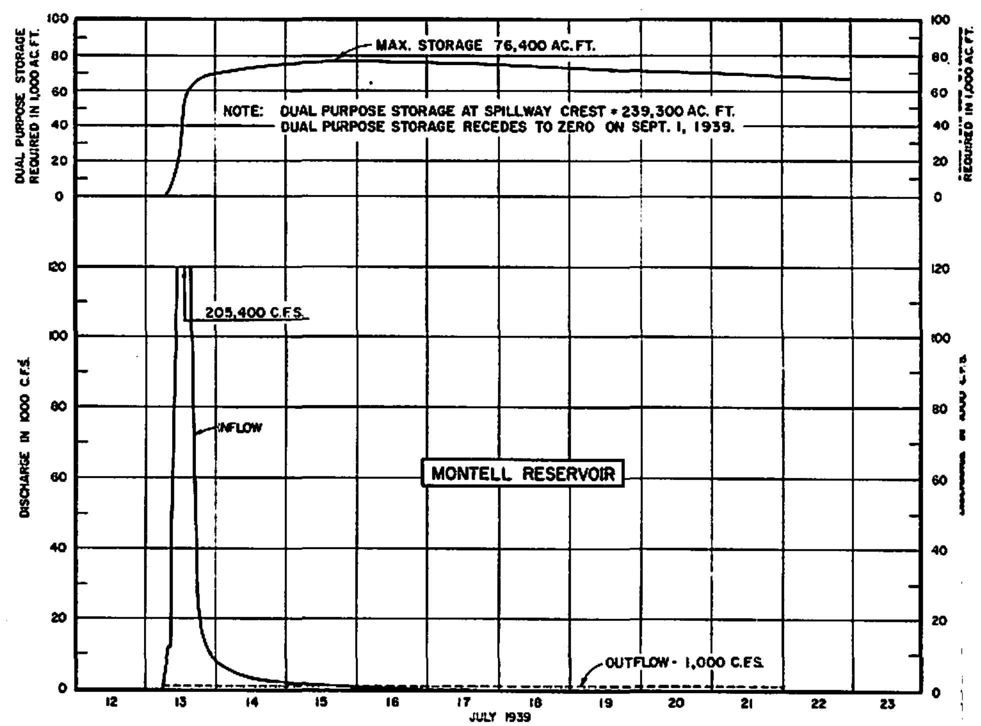
U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC. 1964

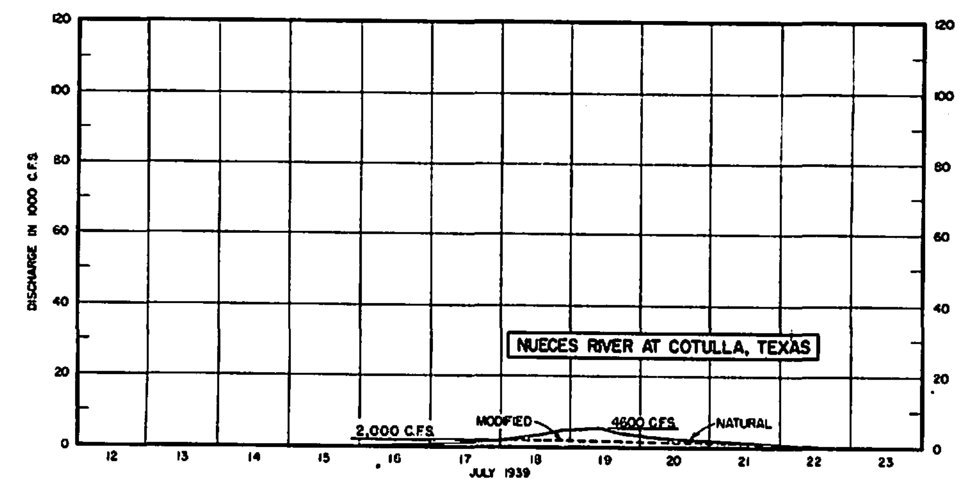
SUBMITTED — CHIEF, PROJECT PLANNING BRANCH; APPROVAL RECOMMENDED — CHIEF, ENGINEERING DIVISION; APPROVED — DISTRICT ENGINEER

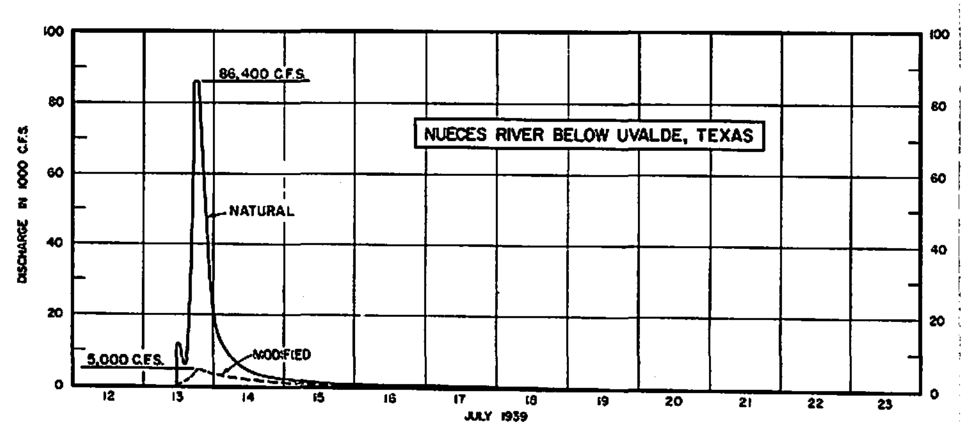
PREPARED — CHIEF, HYDROLOGY SECTION; DRAWN BY: J.A.L.; CHECKED BY: W.J.S.

TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR

FILE: GUAD 707-2







GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
NUECES RIVER

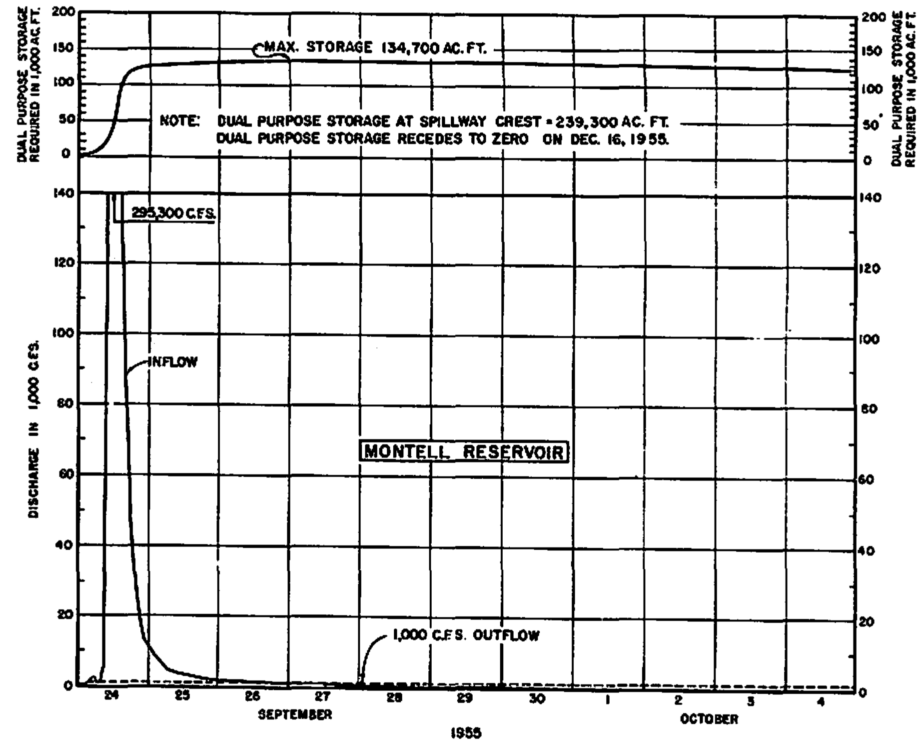
RESERVOIR REGULATION

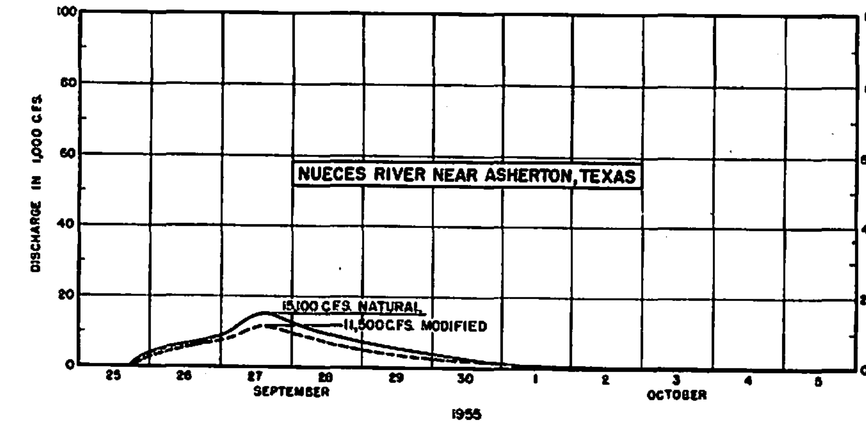
FLOOD OF JULY 1939

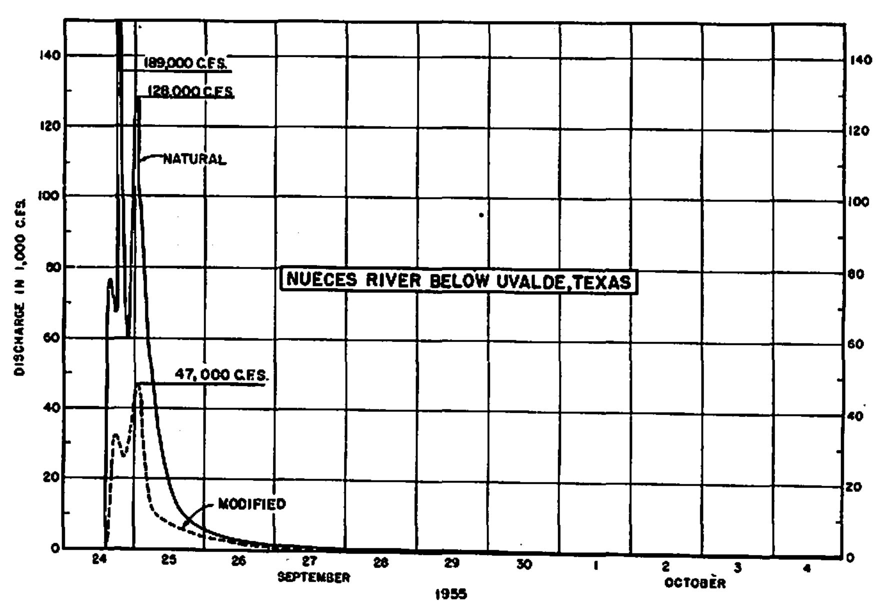
SCALE AS SHOWN

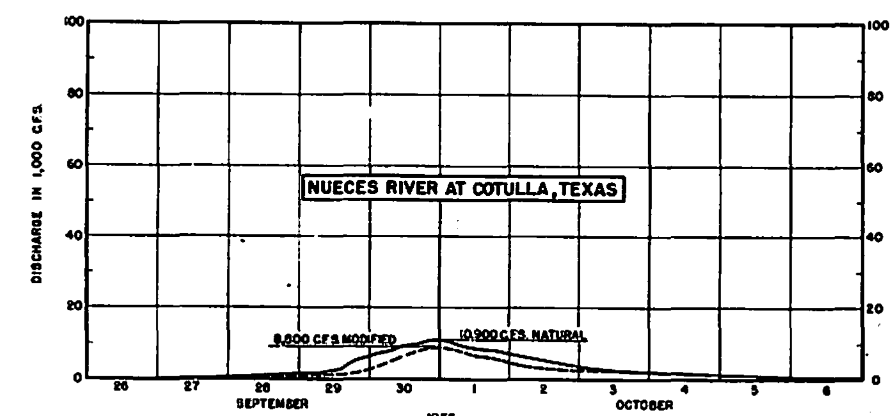
U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
ENGINEER, CHIEF PROJECT PLANNING BRANCH	ENGINEER, CHIEF, ENGINEERING DIVISION	COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: ENGINEER, CHIEF HYDROLOGY SECTION	DRAWN BY: T.L.H. / CHECKED BY: W.J.S.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR / FILE: GUAD 707-2









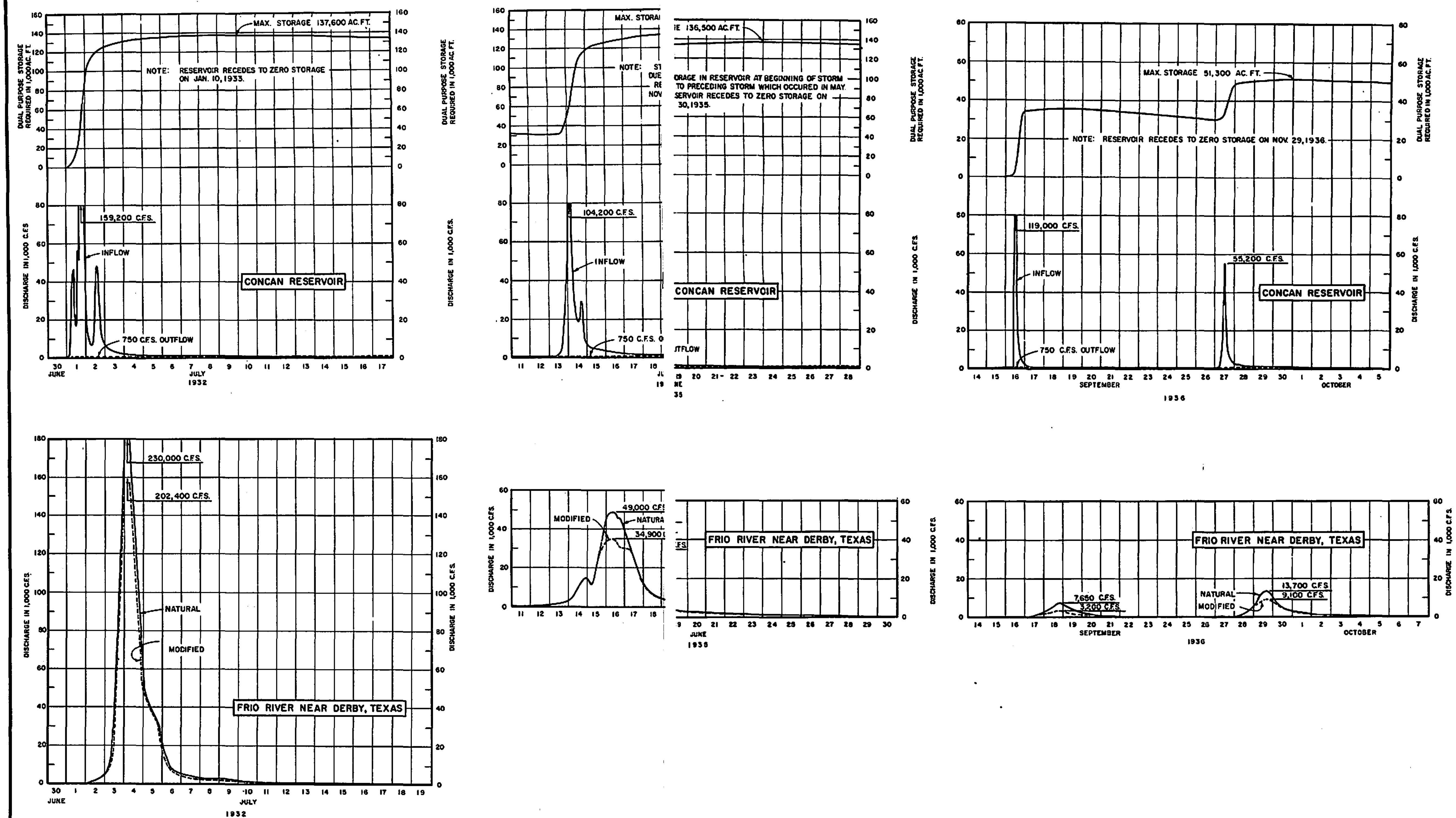
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
NUECES RIVER

RESERVOIR REGULATION
FLOOD OF SEPTEMBER- 1955

SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
W. E. Wood, CHIEF, PROJECT PLANNING BRANCH	CHIEF, ENGINEERING DIVISION	COL, CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: CHIEF, HYDROLOGY SECTION	DRAWN BY: W.J.M. / CHECKED BY: W.J.B.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR / FILE: GUAD. 707-2



NOTE:
Dual purpose storage at spillway crest = 141,200 Ac.Ft.

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
FRIO RIVER

RESERVOIR REGULATION

FLOODS OF JULY 1932, JUNE 1935 & SEPTEMBER 1936

SCALES AS SHOWN

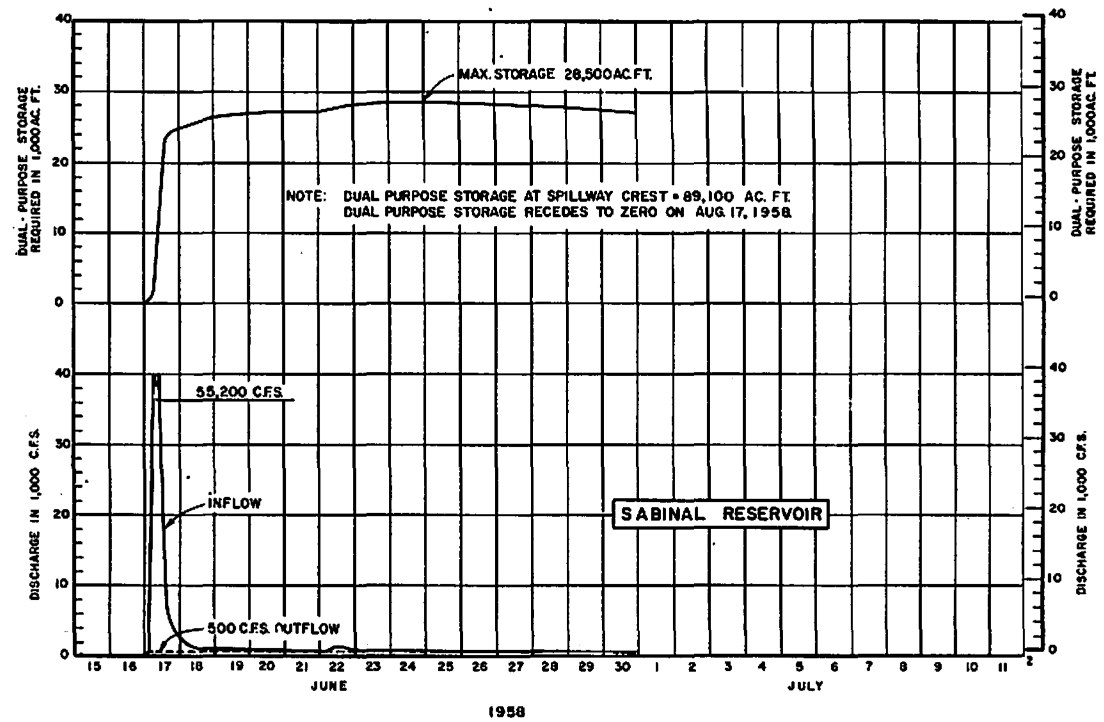
U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

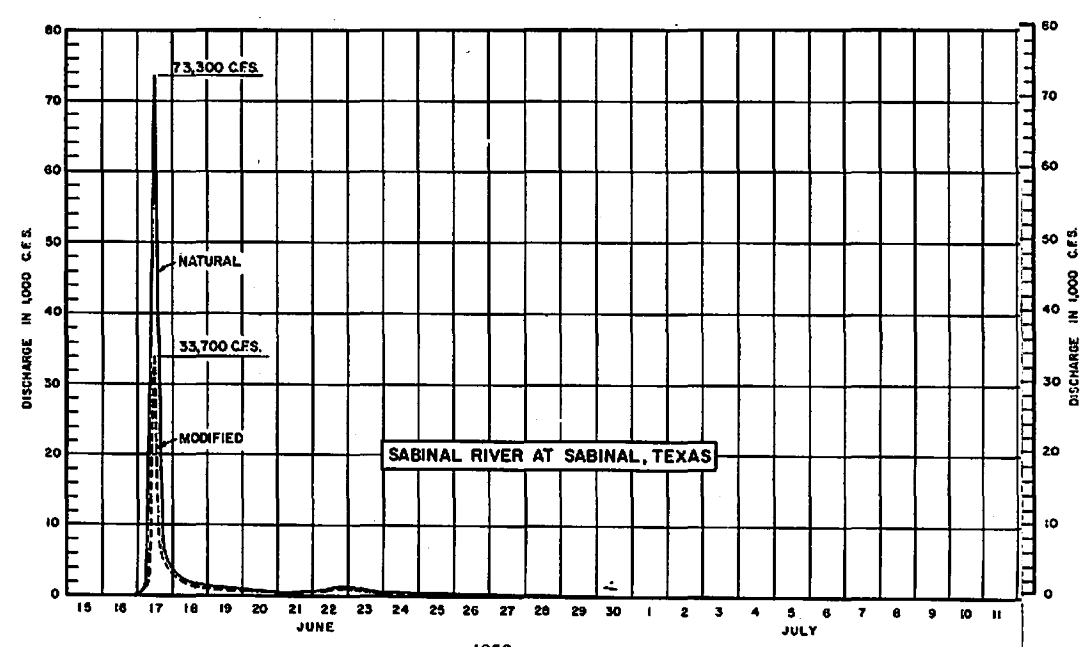
SUBMITTED: CHIEF, PROJECT PLANNING BRANCH — APPROVAL RECOMMENDED: CHIEF, ENGINEERING DIVISION — APPROVED: DISTRICT ENGINEER

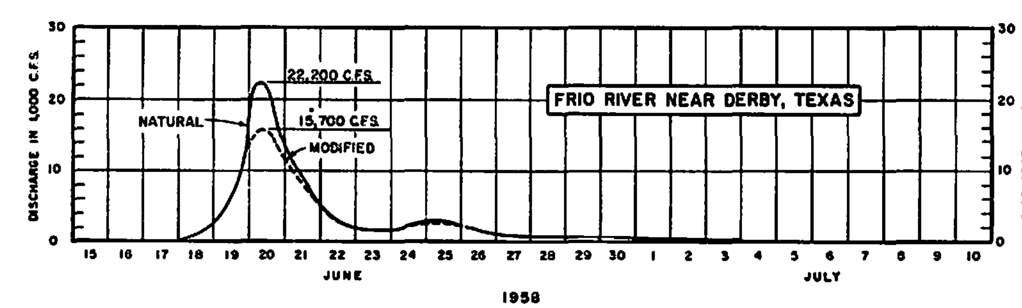
PREPARED: CHIEF, HYDROLOGY SECTION — DRAWN BY: T.L.W.B. — CHECKED BY: W.J.S.

TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR

FILE: GUAD. 707-2







GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
SABINAL RIVER

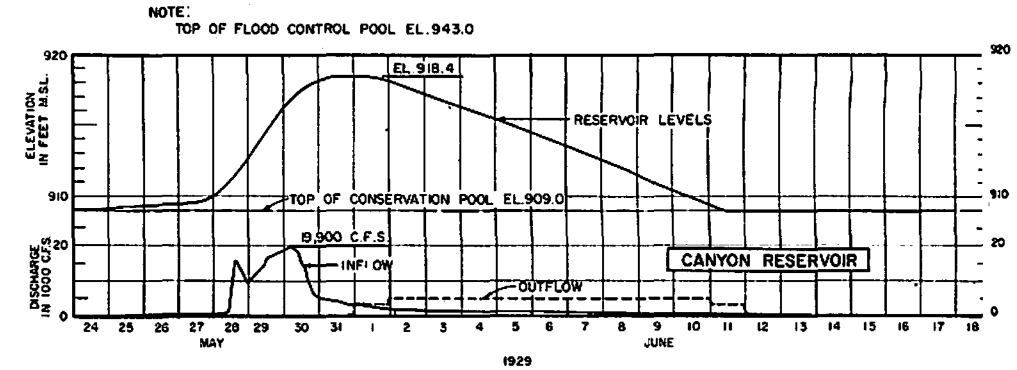
RESERVOIR REGULATION

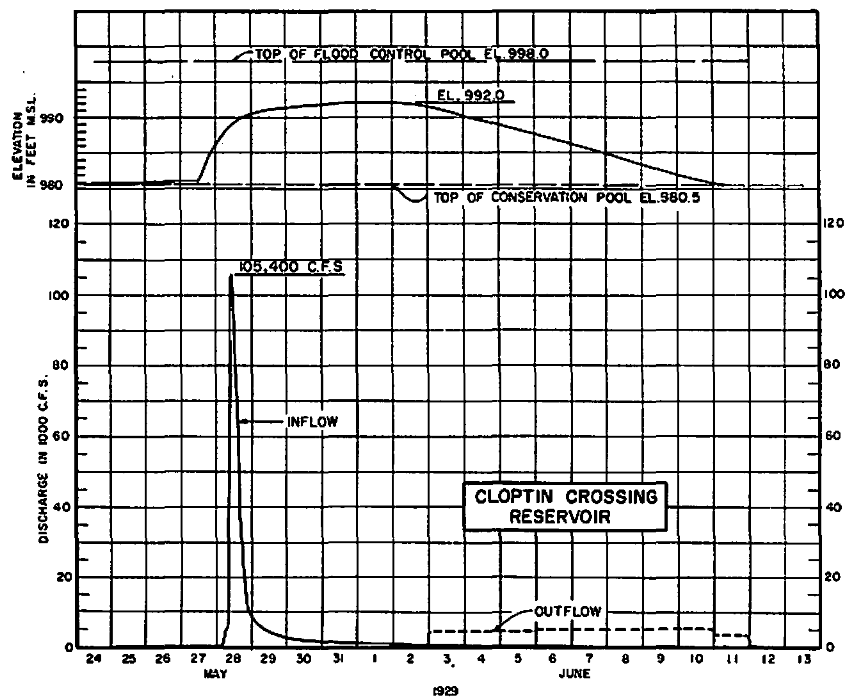
FLOOD OF JUNE 1958

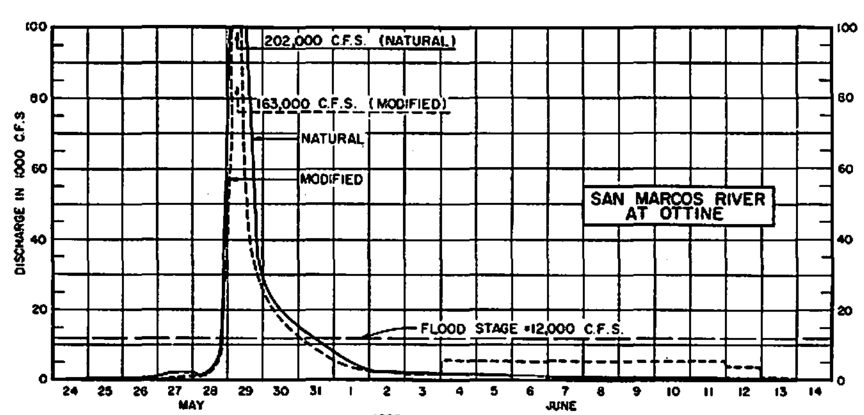
SCALE AS SHOWN

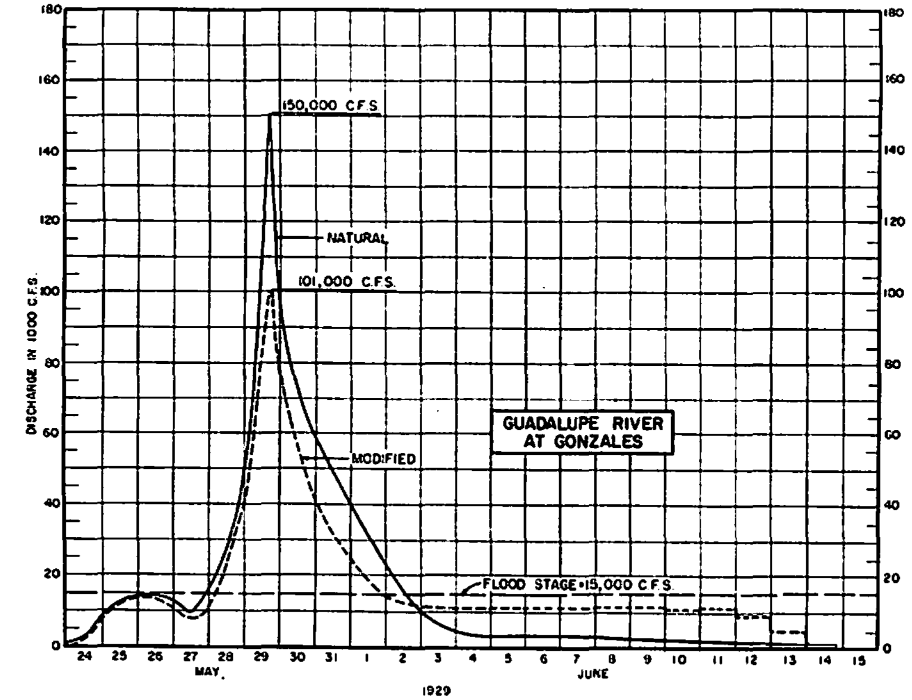
U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

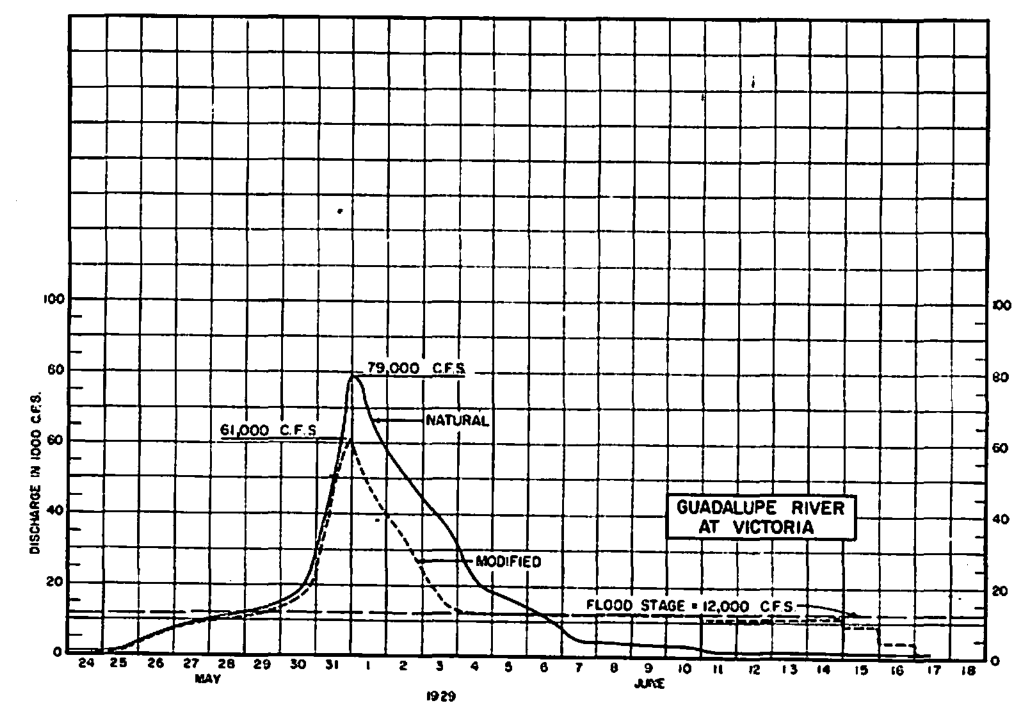
SUBMITTED	APPROVAL RECOMMENDED	APPROVED
CHIEF, PROJECT PLANNING BRANCH	CHIEF, ENGINEERING DIVISION	DISTRICT ENGINEER
PREPARED: CHIEF, HYDROLOGY SECTION	DRAWN BY; CHECKED BY	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
		FILE: GUAD. 707-2











GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
BLANCO RIVER

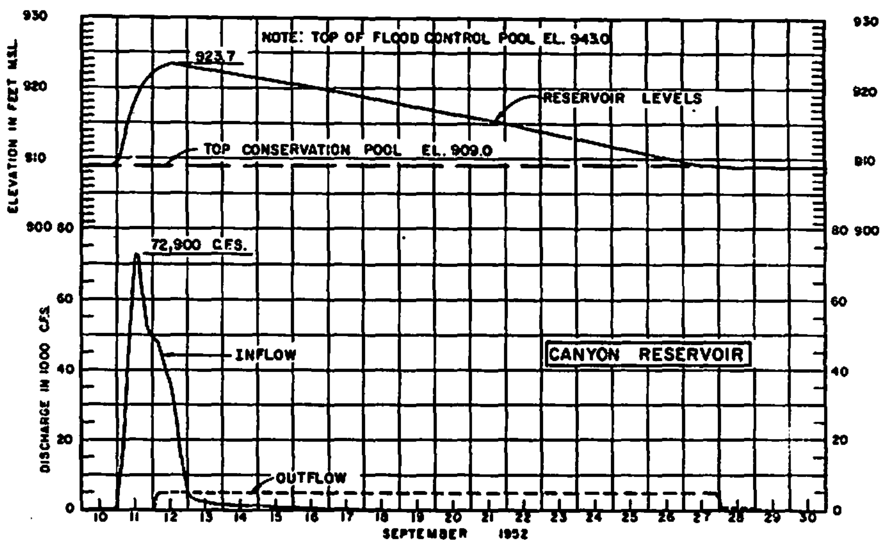
RESERVOIR REGULATION

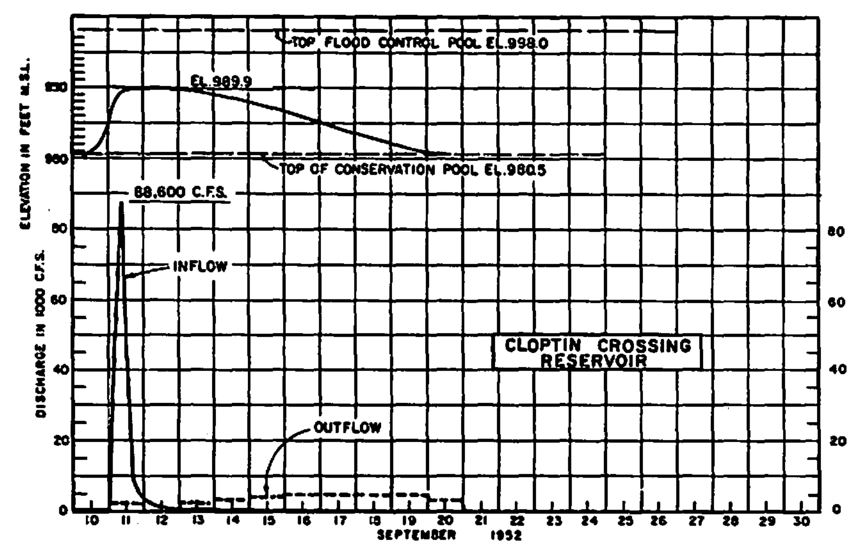
FLOOD OF MAY - JUNE 1929

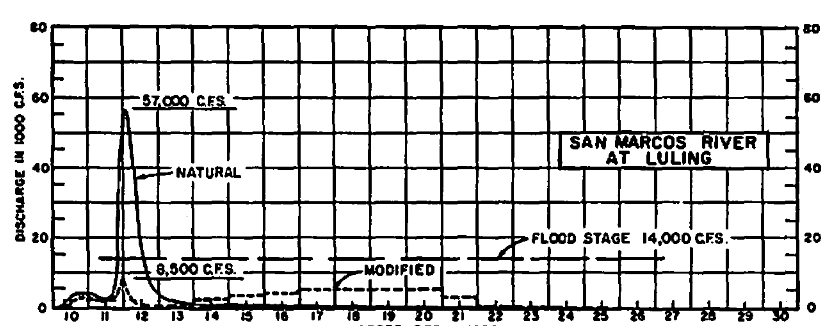
SCALE AS SHOWN

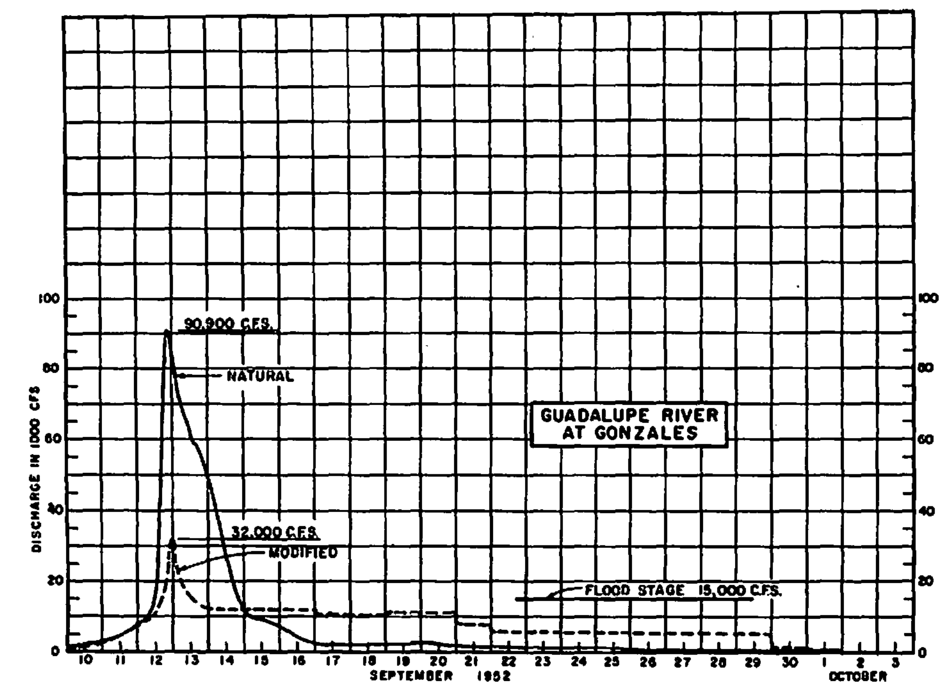
U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC. 1964

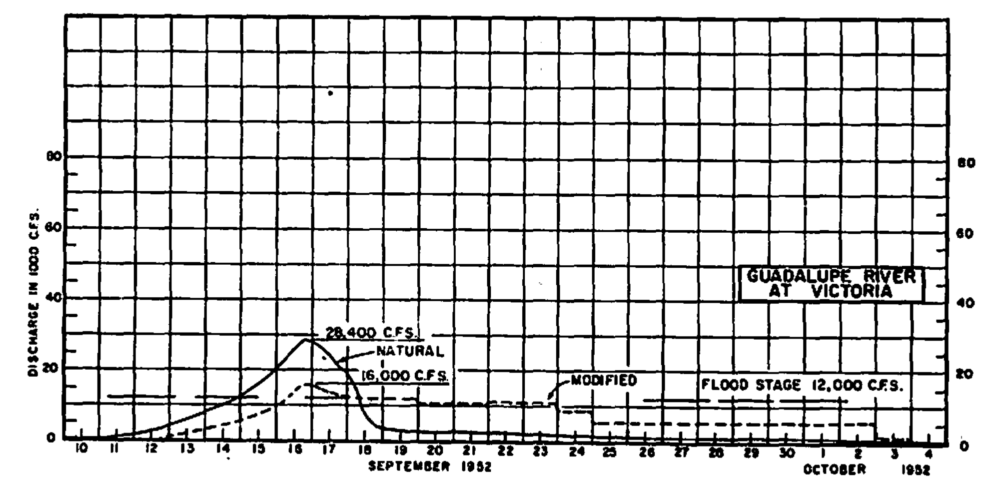
SUBMITTED — CHIEF, PROJECT PLANNING BRANCH
APPROVAL RECOMMENDED — CHIEF, ENGINEERING DIVISION
APPROVED — DISTRICT ENGINEER
PREPARED — ENGINEER
DRAWN BY: B.I.
CHECKED BY: R.A.S.
TO ACCOMPANY SURVEY REPORT CONCERNING EDWARDS UNDERGROUND RESERVOIR
FILE: GUAD 707-2











GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
BLANCO RIVER

RESERVOIR REGULATION

FLOOD OF SEPTEMBER 1952

SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED: W. E. Wood, CHIEF, PROJECT PLANNING BRANCH — APPROVAL RECOMMENDED: C. E. [signature], CHIEF, ENGINEERING DIVISION — APPROVED: [signature], DISTRICT ENGINEER

PREPARED: [signature]

DRAWN BY: R.R. CHECKED BY: W.A.B.

TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR

FILE: GUAD.707-R

TABLE 34

INFILTRATION AND RUNOFF DATA
NUECES RIVER BASIN

Date of storm	Rainfall (inches)	Runoff (inches)	Runoff (Percent)	Initial Loss (inches)	Infiltration Index (inches/hr.)	Conditions preceding each storm
NUECES RIVER NEAR LAGUNA, TEXAS (DRAINAGE AREA - 764 square miles)						
September 1-2, 1932	4.60	1.65	35.9	1.50	0.18	Moist - Light rain August 25-30; heavy rain August 31.
September 16, 1936	3.03	1.40	46.2	0.50	0.17	Moist - Light rain on September 12; heavy rain on September 13; light rain on September 14; heavy rain on September 15.
July 12-13, 1939	4.72	2.18	46.2	1.30	0.17	Dry - No rain July 1-8; light rain July 9; no rain July 10; light rain July 11.
September 23-24, 1955	8.47	3.78	44.6	2.00	0.36	Dry - No rain September 1-12; light rain September 13; no rain September 14-22
FRIO RIVER NEAR CONCAN, TEXAS (DRAINAGE AREA - 405 square miles)						
June 30-July 1, 1932	12.59	5.75	46.0	2.80	0.45	Dry - No rain June 5-29.
June 13-14, 1935	5.95	4.79	80.5	0.25	0.09	Wet - Light rain June 1-2; no rain June 3-4; moderate rain June 5; no rain June 6-9; light rain June 10; moderate rain June 11; heavy rain June 12.
September 16, 1936	4.31	1.71	39.7	0.90	0.42	Moist - No rain September 1-12; moderate rain September 13; heavy rain September 14-15.
SABINAL RIVER NEAR SABINAL, TEXAS (DRAINAGE AREA - 206 square miles)						
May 15, 1951	1.46	0.27	18.5	0.50	0.50	Dry - Moderate rain on May 6; no rain May 7-13; light rain May 14.
May 23-24, 1954	2.07	0.44	21.3	1.20	0.30	Dry - No rain May 1-17; light rain May 18; no rain May 19-22.
June 16-17, 1958	10.50	2.46	23.4	3.50	0.48	Dry - No rain June 1-15.

TABLE 35

INFILTRATION AND RUNOFF DATA
BLANCO RIVER WATERSHED

Date of storm	Rainfall (inches)	Runoff (inches)	Runoff (Percent)	Initial Loss (inches)	Infiltration Index (inches/hr.)	Conditions preceding each storm
BLANCO RIVER NEAR WIMBERLEY (DRAINAGE AREA - 353 square miles)						
May 27-28, 1929	8.95	3.69	41.2	1.80	.44	Moist - Light rain May 11-18; no rain May 19-22; heavy rain May 24 & 26; trace on May 25.
May 10-12, 1930	1.67	.28	16.8	1.00	.61	Dry - Light rain May 2-6; moderate rain May 7; no rain on May 8-9.
June 30-July 1, 1936	3.92	1.01	25.8	1.00	.46	Dry - No rain June 1-27; light rain on June 28; moderate rain June 29.
April 27-28, 1938	2.16	.48	22.2	0.90	.49	Dry - No rain April 8-14, moderate rain April 15-19; no rain April 20-24; light rain April 25-26.
April 7-8, 1942	2.34	.30	12.8	1.50	.82	Dry - Light rain April 1; no rain April 2-6.
September 9-10, 1952	13.75	4.02	29.3	1.50	.50	Dry - No rain August 1-September 8.
April 24-25, 1957	4.47	1.22	27.3	2.80	.25	Moist - Light rain April 1-4; no rain April 5-10; trace April 11-14, 18, 21; light rain April 15-17, 23; moderate rain April 19,22.
May 2-3, 1958	3.15	1.68	53.3	0.80	.42	Dry - No rain April 22-25, 29; light rain April 26-27; trace April 28, 30; light rain May 1.
BLANCO RIVER NEAR KYLE (DRAINAGE AREA - 410 square miles)						
October 3-4, 1959	6.08	.68	11.2	3.00	.57	Dry - No rain September 15-21; light rain September 22-25; no rain September 26-28; light rain September 29-30; light rain October 1; no rain October 2.

comparative values adopted for the Sabinal and Blanco River watersheds are 1.00 inch and 0.25 inch per hour. These adopted values were used in the preparation of the spillway design flood hydrographs.

55. UNIT HYDROGRAPH STUDIES AND SYNTHETIC UNIT HYDROGRAPHS.- Unit hydrograph determinations were made for selected storms for which hydrographs were available at the Laguna gage on the Nueces River, at the Concan gage on the Frio River, at the near Sabinal gage on the Sabinal River, and at the Wimberley gage on the Blanco River. These studies were made in accordance with EM 1110-2-1405. The studies on the Blanco River watershed were submitted to the Office, Chief of Engineers, with letter SWFGP-Hy, subject: "Unit Hydrograph Compilation, Blanco River at Wimberley, Guadalupe River Basin, Texas," dated June 19, 1963. Those on the Nueces River watershed were submitted with letter SWFGP-Hy, subject: "Unit Hydrograph Compilations, Nueces River at Laguna, Frio River at Concan, Sabinal River near Sabinal, Nueces River Basin, Texas," dated March 4, 1964. Unit hydrograph pertinent data for the storms studied on the Nueces River at Laguna, Texas; the Frio River at Concan, Texas; Sabinal River near Sabinal, Texas; and the Blanco River at Wimberley, Texas, are shown on plates 29 through 32, respectively. These unit hydrograph determinations were used as a basis for the adoption of the following coefficients to be used in Snyder's equations for the derivation of synthetic 3-hour unit hydrographs: Upper Nueces River watershed Ct = 0.60, Cp640 = 450; Blanco River watershed Ct = 0.65, Cp640 = 450. The adopted coefficients, representing a 3-hour duration, were adjusted in accordance with EM 1110-2-1405 to a 2-hour duration for use at Sabinal Reservoir. The synthetic unit hydrographs for natural flow at the dam sites were developed for selected periods of rainfall in accordance with EM 1110-2-1405. The unit hydrographs for flow into full reservoirs were derived by subdividing the drainage area above the dam sites into several areas as follows: (a) reservoir area, (b) area adjacent to the reservoir composed of numerous small areas with no well-defined drainage divides, and (c) the portion of several creeks from sides and above the head of reservoirs. Unit hydrographs were developed for the individual areas and the ordinates of these unit hydrographs added graphically to obtain the composite unit hydrograph for flow into full reservoir. The runoff from the reservoir area was not included in the unit hydrograph for flow into full reservoir; but runoff rates were assumed equal to rainfall rates and added directly to the computed design flood. The synthetic unit hydrographs for natural flow and for flow into full reservoir for the four projects are given in tables 36 through 39.

56. SPILLWAY DESIGN STORMS.- The spillway design storms adopted for use in this report were computed following a method described in the U. S. Weather Bureau Hydrometeorological Report No. 33, dated April 1956, subject: "Seasonal Variations of the Probable Maximum Precipitation East of the 105th Meridian for Areas From 10 to 1,000 Square Miles and Durations of 6, 12, 24, and 48 hours." The rainfall quantities as

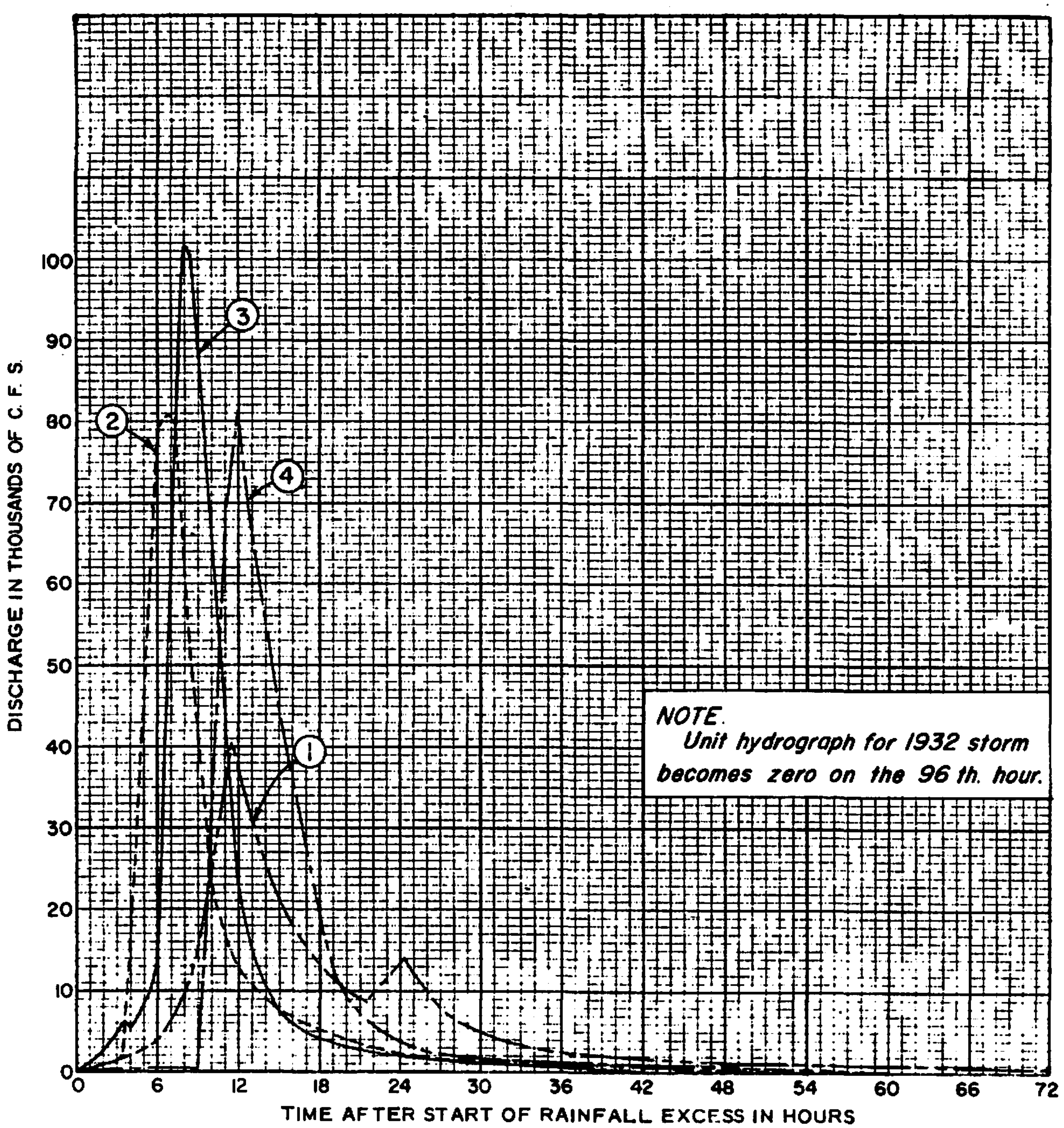
determined from H.R. No. 33 are not adjusted for differences in shape and orientation between the pattern storms and the watersheds above the investigated dam sites. Therefore, based upon analyses of appropriate pattern storms, a ten percent basin shape reduction factor was adopted for each of the projects.

57. The distribution of the maximum 6-hour rainfall was determined in accordance with the method set forth in EM 1110-2-1411 (Civil Works Engineer Bulletin No. 52-8, dated March 26, 1952, subject: "Standard Project Flood Determinations.") A 3-hour increment of rainfall was used for Montell, Concan, and Cloptin Crossing Reservoir. For Sabinal Reservoir the rainfall was broken down in 2-hour increments. The ten percent basin shape reduction factor was applied to the unadjusted rainfall, and smooth curves were drawn through points based upon the adjusted rainfall values. The predetermined increments of rainfall were taken from these curves. The critical arrangements of rainfall adjusted for basin shape and adopted as the spillway design storm rainfall for Montell, Concan, Sabinal, and Cloptin Crossing Reservoirs are shown in tables 40 through 43, respectively. The tables also indicate the loss and rainfall excess for the above projects.

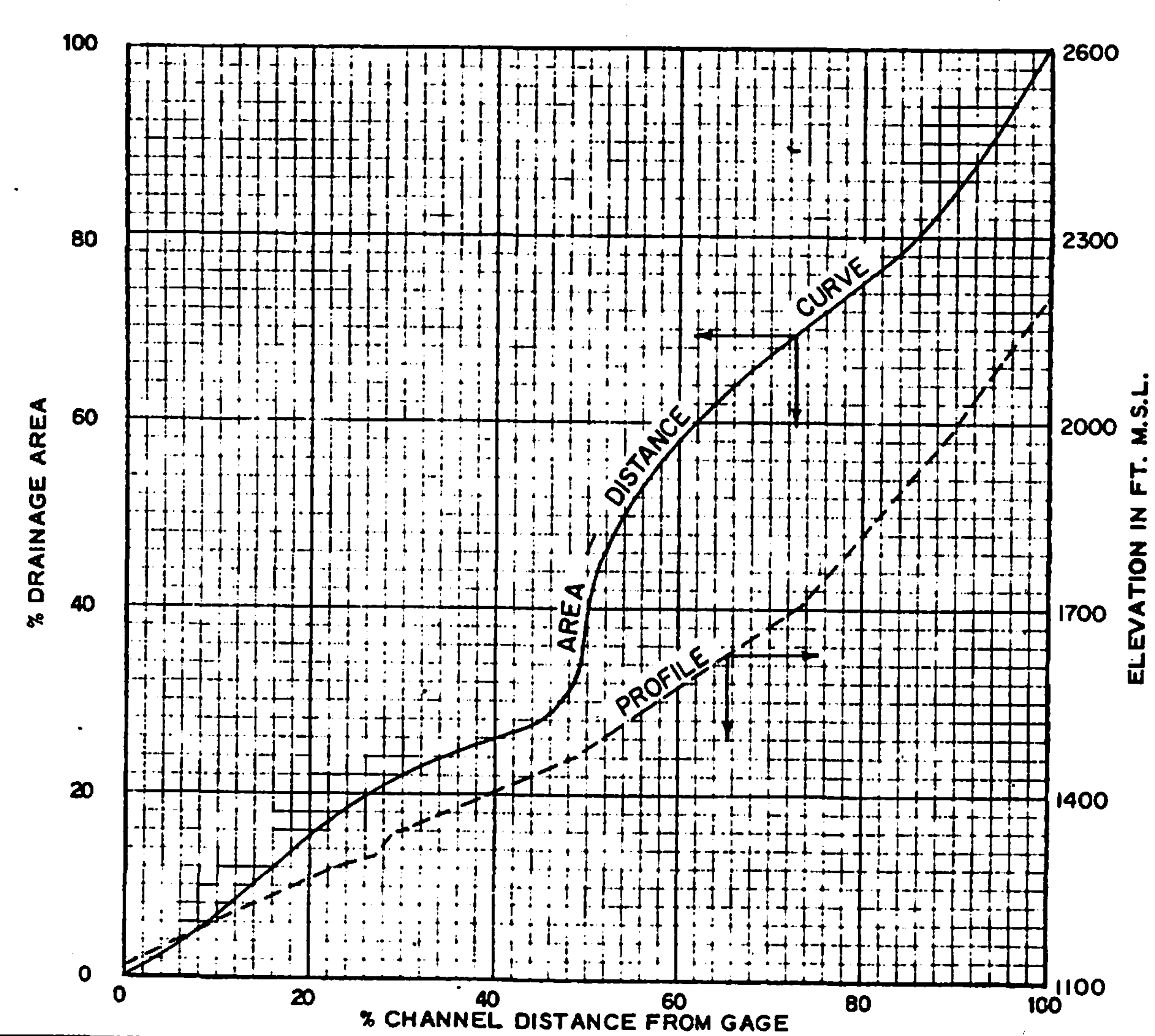
58. SPILLWAY DESIGN FLOOD HYDROGRAPHS.- Spillway design flood hydrographs representing flow into full reservoirs were determined for Montell, Concan, Sabinal, and Cloptin Crossing Reservoirs by applying the rainfall-excess values given in tables 40 through 43 to the appropriate unit hydrographs given in tables 36 through 39, and adding to the resultant flood hydrograph the runoff from the reservoir surface (assumed at a rate equal to the rate of rainfall). As a result of a study of average base flow conditions at the dam sites, no base flow was considered in the computation of the spillway design floods. The resulting spillway design flood hydrographs had, at Montell, a peak discharge of 893,900 second-feet, and a runoff volume of 821,300 acre-feet; at Concan, a peak discharge of 592,500 second-feet, and a runoff volume of 489,400 acre-feet; at Sabinal, a peak discharge of 381,800 second-feet, and a runoff volume of 249,000 acre-feet; and at Cloptin Crossing, a peak discharge of 414,900 second feet, and a runoff volume of 353,000 acre-feet.

59. The spillway design flood hydrographs for natural flow at the dam sites were based on the unit hydrographs for natural flow at dam site given in tables 36 through 39 and the rainfall excess given in tables 40 through 43. The computed natural hydrographs had, at Montell, a peak discharge of 882,000 second-feet, and a runoff volume of 815,600 acre-feet; at Concan, a peak discharge of 591,600 second-feet, and a runoff volume of 485,900 acre-feet; at Sabinal, a peak discharge of 336,700 second-feet, and a runoff volume of 245,300 acre-feet; and at Cloptin Crossing, a peak discharge of 409,800 second-feet, and a runoff volume of 343,800 acre-feet.

OBSERVED UNIT HYDROGRAPHS



DRAINAGE AREA CHARACTERISTICS			
DRAINAGE AREA	764 sq. mi.	L	60.2 mi.
MAXIMUM ELEVATION	2400 ft. m.s.l.	L_{ca}	30.6 mi.
MINIMUM ELEVATION	1220 ft. m.s.l.	$(LL_{ca})^{0.3}$	9.54
MEAN ELEVATION (weighted)	ft. m.s.l.	DRAINAGE DENSITY	0.511 mi. / sq. mi.
LAND SLOPE	ft. / mi.	MAP SCALE	1:250,000
MAIN STREAM SLOPE	17.85 ft./mi.	METHOD OF FLOW SEPARATION	TYPE "A"
		BASIN SHAPE FACTOR	4.74

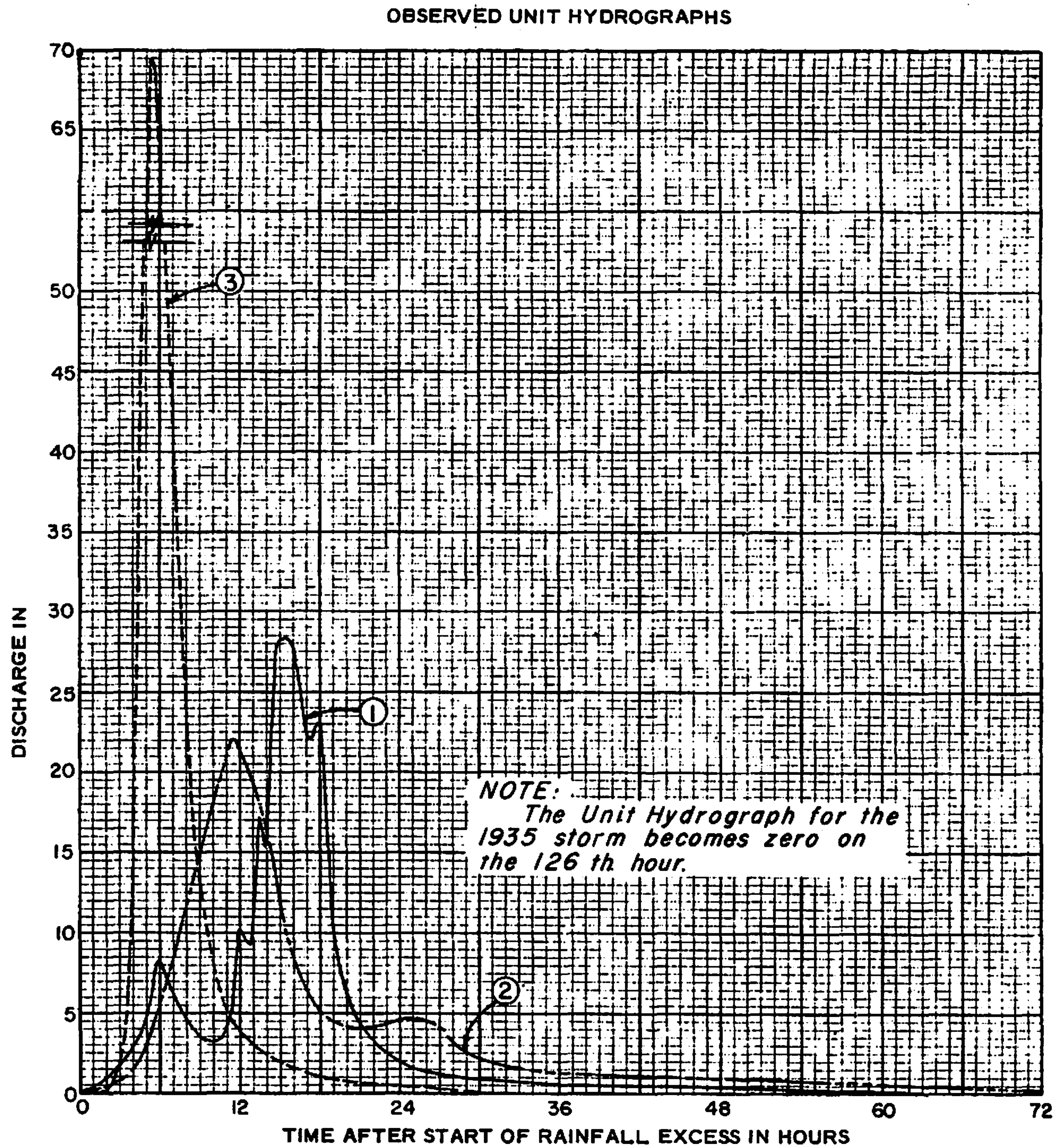


DATE OF RAINFALL	LEGEND	AVE. P (in.)	RAINFALL EXCESS DURATION (hr.)	RAINFALL EXCESS AMOUNT (in.)	L_{cP} (mi.)	STAGE RECORD	Q_{pR} (c.f.s.)	Q_p tr= 2 hrs. (c.f.s.)	t_{pR} (hr.)	t_p (hr.)	t_v (hr.)	C_{tR}	C_p640	K_m (hr.)	T_c (hr.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1-2 SEPT. 1932	1	4.60	6	1.65	Upstr	REC.	40,550	38,600*	8 5	9.0	12.6	.89	451	3.58	11.0
16 SEPT. 1936	2	3.03	3	1.40	Upstr	REC.	80,770	78,290**	5.0	4.5	6.4	.52	530	2.99	7.5
12-13 JULY 1939	3	4.72	6	2.18	Center	REC	101,610	110,650	3 4	3.0	5.1	.36	452	2.15	5.0
23-24 SEPT. 1955	4	8.47	9	3.78	Upstr	REC.	81,090	82,150	4 5	4.5	6.5	.48	487	3.24	10.5
* tr = 6 hrs.	** tr = 3 hrs.														

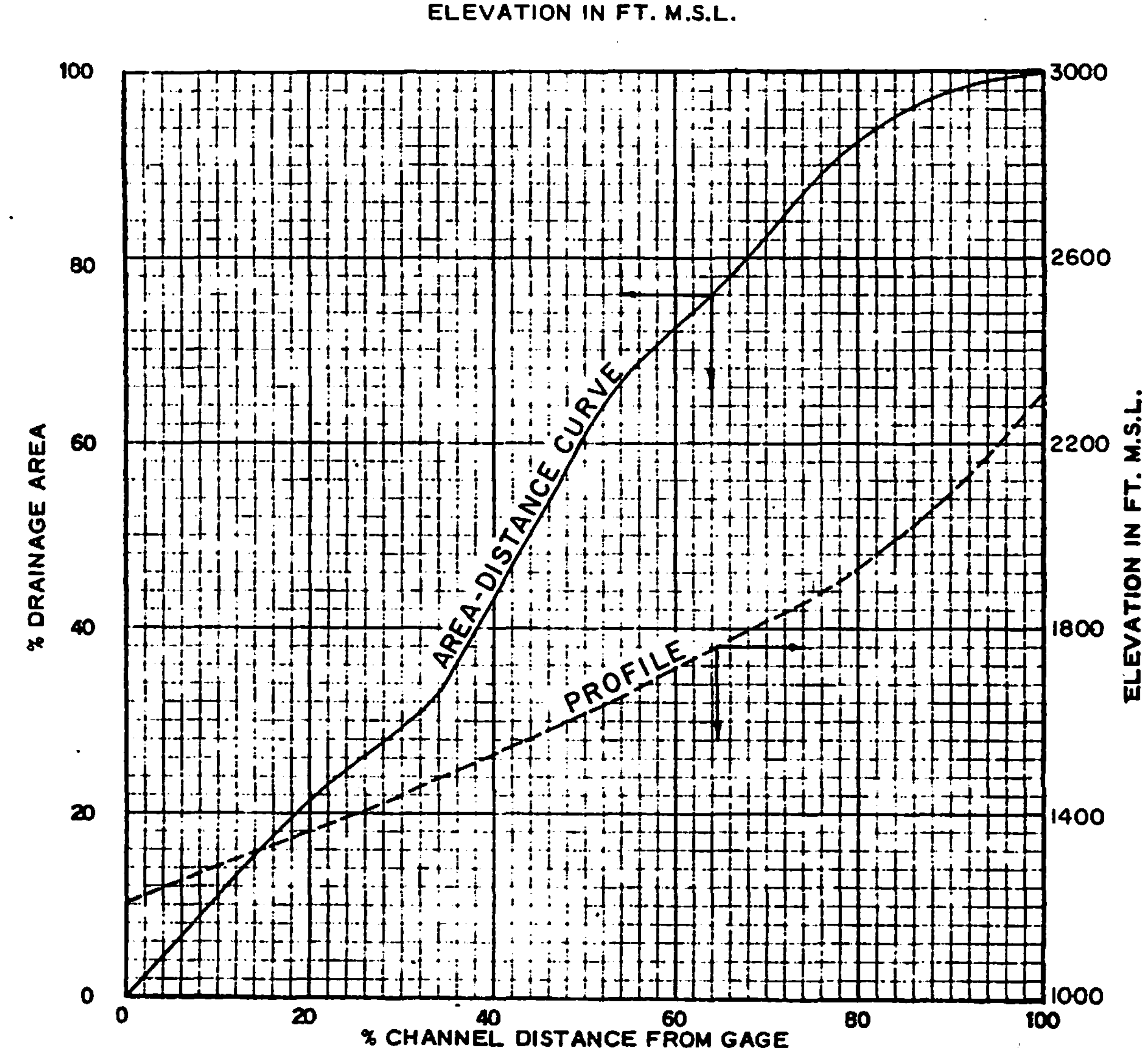
ENGINEERING INVESTIGATIONS
UNIT HYDROGRAPHS

PERTINENT DATA
NUECES RIVER BASIN
NUECES RIVER AT LAGUNA, TEXAS

SUBMITTED BY
DISTRICT ENGINEER, FORT WORTH DISTRICT



DRAINAGE AREA CHARACTERISTICS			
DRAINAGE AREA	405 sq. mi.	L	41.8 mi.
MAXIMUM ELEVATION	2371.0 ft. m.s.l.	L_{ca}	23.6 mi.
MINIMUM ELEVATION	1204.0 ft. m.s.l.	$(LL_{ca})^{0.3}$	7.9
MEAN ELEVATION (weighted)	ft. m.s.l.	DRAINAGE DENSITY	0.68 mi./sq. mi.
LAND SLOPE	ft./mi.	MAP SCALE	1:250,000
MAIN STREAM SLOPE	15.68 ft./mi.	METHOD OF FLOW SEPARATION	TYPE A
		BASIN SHAPE FACTOR	4.31



DATA FROM OBSERVED UNIT HYDROGRAPHS

DATE OF RAINFALL	LEGEND	AVE. P (in.)	RAINFALL EXCESS DURATION (hr.)	RAINFALL EXCESS AMOUNT (in.)	L_cP (mi.)	STAGE RECORD	Q_{pR} (c.f.s.)	Q_p tr = 3 hrs. (c.f.s.)	t_{pR} (hr.)	t_p (hr.)	t_v (hr.)	C_{tR}	C_p640	K_m (hr.)	T_c (hr.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
30 JUNE-1 JULY 1932	——(1)	12.59	9	5.75	Upstr	Rec	28080	38400	4.8	4.5	4.0	0.61	332	2.5	4.5
13-14 JUNE 1935	-----(2)	5.95	12	4.79	Upstr	Rec	21920	37690	5.4	4.5	7.2	0.68	293	3.7	4.5
16 SEPT. 1936	---(3)	4.31	4	1.71	Unifor	Rec	69060	69300*	2.7	3.0	2.5	0.34	460	2.0	3.0

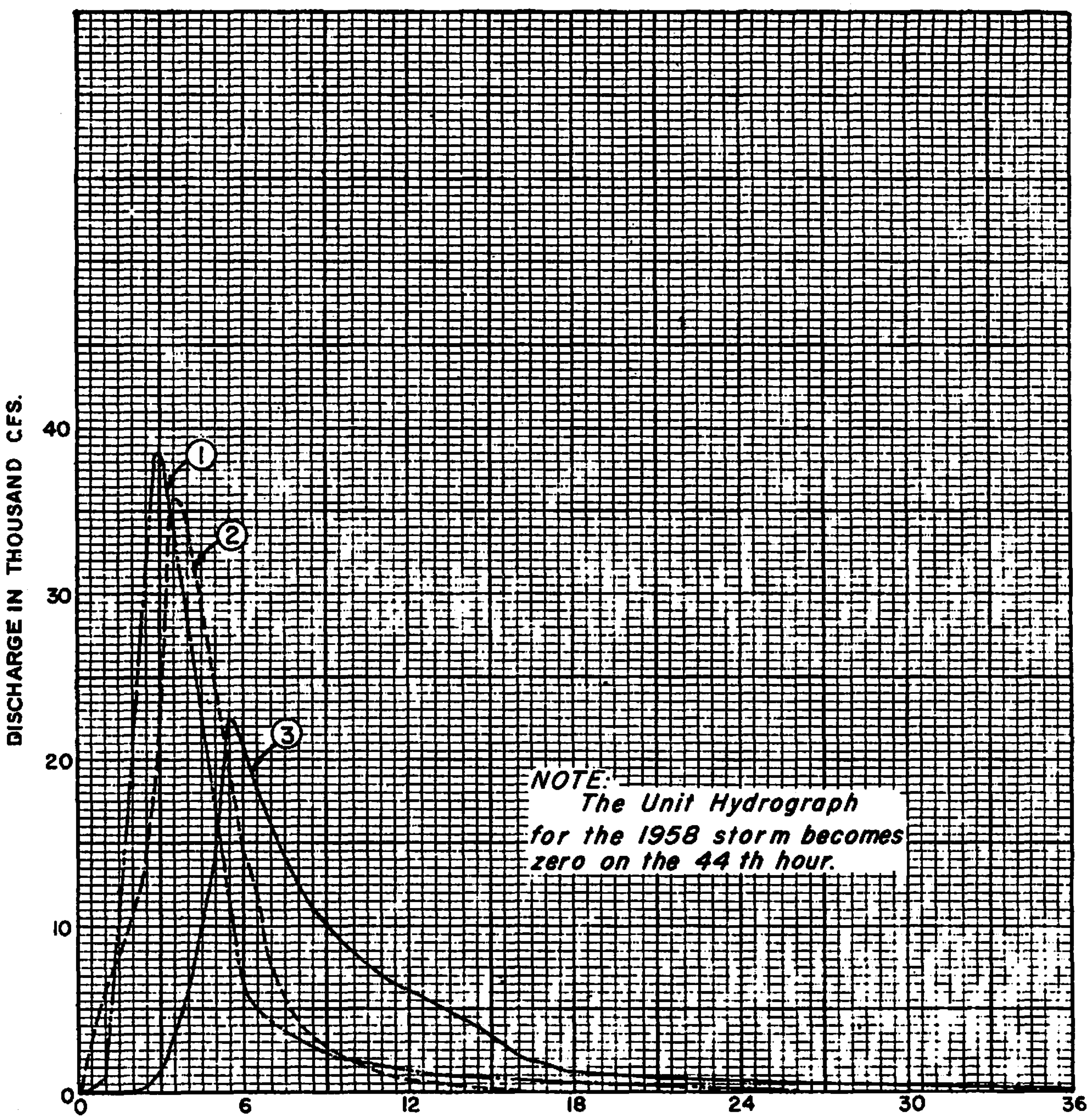
*t_r = 2 hours

ENGINEERING INVESTIGATIONS
UNIT HYDROGRAPHS

PERTINENT DATA
NUECES RIVER BASIN
FRIO RIVER AT CONCAN, TEXAS

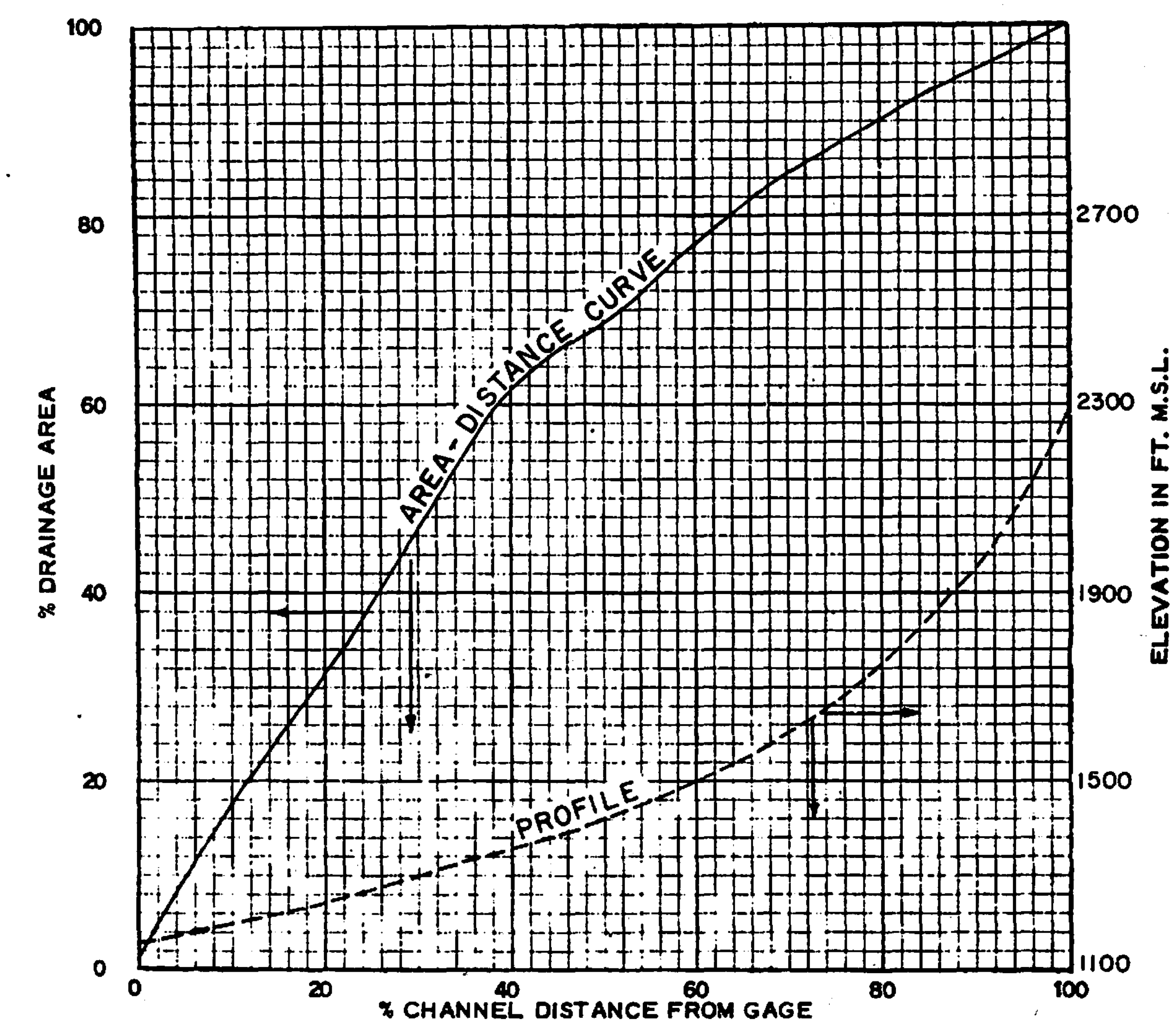
SUBMITTED BY
DISTRICT ENGINEER, FORT WORTH DISTRICT

OBSERVED UNIT HYDROGRAPHS



DRAINAGE AREA CHARACTERISTICS			
DRAINAGE AREA	206 sq. mi.	L	31.96 mi.
MAXIMUM ELEVATION	2300 ft. m.s.l.	L_{ca}	16.69 mi.
MINIMUM ELEVATION	1150 ft. m.s.l.	$(LL_{ca})^{0.3}$	6.58
MEAN ELEVATION (weighted)	ft. m.s.l.	DRAINAGE DENSITY	0.624 mi. / sq. mi.
LAND SLOPE	ft. / mi.	MAP SCALE	1:250,000
MAIN STREAM SLOPE	25.87 ft. / mi.	METHOD OF FLOW SEPARATION	TYPE A
		BASIN SHAPE FACTOR	4.96

ELEVATION IN FT. M.S.L.



DATA FROM OBSERVED UNIT HYDROGRAPHS															
DATE OF RAINFALL	LEGEND	AVE. P (in.)	RAINFALL EXCESS DURATION (hr.)	RAINFALL EXCESS AMOUNT (in.)	L_{cP} (mi.)	STAGE RECORD	Q_{pR} (c.f.s.)	Q_p tr = 1 hrs. (c.f.s.)	t_{pR} (hr.)	t_p (hr.)	t_v (hr.)	C_{tR}	C_p640	K_m (hr.)	T_c (hr.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
15 MAY 1951	——(1)	1.46	1.0	0.27	Upst	Rec	38560	38560	2.5	2.5	3.3	0.38	468	1.0	4.5
23-24, MAY 1954	--- (2)	2.07	2.0	0.44	unifor	Rec	35710	*38970	2.4	2.2	3.1	0.36	409	2.1	4.1
16-17 JUNE 1958	——(3)	10.50	6.0	2.46	unifor	Rec	22420	**29060	2.4	3.0	4.9	0.37	263	3.1	3.9

* t_r = 0.50 hrs.

** t_r = 2.0 hrs.

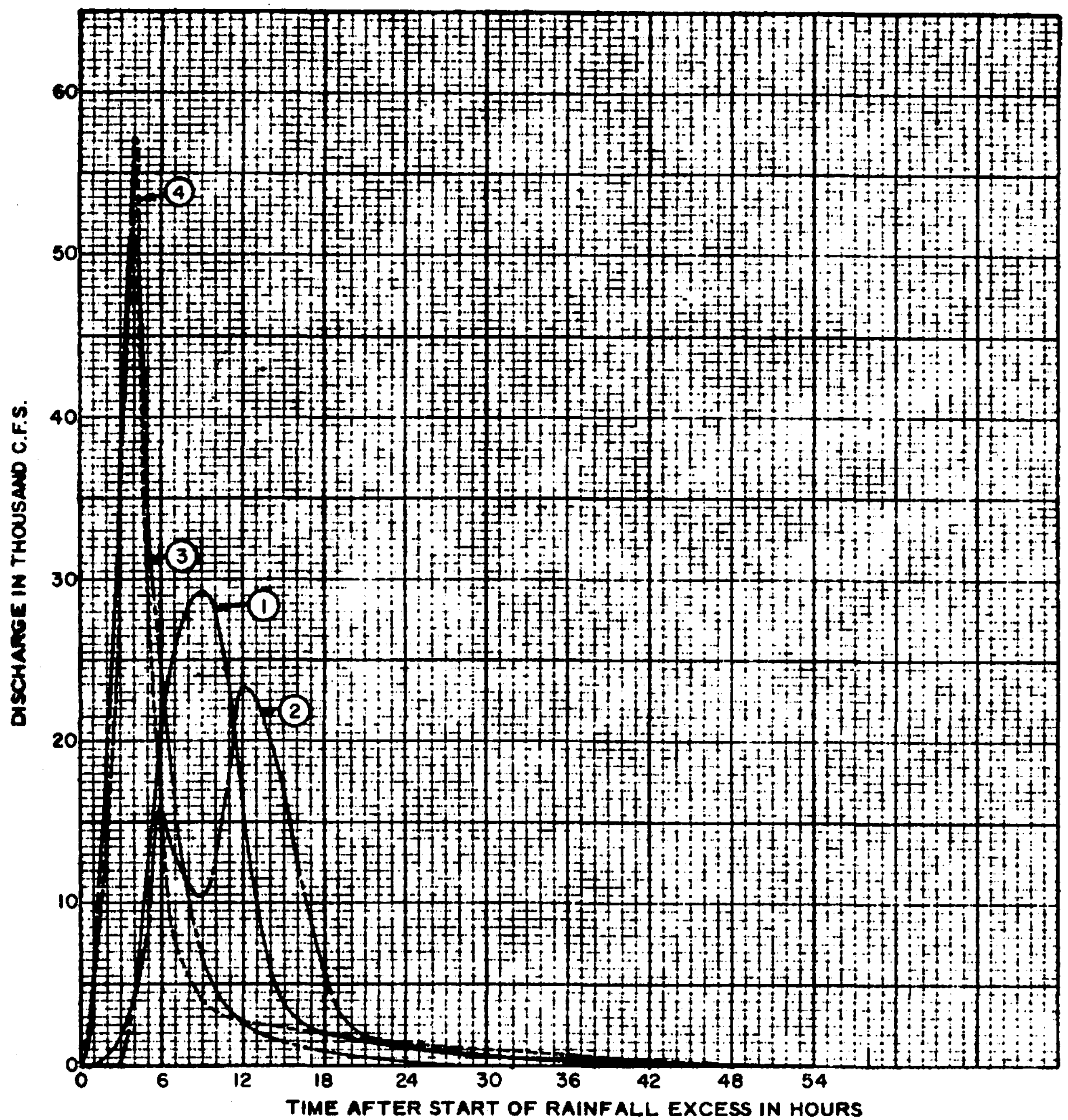
ENGINEERING INVESTIGATIONS
UNIT HYDROGRAPHS

PERTINENT DATA
NUECES RIVER BASIN

SABINAL RIVER
NEAR SABINAL, TEXAS

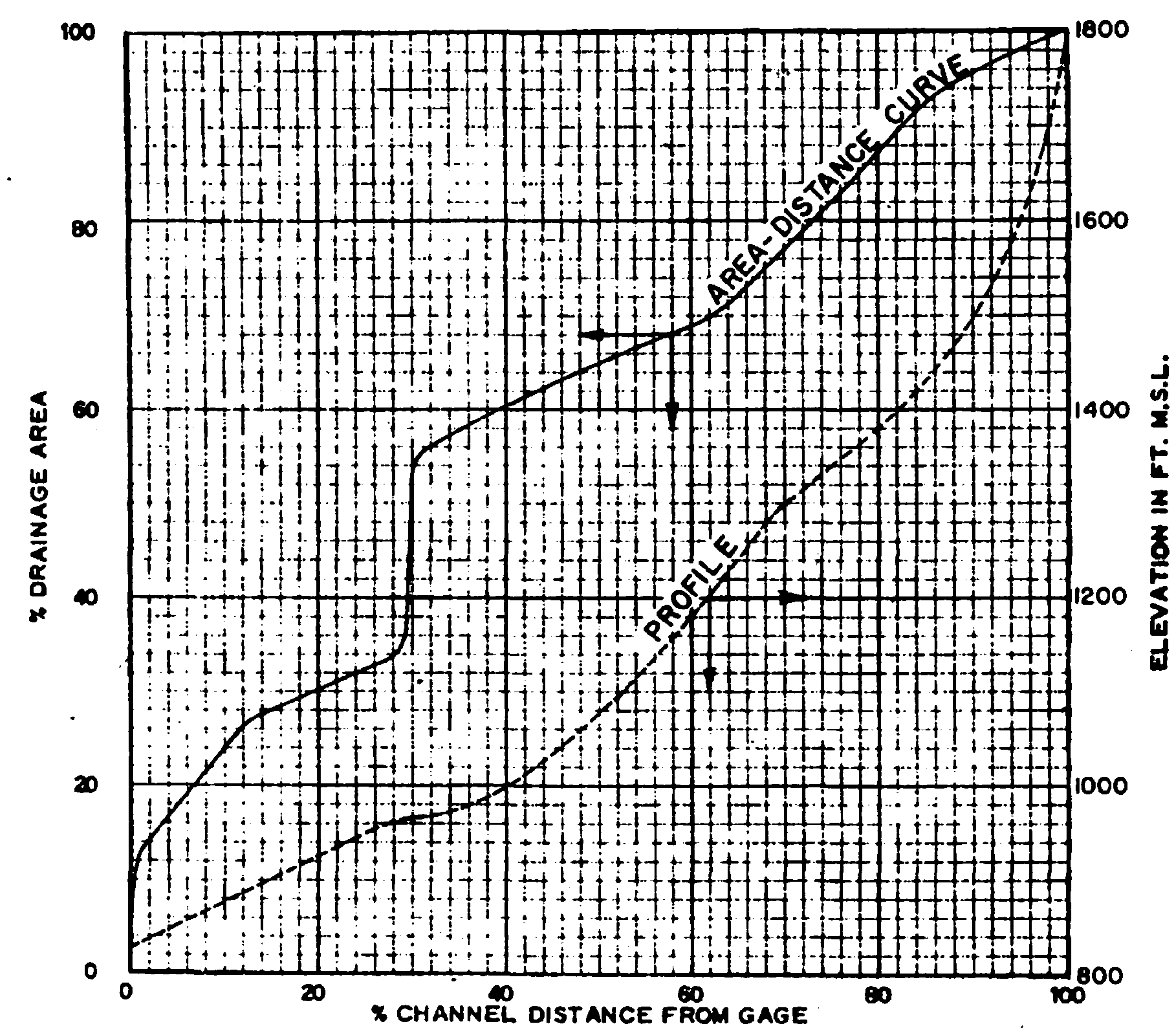
SUBMITTED BY
DISTRICT ENGINEER, FORT WORTH DISTRICT

OBSERVED UNIT HYDROGRAPHS



DRAINAGE AREA CHARACTERISTICS

DRAINAGE AREA	364 sq. mi.	L	56.3 mi.
MAXIMUM ELEVATION	2000 ft. m.s.l.	L_{ca}	29.6 mi.
MINIMUM ELEVATION	820 ft. m.s.l.	$(LL_{ca})^{0.3}$	9.2
MEAN ELEVATION (weighted)	ft. m.s.l.	DRAINAGE DENSITY	.771 mi./sq. mi.
LAND SLOPE	ft./mi.	MAP SCALE	1:250,000
MAIN STREAM SLOPE	11.2 ft./mi.	METHOD OF FLOW SEPARATION	TYPE A
		BASIN SHAPE FACTOR	8.37



DATA FROM OBSERVED UNIT HYDROGRAPHS

DATE OF RAINFALL	LEGEND	AVE. P (in.)	RAINFALL EXCESS DURATION (hr.)	RAINFALL EXCESS AMOUNT (In.)	L_{cP} (mi.)	STAGE RECORD	Q_{pR} (c.f.s.)	Q_p tr = 3 hrs. (c.f.s.)	t_{pR} (hr.)	t_p (hr.)	t_v (hr.)	C_{tR}	C_p640	K_m (hr.)	T_c (hr.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
30 JUNE-2 JULY,1936	——(1)	3.97	6	1.01	Dnstr	REC.	29,320	32,000	5.29	4.5	5.66	.57	426	2.4	7.5
9-11 SEPT. 1952	—–—(2)	15.48	3	4.02	Upstr	REC.	23,620	23,600	8.15	7.5	6.39	.89	529	3.0	13.5
24-25 APRIL, 1957	----(3)	4.47	2	1.22	Upstr	REC.	51,050	51,050*	3.0	3.0	2.70	.33	421	2.7	7.0
2-3 MAY, 1958	------(4)	3.15	2	1.68	Upstr	REC.	57,200	57,200*	3.0	3.0	2.64	.33	471	1.8	5.0

NOTE
* tr.= 2.0 HRS.

ENGINEERING INVESTIGATIONS
UNIT HYDROGRAPHS

PERTINENT DATA
GUADALUPE RIVER BASIN
BLANCO RIVER, WIMBERLEY, TEXAS

SUBMITTED BY
DISTRICT ENGINEER, FORT WORTH DISTRICT

TABLE 36
SYNTHETIC UNIT HYDROGRAPH FOR
A UNIFORM 3-HOUR RAINFALL
MONTELL DAM AND RESERVOIR - 707 sq. mi.

Time in 3-hour periods	Unit Hydrographs (cfs)	
	Flow into full reservoir	Natural flow at damsite
0	0	0
1	23,420	5,600
2	59,230	60,940
3	33,780	33,540
4	15,700	18,200
5	8,700	12,200
6	5,000	8,500
7	2,700	5,800
8	1,000	3,900
9	400	2,100
10	0	1,000
11		300
12		0
Total	149,930	152,080

TABLE 37
SYNTHETIC UNIT HYDROGRAPHS FOR
A UNIFORM 3-HOUR RAINFALL
CONCAN DAM AND RESERVOIR - 391 sq. mi.

Time in 3-hour periods	Unit Hydrographs (cfs)	
	Flow into full reservoir	Natural flow at damsite
0	0	0
1	20,610	5,060
2	35,620	37,840
3	14,000	20,210
4	6,000	8,400
5	3,600	5,200
6	1,800	3,400
7	800	2,100
8	390	1,300
9	0	600
10		0
Total	82,820	84,110

TABLE 38
SYNTHETIC UNIT HYDROGRAPHS FOR
A UNIFORM 2-HOUR RAINFALL
SABINAL DAM AND RESERVOIR - 210 sq. mi.

Time in 2-hour periods	Unit Hydrographs (cfs)	
	Flow into full reservoir	Natural flow at damsite
0	0	0
1	14,460	1,220
2	24,430	23,040
3	13,550	16,000
4	7,400	10,000
5	3,700	6,000
6	1,700	4,000
7	700	2,500
8	200	1,500
9	0	700
10		0
Total	66,140	67,760

TABLE 39
SYNTHETIC UNIT HYDROGRAPH FOR
A UNIFORM 3-HOUR RAINFALL
CLOPTIN CROSSING DAM AND RESERVOIR - 307 sq. mi.

Time in 3-hour periods	Unit Hydrographs (cfs)	
	Flow into full reservoir	Natural flow at damsite
0	0	0
1	12,230	4,090
2	23,620	24,150
3	13,500	16,400
4	6,300	6,000
5	3,600	5,300
6	2,200	3,500
7	1,350	2,100
8	650	900
9	0	0
Total	63,450	66,040

TABLE 40
RAINFALL AND RAINFALL-EXCESS FOR SPILLWAY DESIGN STORM
MONTELL DAM AND RESERVOIR

3-hour period	Average rainfall (inches)	Loss (inches)	Rainfall-excess (inches)
0	0	0	0
1	.41	.41	0
2	.42	.42	0
3	.43	.43	0
4	.43	.43	0
5	.44	.44	0
6	.45	.45	0
7	.48	.45	.03
8	.49	.45	.04
9	.50	.45	.05
10	.51	.45	.06
11	.52	.45	.07
12	.55	.45	.10
13	.58	.45	.13
14	.60	.45	.15
15	.63	.45	.18
16	.67	.45	.22
17	.76	.45	.31
18	.84	.45	.39
19	1.05	.45	.60
20	1.39	.45	.94
21	2.00	.45	1.55
22	3.11	.45	2.66
23	12.46	.45	12.01
24	2.59	.45	2.14
Total	32.31	10.68	21.63

TABLE 41
RAINFALL AND RAINFALL-EXCESS FOR SPILLWAY DESIGN STORM
CONCAN DAM AND RESERVOIR

3-hour period	Average rainfall (inches)	Loss (inches)	Rainfall-excess (inches)
0	0	0	0
1	.46	.46	0
2	.46	.46	0
3	.47	.45	.02
4	.47	.45	.02
5	.47	.45	.02
6	.47	.45	.02
7	.47	.45	.02
8	.47	.45	.02
9	.48	.45	.03
10	.50	.45	.05
11	.54	.45	.09
12	.55	.45	.10
13	.56	.45	.11
14	.58	.45	.13
15	.61	.45	.16
16	.63	.45	.18
17	.80	.45	.35
18	.83	.45	.38
19	1.00	.45	.55
20	1.14	.45	.69
21	2.03	.45	1.58
22	2.71	.45	2.26
23	13.94	.45	13.49
24	3.48	.45	3.03
Total	34.12	10.82	23.30

TABLE 42
RAINFALL AND RAINFALL-EXCESS FOR SPILLWAY DESIGN STORM
SABINAL DAM AND RESERVOIR

2-hour period	Average rainfall (inches)	Loss (inches)	Rainfall-excess (inches)
0	0	0	0
1	.31	.31	0
2	.33	.33	0
3	.33	.33	0
4	.33	.33	0
5	.33	.33	0
6	.33	.33	0
7	.33	.33	0
8	.33	.33	0
9	.33	.33	0
10	.33	.33	0
11	.33	.33	0
12	.33	.33	0
13	.33	.33	0
14	.33	.33	0
15	.35	.35	0
16	.35	.35	0
17	.35	.35	0
18	.35	.35	0
19	.35	.35	0
20	.35	.35	0
21	.38	.38	0
22	.40	.40	0
23	.40	.40	0
24	.40	.40	0
25	.42	.42	0
26	.45	.45	0
27	.45	.45	0
28	.50	.50	0
29	.70	.50	.20
30	.90	.50	.40
31	1.30	.50	.80
32	1.60	.50	1.10
33	2.00	.50	1.50
34	3.88	.50	3.38
35	10.67	.50	10.17
36	4.85	.50	4.35
Total	36.00	14.10	21.90

TABLE 43

RAINFALL AND RAINFALL-EXCESS FOR THE SPILLWAY DESIGN STORM
CLOPTIN CROSSING DAM AND RESERVOIR

3-hour period	Average rainfall (inches)	Loss (inches)	Rainfall-excess (inches)
0	0	0	0
1	.46	.46	0
2	.47	.47	0
3	.47	.47	0
4	.47	.47	0
5	.47	.47	0
6	.47	.47	0
7	.48	.48	0
8	.48	.48	0
9	.48	.48	0
10	.48	.48	0
11	.50	.50	0
12	.54	.54	0
13	.58	.58	0
14	.62	.62	0
15	.66	.66	0
16	.70	.70	0
17	.75	.75	0
18	.85	.75	.10
19	.95	.75	.20
20	1.10	.75	.35
21	1.95	.75	1.20
22	3.70	.75	2.95
23	14.80	.75	14.05
24	2.90	.75	2.15
TOTAL	35.33	14.33	21.00

60. SPILLWAY DESIGN FLOOD ROUTINGS.- The spillway design flood hydrographs for flow into full reservoir were routed through Montell, Concan, Sabinal, and Cloptin Crossing Reservoirs assuming an initial reservoir level at the top of the controlled storage. The routing computations indicate the maximum reservoir levels and the peak outflows for the reservoirs would be as follows: 1366.0 feet msl and 581,000 second-feet at Montell, 1394.2 feet msl and 433,000 second-feet at Concan, 1238.8 feet msl and 270,600 second-feet at Sabinal, and 1017.5 feet msl and 196,400 second-feet at Cloptin Crossing Reservoir. The spillway design flood inflow-outflow hydrographs and reservoir elevations for Montell, Concan, Sabinal, and Cloptin Crossing Reservoirs are shown on plates 33 through 36, respectively.

61. FACTORS OF SAFETY AGAINST OVERTOPPING.- To evaluate the factors of safety to the dams provided by the freeboard storages and the spillways, floods greater than the spillway design floods were constructed for routing through the reservoirs. Two tests were imposed on the reservoirs for this purpose. The first test consisted of increasing the peak discharges of the spillway design floods by various amounts but holding the volume equal to that of the spillway design floods. The second test consisted of increasing both the peak discharges and the volumes of the spillway design floods by various percentages.

62. The hypothetical flood hydrographs for the first test, i.e., increasing the peak discharges of the spillway design floods and holding the volumes constant, were computed for flow into full reservoir condition. The unit hydrographs for the flow into full reservoir condition were modified by increasing the unit hydrograph peaks for the areas above head of reservoir by 10, 25, and 50 percent. The hypothetical flood hydrographs were developed by applying the modified unit hydrographs to the rainfall excess from the maximum 6-hour period of rainfall excess for each spillway design storm while using the adopted unit hydrographs for the remaining rainfall excess.

63. The hypothetical flood hydrographs for the second test, i.e., increasing both the peak discharges and flood volumes by various percentages, were developed by increasing each ordinate of the spillway design floods for the flow into full reservoir condition by 10, 25, and 50 percent.

64. In order to obtain a comparison between maximum reservoir elevations produced by the spillway design floods and the hypothetical flood hydrographs, the hypothetical floods were routed through the proposed reservoirs under the same assumptions as were the spillway design floods. The results of these studies for Montell, Concan, Sabinal, and Cloptin Crossing Reservoirs are shown on plates 37 through 40, respectively. The routing studies indicate that the spillway design floods, under conditions of flow into full reservoir, could be increased about

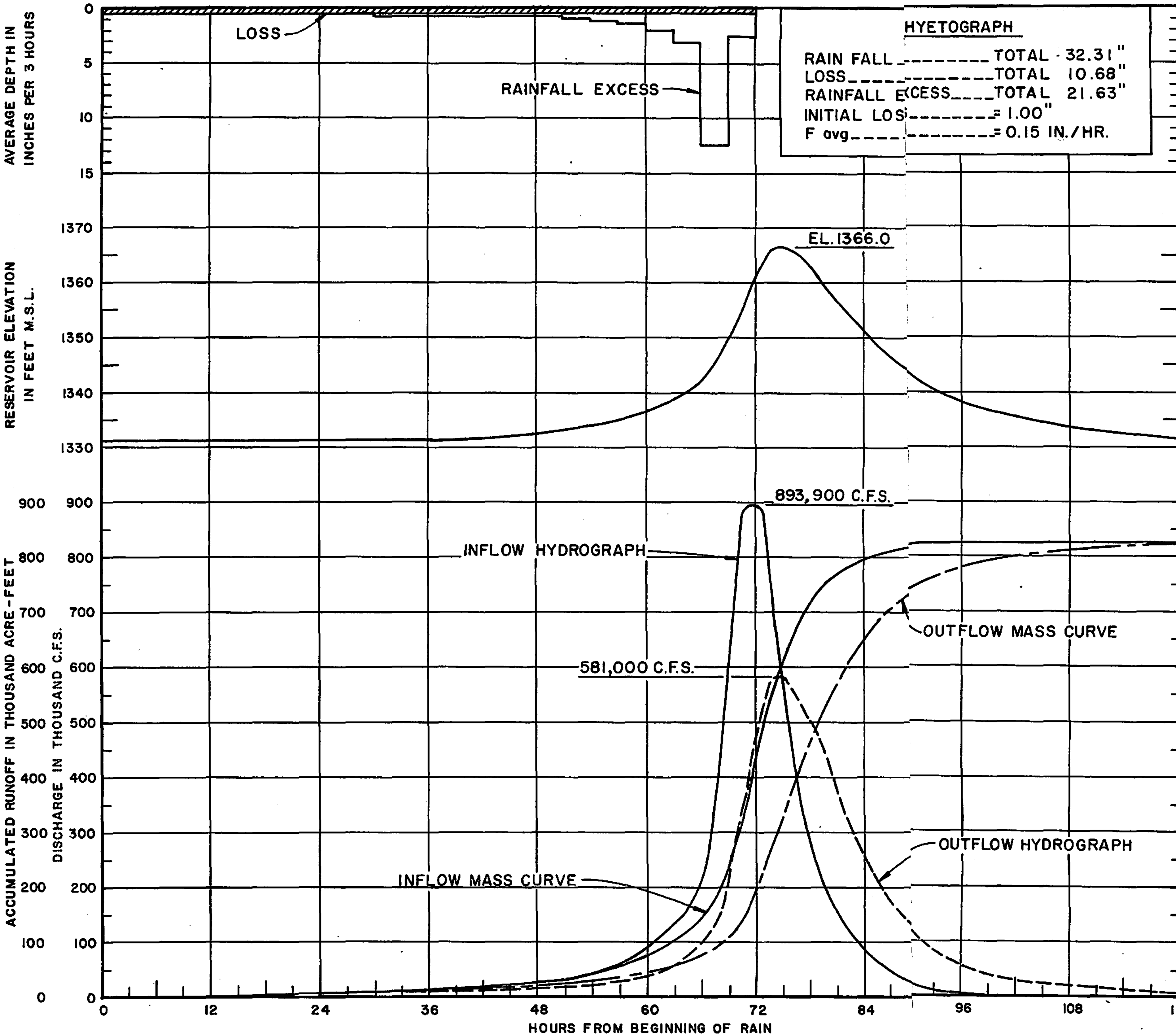
22, 29, 26, and 37 percent in both peak and volume, without overtopping the Montell, Concan, Sabinal, and Cloptin Crossing dams, respectively.

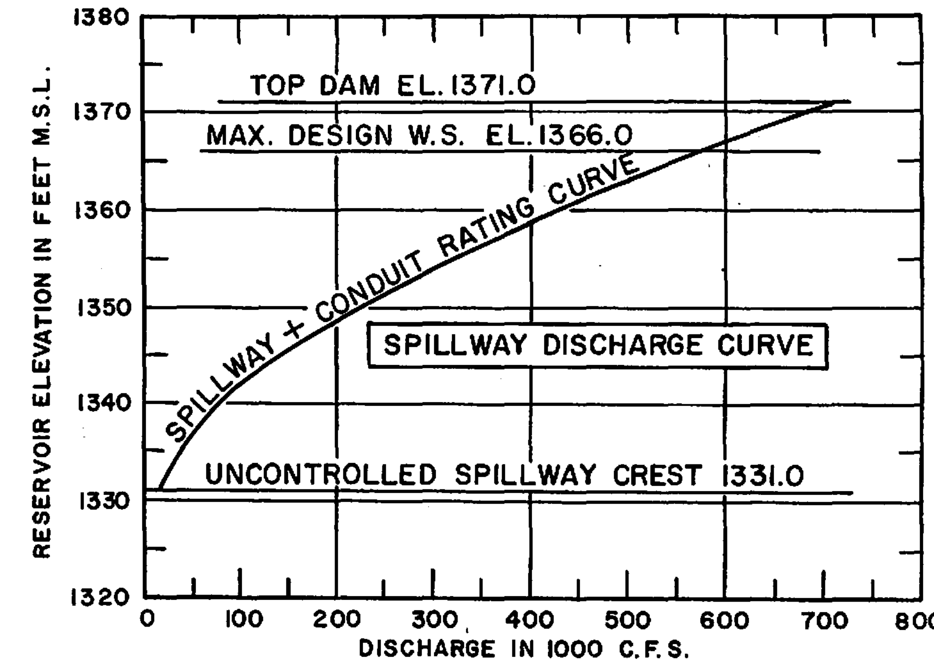
65. GUIDE TAKING LINE.- The guide taking line for the recommended reservoirs has been based upon the policy for real estate acquisition set forth in Change 9 dated March 9, 1962, of EM 405-2-150. The upper guide contour has been established at five feet above the top of controlled storage for Montell, Concan, and Cloptin Crossing Reservoirs and three feet above top of gates for Sabinal Reservoir. The upper guide contours thus established have been adopted throughout the entire reservoir area. More detailed studies will be made during preconstruction planning stages to evaluate the backwater effects in the upper reaches of the reservoirs. The adopted elevations for the upper guide contour are 1336.0 for Montell Reservoir, 1371.5 for Concan Reservoir, 1229.5 for Sabinal Reservoir, and 1003.0 for Cloptin Crossing Reservoir.

66. RELOCATION CRITERIA.- The criteria for the alteration or relocation of railroads, highways, bridges, and utilities is based upon the addition of a reasonable freeboard to the higher of the following levels: (1) the top of the flood-control pool or (2) the maximum elevation of the 50-year reservoir operation resulting from flood occurrences on a full conservation pool after 100 years of sediment deposition. In the upper portions of the main part of a reservoir and on tributary arms, the foregoing criteria or the envelope curve of the backwater profile for the 50-year reservoir operation plus freeboard will be adopted. For the purpose of this report the same elevations adopted for the upper guide taking line in paragraph 65 have been adopted as the basis for relocation estimates. More detailed studies will be made during preconstruction planning stages.

67. FREEBOARD REQUIREMENTS.- Freeboard requirements for the recommended projects were determined in accordance with the method set forth in a paper by Saville, McClendon and Cochran entitled, "Freeboard Allowances for Waves in Inland Reservoirs," Journal of the Waterway and Harbors Division, Proceedings American Society of Civil Engineers, May 1962, distributed by OCE with Civil Works Letter 62-8 dated 6 August 1962. Computations for wave heights and wave runup were based on the computed effective fetch at the maximum water surface for each reservoir. The computed wave height and total freeboard for an overland wind velocity of 40 miles per hour (52 miles per hour over water) was adopted as a basis for design. The results of these computations are summarized in table 44.

68. HYDROLOGIC NETWORK.- It is proposed to supplement the existing rainfall and streamflow stations by expanding the hydroclimatic and hydrologic reporting networks. The records and reports will be used to update hydrologic design criteria for preconstruction planning; in connection with construction activities; and to prescribe





NOTES:

Drainage area 707 square miles. Outflow partially controlled by 1-15' diameter conduit, invert elevation 1216.0 with 3-5'-8" x 12'-0" slide gates. Spillway is uncontrolled 960' broadcrested wier, crest at elevation 1331.0.

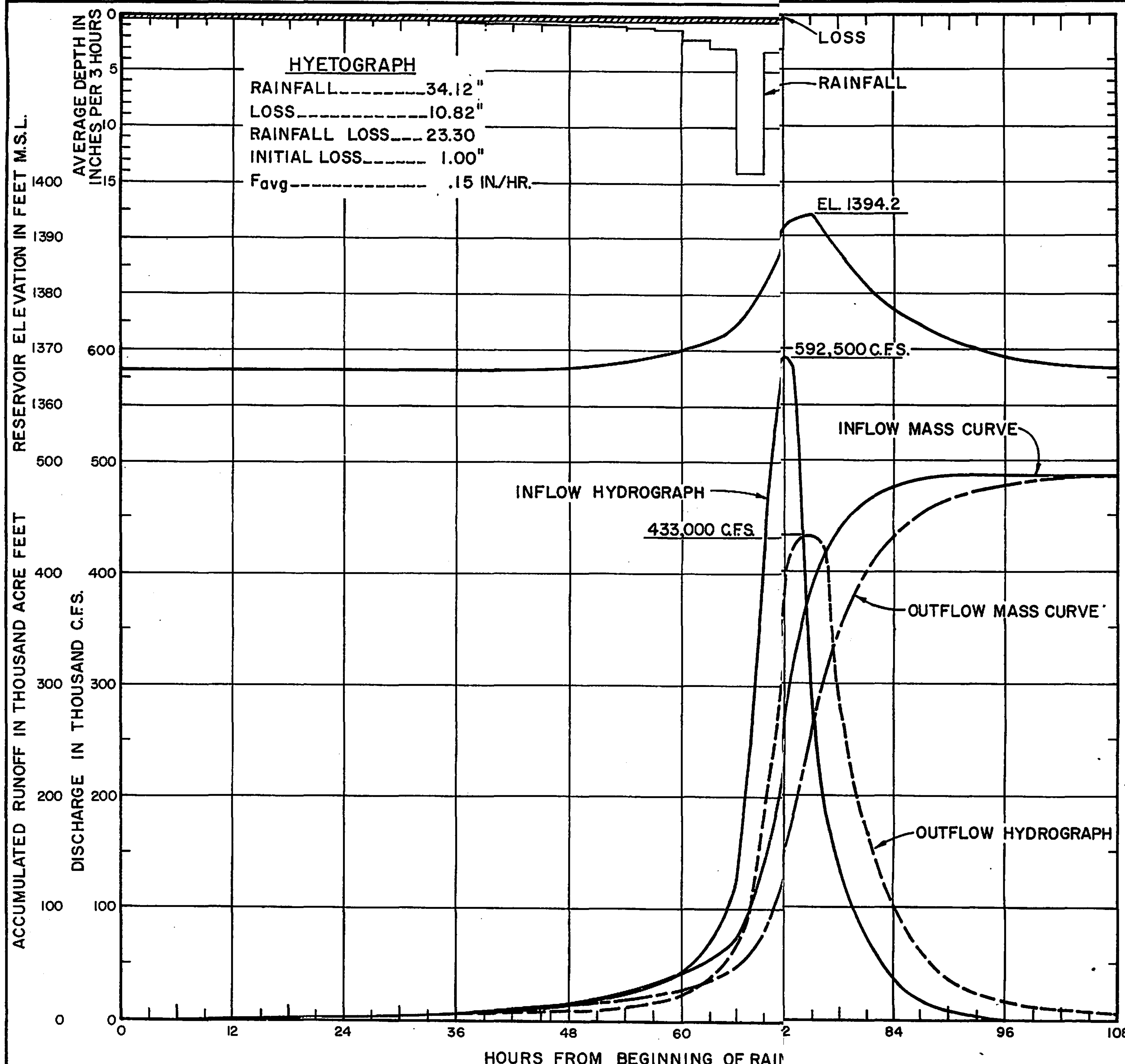
Flood-control conduit operative during spillway design flood.

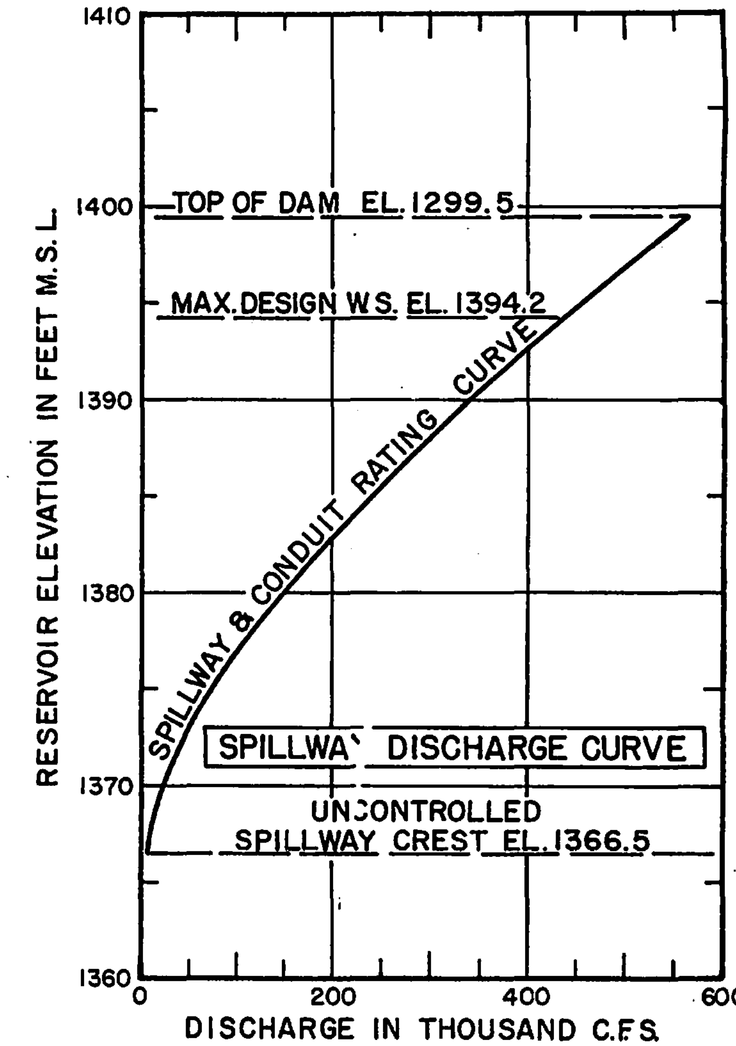
Reservoir level, at spillway crest, elevation 1331.0 at beginning of rain, returns to spillway crest 123 hours after beginning of rain.

EDWARDS UNDERGROUND RESERVOIR

MONTELL RESERVOIR
INFLOW - OUTFLOW HYDROGRAPH
SPILLWAY DESIGN FLOOD

DEC 1964 PLATE 33





NOTES:

Drainage area 391 square miles. Outflow partially controlled by 1-13' diameter conduit invert elevation 1240.0, with two 6'-13' tractor type gates. Spillway is uncontrolled 1030' Broadcrested Weir, crest elevation 1366.5.

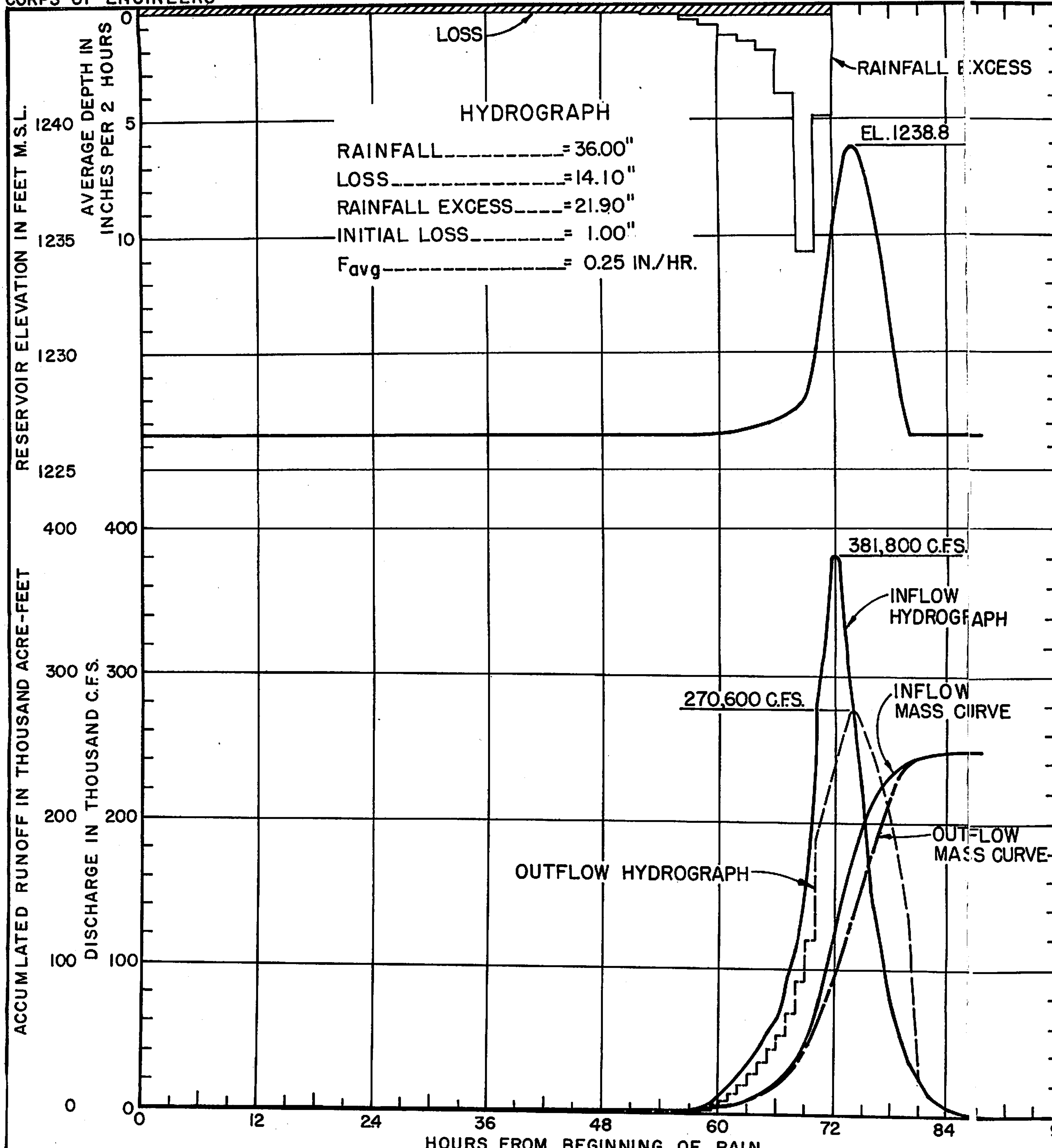
Flood Control conduit operative during spillway design storm.

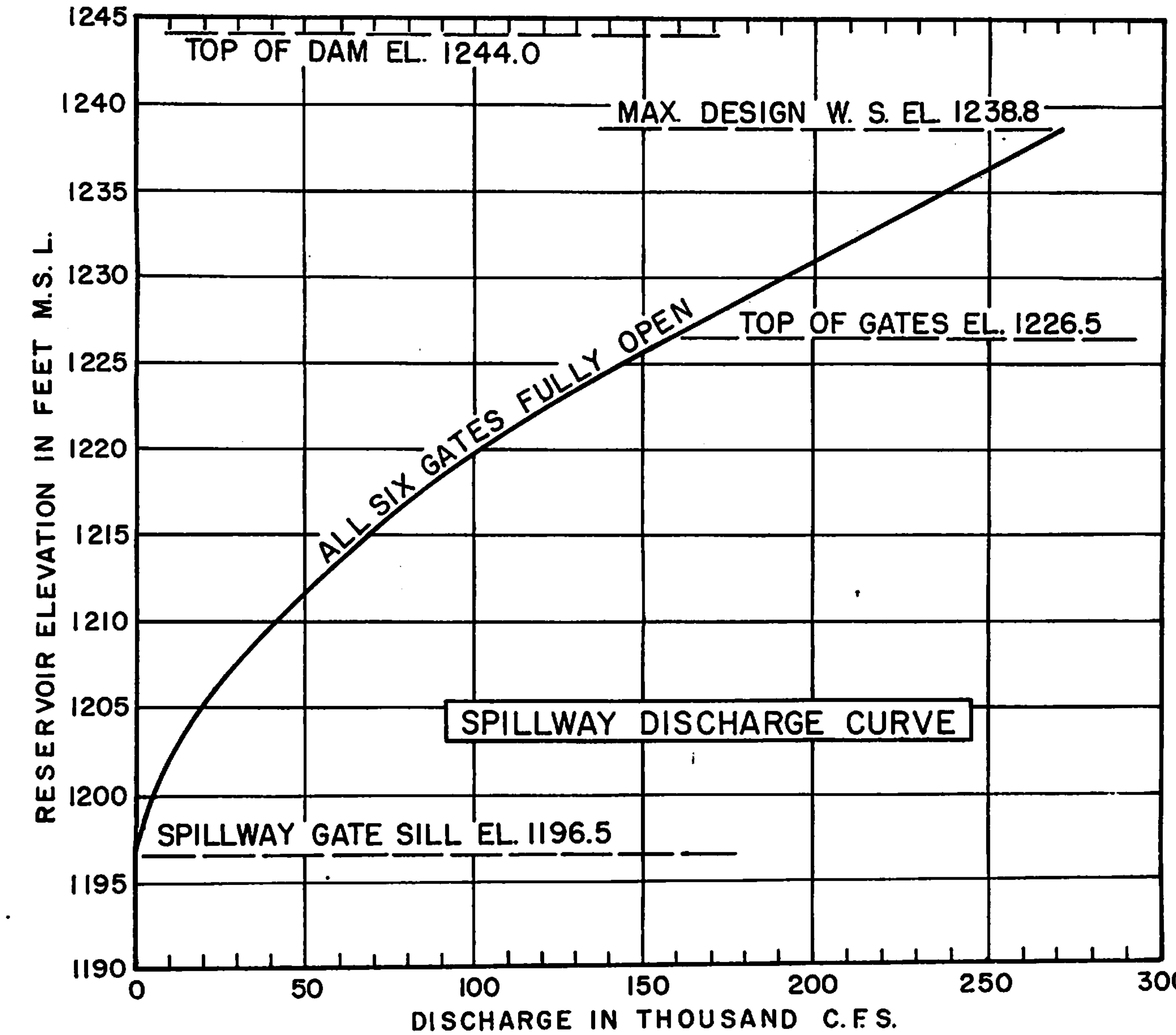
Reservoir level, at spillway crest elevation 1366.5 at beginning of rain, returns to spillway crest 111 hours after beginning of rain.

EDWARDS UNDERGROUND RESERVOIR

CONCAN RESERVOIR
INFLOW-OUTFLOW
HYDROGRAPHS
SPILLWAY DESIGN FLOOD

DEC. 1964 PLATE 34





NOTES:

Drainage area 210 square miles. Outflow controlled by six 40' x 30' tainter gates, sill elevation 1196.5

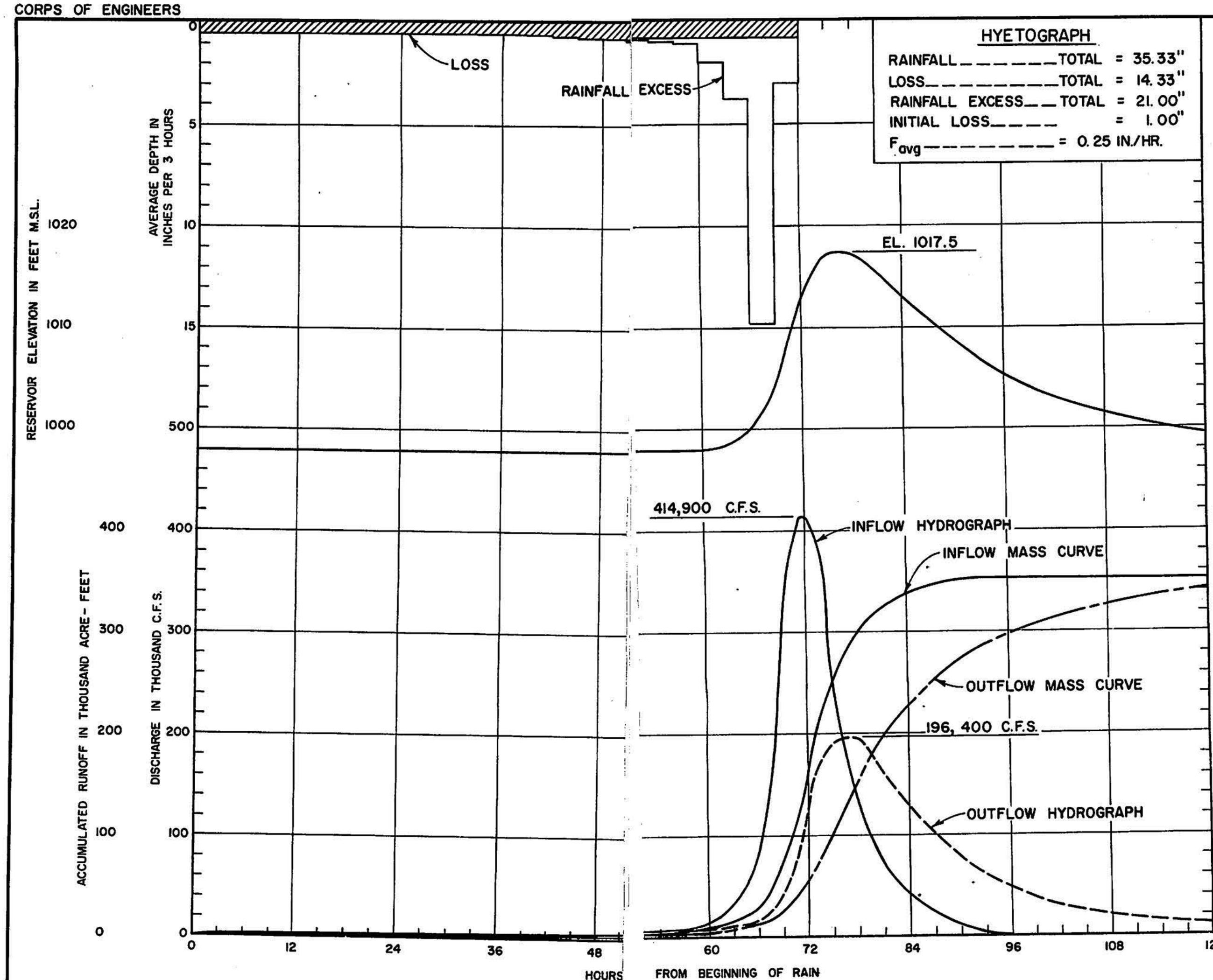
Low flow outflow inoperative during spillway design flood.

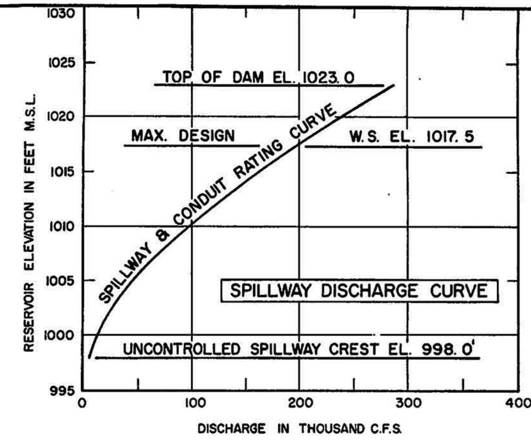
Reservoir level at top of gates, elevation 1226.5 at beginning of rain.

EDWARDS UNDERGROUND RESERVOIR

SABINAL RESERVOIR
INFLOW-OUTFLOW HYDROGRAPHS
SPILLWAY DESIGN FLOOD

DEC 1964 PLATE 35





NOTES:

Drainage area 307 square miles. Outflow partially controlled by one 13' diameter conduit, invert elevation 855.0', with two 6'x13' tractor type gates. Spillway is uncontrolled 760' Broadcrested Weir, crest elevation 998.0'

Flood - control conduit operative during spillway design flood.

Reservoir level, at spillway crest elevation 998.0' at beginning of rain, returns to spillway crest 144 hours after beginning of rain.

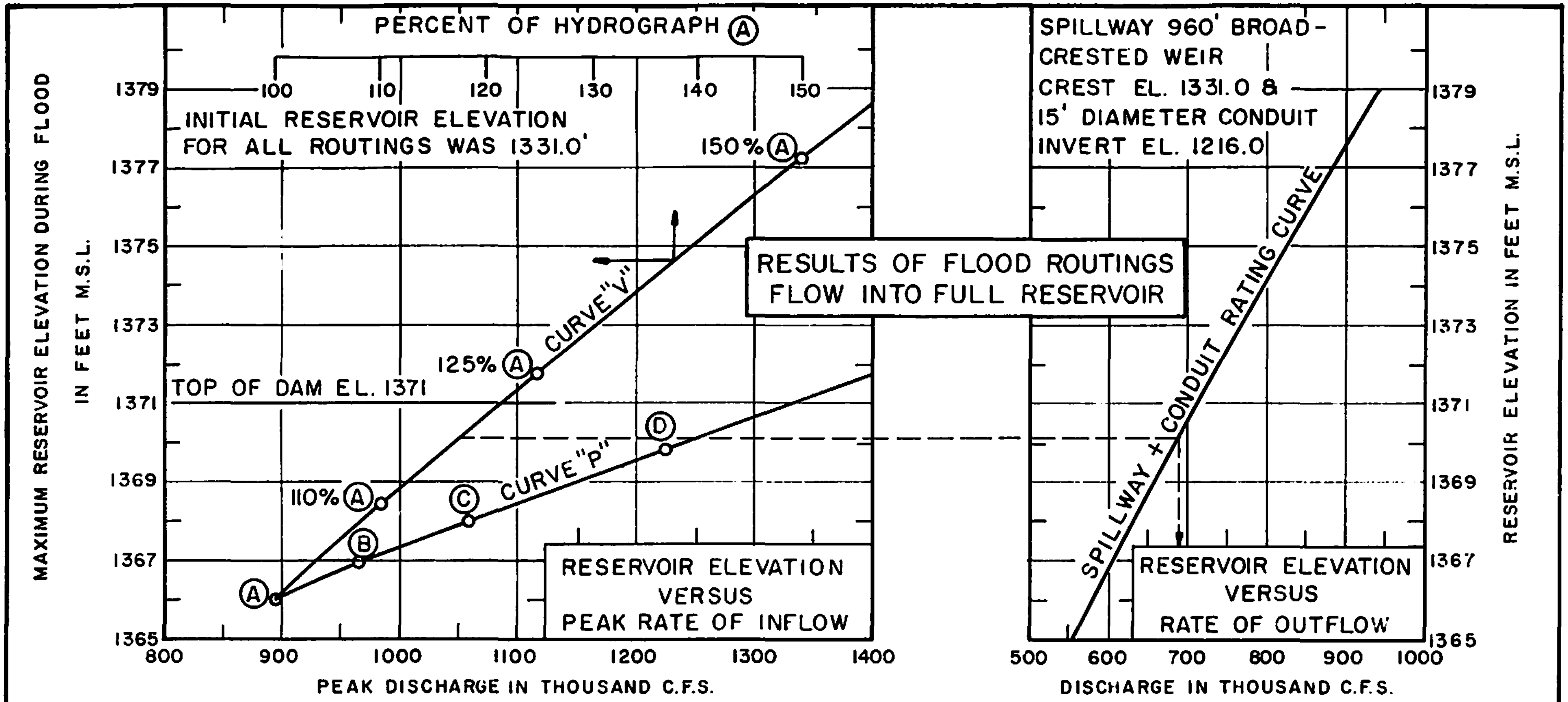
EDWARDS UNDERGROUND RESERVOIR

CLOPTIN CROSSING RESERVOIR
INFLOW-OUTFLOW HYDROGRAPHS
SPILLWAY DESIGN FLOOD

DEC 1964 PLATE 36

 W.H.W.-T.L.W.

CORPS OF ENGINEERS U.S. ARMY



NOTES:

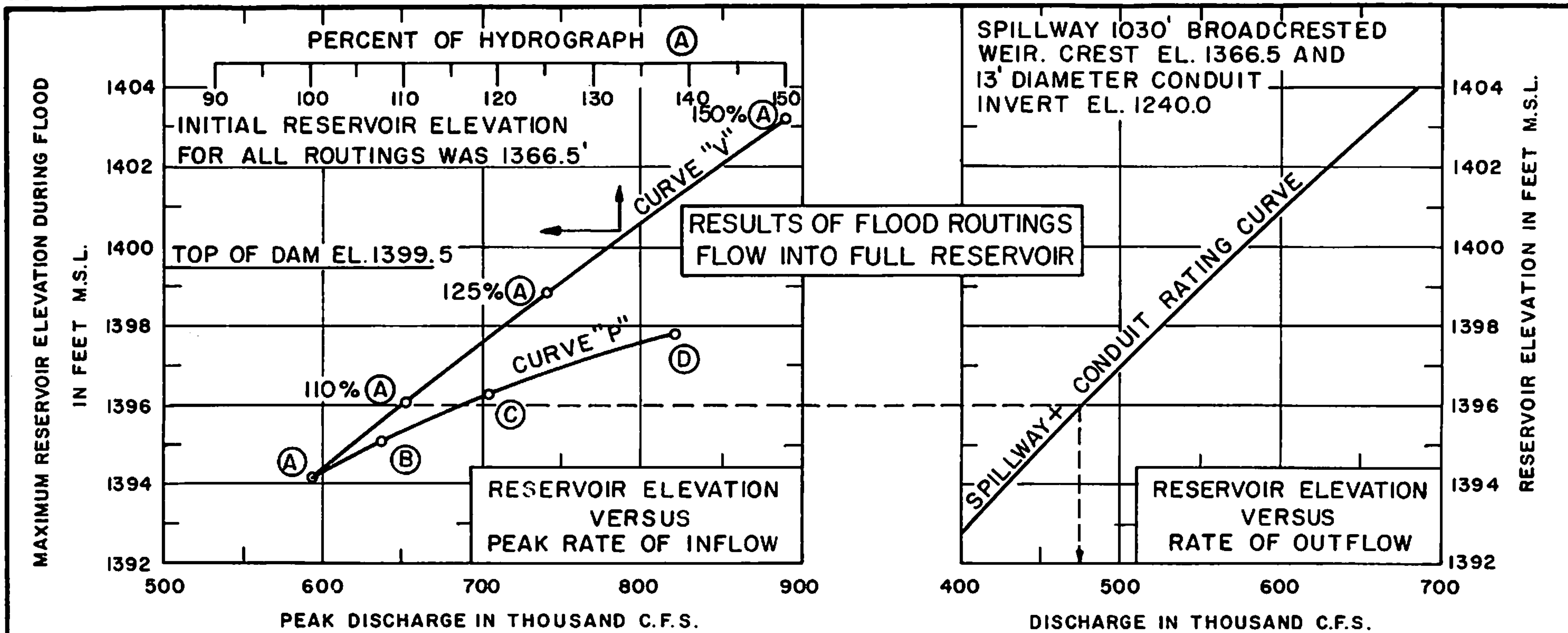
Points (B), (C), (D) on curve "P" were obtained by routing the hydrograph of the computed spillway design flood, for flow into full reservoir, whose peak discharge has been increased by increasing the peak of the unit hydrograph for area above head of reservoir by 10, 25 and 50 percent for the maximum 6 hour rainfall and with no increase in volume.

Points on curve "V" were obtained by routing the hydrograph of the computed spillway design flood, for flow into full reservoir, with all ordinates of flood hydrograph increased by 10, 25 and 50 percent.

EDWARDS UNDERGROUND RESERVOIR

MONTELL RESERVOIR
RESULTS OF FLOOD ROUTINGS

DEC. 1964 PLATE 37



NOTES:

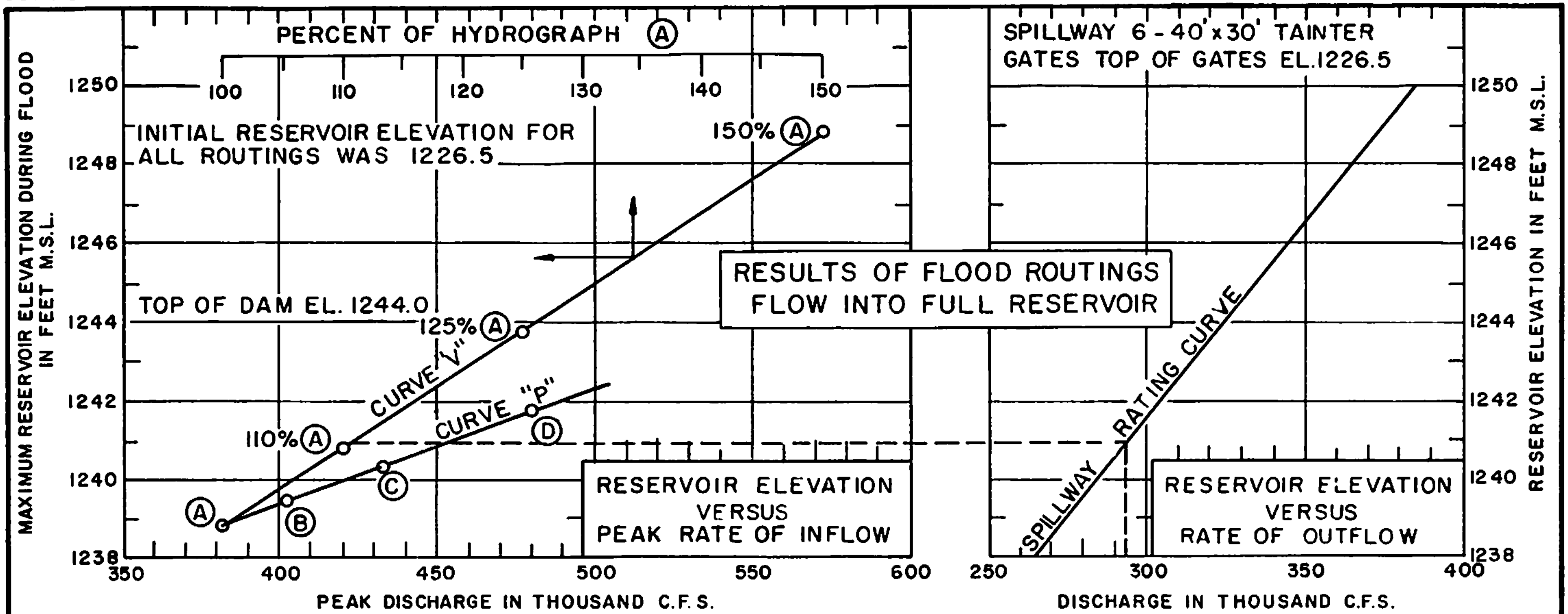
Points Ⓑ, Ⓒ & Ⓓ on curve "P" were obtained by routing the hydrographs of the computed spillway design flood, for flow into full reservoir, whose peak discharge has been increased by increasing the peak of the unit hydrograph for area above head of reservoir by 10, 25 and 50 percent for the maximum 6 hour rainfall and with no increase in volume.

Points on curve "V" were obtained by routing the hydrograph of the computed spillway design flood, for flow into full reservoir, with all ordinates of flood hydrograph increased by 10, 25 and 50 percent.

EDWARDS UNDERGROUND RESERVOIR

CONCAN RESERVOIR
RESULTS OF FLOOD ROUTINGS

DEC. 1964 PLATE 38



NOTES:

Points (B), (C) & (D) on curve "P" were obtained by routing the hydrograph of the computed spillway design flood, for flow into full reservoir, whose peak discharge has been increased by increasing the peak of the unit hydrograph for area above head of reservoir by 10, 25 and 50 percent for the maximum 6 hour rainfall and with no increase in volume.

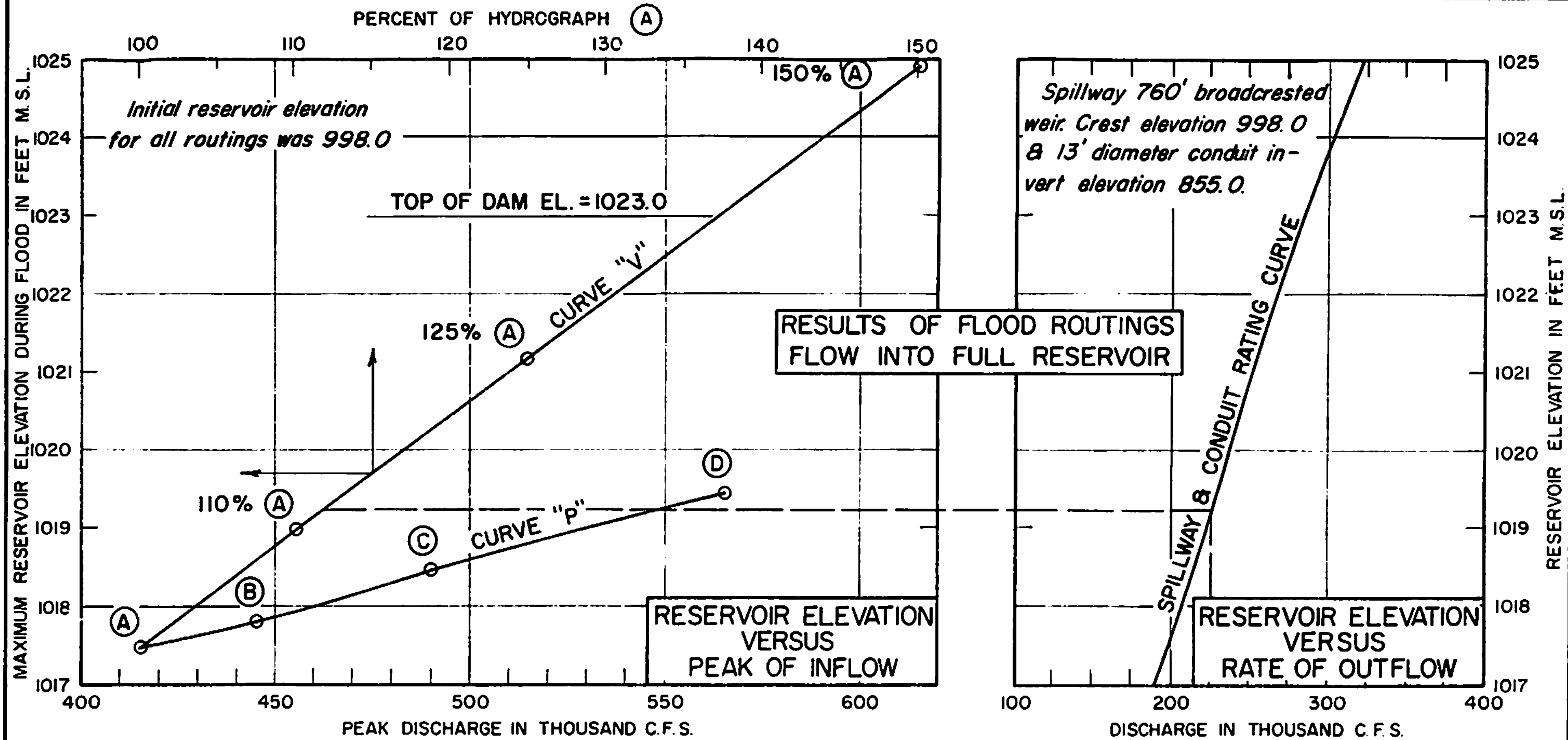
Points on curve "V" were obtained by routing the hydrograph of the computed spillway design flood, for flow into full reservoir, with all ordinates of flood hydrograph increased by 10, 25 and 50 percent.

EDWARDS UNDERGROUND RESERVOIR

SABINAL RESERVOIR
RESULTS OF FLOOD ROUTINGS

DEC. 1964 PLATE 39

CORPS OF ENGINEERS U.S. ARMY



NOTE:

Points (B), (C), & (D) on curve "P" were obtained by routing the hydrographs of the computed spillway design flood, for flow into full reservoir whose peak discharge has been increased by increasing the peak of the unit hydrograph for area above head of reservoir by 10, 25, and 50 percent for the maximum 6 hour rainfall and with no increase in volume.

Points on curve "V" were obtained by routing the hydrographs of the computed spillway design flood for flow into full reservoir with all ordinates of the flood hydrograph increased by 10, 25, and 50 percent.

EDWARDS UNDERGROUND RESERVOIR

CLOPTIN CROSSING RESERVOIR
RESULTS OF FLOOD ROUTINGS

DEC. 1964 PLATE 40

TABLE 44

FREEBOARD REQUIREMENTS

Reservoir	Max. design water surface elevation (ft. msl)	Effective fetch (miles)	Total required freeboard (feet)(1)	Total freeboard provided (feet)	Elevation at top of dam (ft. msl)
Montell	1366.0	2.96	3.8	5.0	1371.0
Concan	1394.2	1.73	2.9	5.3	1399.5
Sabinal	1238.8	2.01	3.2	5.2	1244.0
Cloptin Crossing	1017.5	2.10	3.3	5.5	1023.0

(1) Based on an overland wind velocity of 40 miles per hour (52 miles per hour over water) and computed wind tide.

flood-control regulations for the recommended reservoirs. The expanded network will include inflow and outflow stations and reservoir level gages at the recommended projects, Montell, Concan, Sabinal, and Cloptin Crossing Reservoirs. Evaporation and recording rainfall stations also will be provided at Montell, Concan, Sabinal, and Cloptin Crossing Reservoirs. Appropriate instrumentation for the study of ground water, the accurate determination of base flows and recharge values and the investigation of water quality will also be considered after the project is authorized, in line with the Bureau of the Budget Circular No. A-67 dated 28 August 1964. Detailed requirements for the complete hydrologic network will be presented in connection with preconstruction planning studies.

THE EDWARDS RESERVOIR

69. GENERAL.- The Edwards Reservoir is a segment of an aquifer that extends some 250 miles from Austin westward to Comstock. That segment of the aquifer known as the Edwards Reservoir, which is the source of water for some one million people in the area including the city of San Antonio, lies between the cities of Kyle in the Blanco River watershed on the east and Brackettville in the West Nueces River watershed on the west. Ground water divides at these two locations separate the Edwards Reservoir hydrologically from adjacent portions of the aquifer. The centerline of the aquifer connects roughly the cities of Kyle, San Marcos, San Antonio, Uvalde, and Brackettville. The aquifer is roughly 175 miles long and varies in width from 5 to 25 miles. The northern or upper boundary of the aquifer coincides approximately with the upper boundary of the Balcones Fault Zone while the lower boundary is less well defined, being simply the beginning of an area of low transmissibility or poor circulation. The normal flow of water to the south in the underground reservoir is blocked by this zone where the circulation is restricted, which causes the water to flow in an easterly direction toward San Antonio, thence in a northeasterly direction toward Kyle. The lower limit of the Edwards Reservoir is commonly called the "bad water line." South of this line, the water is charged with noticeable amounts of hydrogen sulfide and there is an appreciable increase in the hardness of the water. The approximate boundaries of the reservoir are shown on plate 1.

70. As previously stated, one of the purposes of this investigation is the determination of whether improvement of the yield of the Edwards Reservoir is possible. The following excerpt from a published report 1/ is considered pertinent to this investigation:

> "The dependable yield of a reservoir such as the Edwards limestone over a long period cannot be in excess of the average rate of replenishment. . . . Depending on the Edwards Reservoir to meet all future demands . . . would result in overpumping of the reservoir with consequent depletion of storage and large continuing declines of water levels in wells. Eventually the reservoir would be depleted to such an extent that it would be impossible to obtain more water through wells than the amount entering the reservoir as recharge, and large sections of the reservoir would be almost completely dewatered. . . ."

Prior to the drilling of wells into the reservoir, a natural balance existed between recharge to the reservoir and discharge from the springs. Large scale withdrawals from wells upset this balance and result in the lowering of water levels in the reservoir. As the reservoir level continues to be lowered by an excess of pumpage over recharge, the springs stop flowing as the level drops below the spring outlets.

1/ Progress Report on the Edwards Limestone Reservoir by Wm. F. Guyton and Associates, June 1959.

71. RECHARGE.- Inflow to the reservoir is in the form of recharge and cannot actually be measured, but must be estimated by one of several methods. Ideally, the amount of recharge from a particular stream may be determined as the difference between flow measured immediately above and immediately below the recharge zone. If the capacity of the recharge facility may be determined, then the measurement of flow above the recharge zone is sufficient to determine the amount of recharge. Estimates of recharge for each of the several streams crossing the zone of recharge of the Edwards area have been determined by the most applicable procedure and published by the San Antonio City Water Board and by the Texas Water Commission in cooperation with the U. S. Geological Survey and several state agencies. These recharge values were reviewed and those published by the Texas Water Commission were adopted for use in this report. A tabulation of the total annual recharge values for the contributing area is given in table 45.

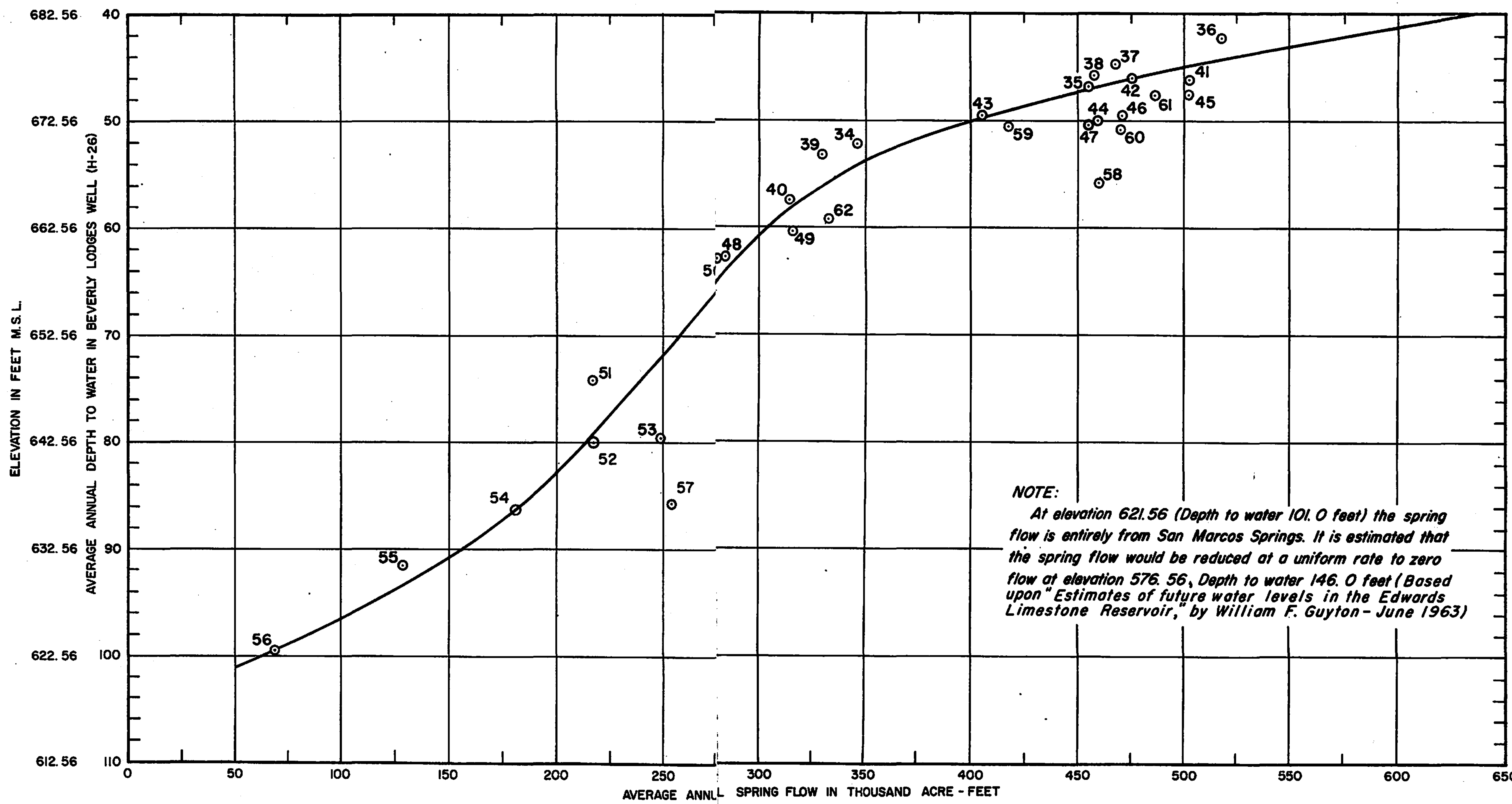
72. SPRINGFLOW.- The principal springs which serve as natural outlets for the Edwards Reservoir are Leona Springs, San Antonio, and San Pedro Springs, Hueco Springs, Comal Springs, and San Marcos Springs. The flow from each of these springs is dependent to some extent on the level of the underground reservoir. As the level declined in the recent drought period, several of the springs ceased flowing in 1950. Comal Springs ceased flowing from June 13 to about November 3, 1956, and San Marcos Springs experienced one of its lowest flows of record during 1956. Flow from each of the springs has been determined mainly by the Ground Water Branch of the U. S. Geological Survey and published in previous reports. A study of these springflow records and the records of water levels in Beverly Lodges Well (H-26) indicated that a good correlation existed between total annual springflow and the year-end elevation of Beverly Lodges Well. The curve on plate 41, resulting from this correlation, was used in subsequent routing studies for the Edwards Underground Reservoir. A tabulation of the total annual flow of the major springs of the Edwards Reservoir area is given in table 45.

73. WELLS.- The first irrigation well tapping the Edwards Reservoir was drilled about 1884. Accurate early records of withdrawals through wells are not available but it has been estimated that in 1897 well discharge amounted to about 29 million gallons per day in Bexar County. The majority of the wells are in Uvalde, Medina, and Bexar Counties. Table 46 is indicative of the increase in withdrawals through wells which has occurred in these counties The estimated historic annual withdrawal from wells for the period 1934-1962 has been estimated by the Ground Water Branch of the U. S. Geological Survey and is presented in table 45.

TABLE 45

RECHARGE AND DISCHARGE - EDWARDS UNDERGROUND RESERVOIR
(1000 Acre-Feet)

Year	Recharge	Spring flow	Withdrawal through wells
1934	180	346	102
5	1258	454	103
6	910	517	113
7	401	467	120
8	433	457	122
9	399	330	119
1940	309	314	121
1	851	502	138
2	558	475	144
3	273	404	149
4	561	458	149
5	528	502	152
6	556	479	158
7	423	454	167
8	178	283	168
9	508	316	178
1950	200	279	193
1	140	217	206
2	276	217	212
3	168	249	224
4	161	181	242
5	192	128	267
6	44	69	324
7	1143	254	237
8	1711	459	219
9	690	417	235
1960	825	469	228
1	693	486	228
2	252	333	268
Average	511	363	182



EDWARDS UNDERGROUND RESERVOIR

ESTIMATED
SPRING FLOW VS ELEVATION

DEC. 1964 PLATE 41

TABLE 46

WITHDRAWALS FROM WELLS (ESTIMATED)

Year	Amount Ac.Ft./Yr.	Rate MGD
	BEXAR COUNTY	
1897	32,400	29
1934	96,100	86
1954	207,900	186
1956	233,600	209
	UVALDE AND MEDINA COUNTIES	
1934	3,900	3.5
1954	26,800	24
1956	76,000	68

74. STORAGE CAPACITY.- The total capacity of the underground reservoir is unknown, but by use of the water budget equation "inflow minus outflow equals change-in-storage," the capacity of the recorded range of fluctuation of the water surface is indicated by the elevation of water in wells. Well elevations have been observed and recorded over practically the entire length of the underground reservoir and have been published by the Ground Water Branch of the U. S. Gelogical Survey in several bulletins. The records of well levels indicate that in the aquifer the water surface slopes to the south or southeast in the outcrop area where water table conditions prevail and in a more easterly direction in the artesian zone. Since the water surface slopes due to the nature of the underground reservoir, it was believed that the average of the elevations of a group of wells spaced at intervals along the major axis of the reservoir should be used as a measure of the reservoir water surface. However, a good correlation exists between this average elevation and the elevation of a single well, H-26, known as the Beverly Lodges Well, located about 4 miles northeast of the heart of San Antonio. Accordingly, for simplicity in computations, the accumulated annual differences in recharge and discharge were plotted versus the year-end elevation of Well H-26. This correlation produced a reasonable check on the elevation-storage curve shown in a previous publication.2/ The published curve has been adopted and is shown on plate 42. Bulletin 6201 of the Texas Water Commission 3/ offers a more refined

2/Estimates of Future Water Levels in the Edwards Limestone Reservoir, by William F. Guyton and Associates, June 1963.

3/TWC Bulletin 6201, Recharge, Discharge, and Changes in Ground-Water Storage in the Edwards and Associated Limestones, San Antonio Area, Texas. January 1962.

concept of capacity of the underground reservoir. It divides the reservoir, arbitrarily, into four divisions along its major axis and determines inflow, outflow, and storage changes for each part. The idea of underflow, the underground flow from one segment into the next most down-gradient segment, is introduced, and correlated with differences in elevation of the two segments as indicated by key wells in each segment. The accumulated annual changes in storage within each segment are plotted against the elevations indicated by another key well within that segment. In this manner a separate elevation-capacity relationship is determined for each of the four portions of the reservoir. Because of the many routings which had to be made and the consequent need for a more simplified procedure, the single segment storage curve has been adopted for use in this report.

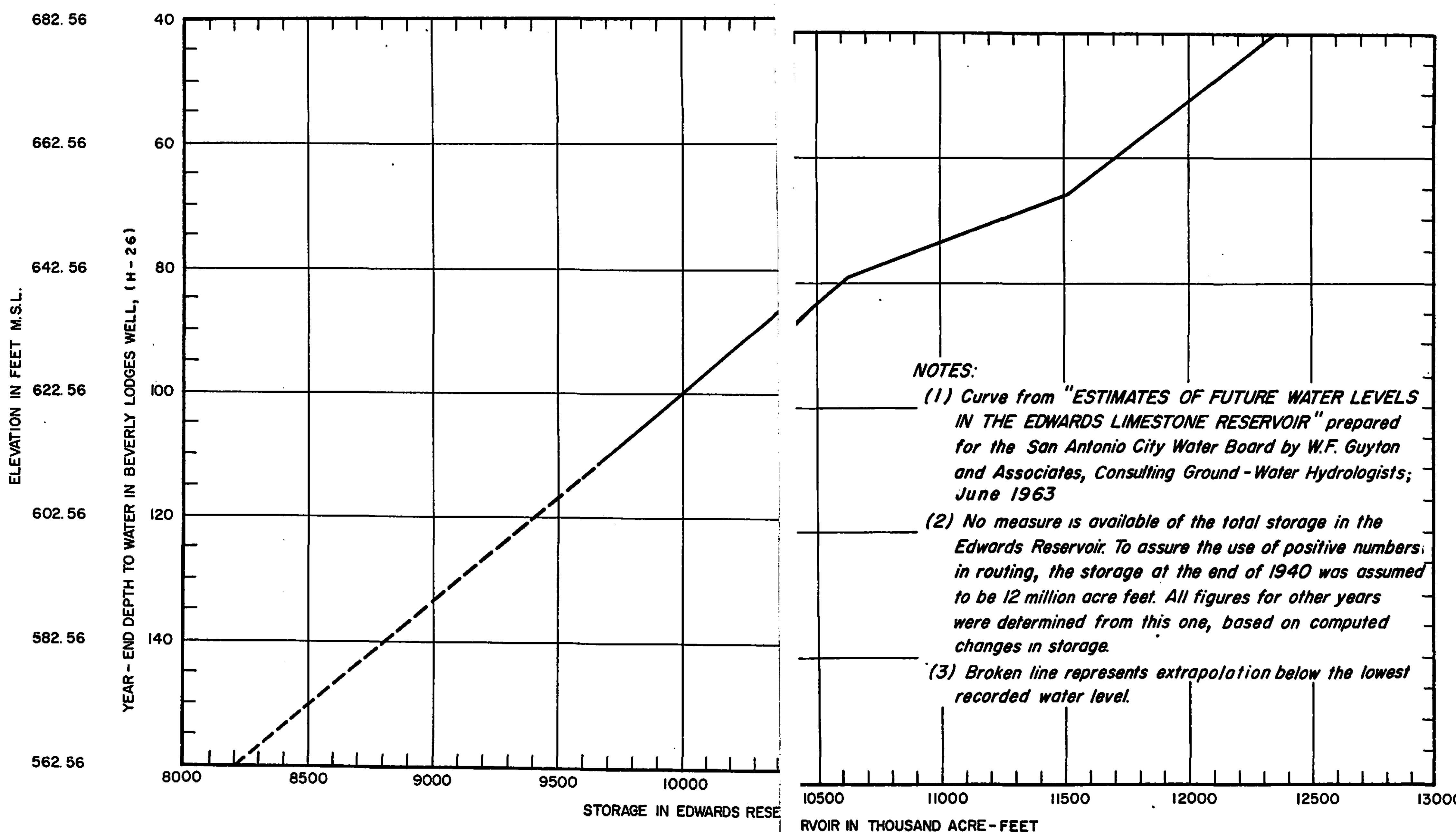
75. DESIRED MINIMUM RESERVOIR LEVEL.- The computed storage in the Edwards Reservoir is that storage between the recorded extremes of elevation, or some 2-1/2 million acre-feet. However, it is known that storage exists below the recorded low and it has been assumed in this report that the storage capacity below this low is about 30,000 acre-feet per foot which simply represents an extrapolation of the lower part of the curve shown on plate 42. The yield of an underground reservoir cannot, over a long period of time, exceed the average annual recharge. The reservoir might be drawn down to some point such that no springflow would occur and the entire recharge thereafter would be available for pumpage. In this case, if pumpage never exceeded the average recharge during any part of the hydrologic cycle, then the dependable yield during the critical drought period would be the average recharge. This presumes, however, that the level of the reservoir is drawn down far enough that even during periods of exceptionally high recharge, the reservoir would not refill to the spring outlets, and consequently no springflow would occur. For various reasons, however, it is not desirable that the reservoir level be reduced to the extreme level required to develop the maximum pumpage. The following excerpt from a published report 4/ is pertinent to this point:

> " . . . Another factor limiting the safe yield of wells in the reservoir is the presence of water of poor quality in the Edwards formation south and southeast of the Edwards Reservoir. There is apparently no barrier to the movement of this water into the fresh water area if water levels are lowered in the Edwards Reservoir sufficiently and the present hydraulic gradient

4/ The Edwards Limestone Reservoir by Wm. F. Guyton and Associates, November 1955.

CORPS OF ENGINEERS

U. S. ARMY



NOTES:

(1) Curve from "ESTIMATES OF FUTURE WATER LEVELS IN THE EDWARDS LIMESTONE RESERVOIR" prepared for the San Antonio City Water Board by W.F. Guyton and Associates, Consulting Ground - Water Hydrologists; June 1963

(2) No measure is available of the total storage in the Edwards Reservoir. To assure the use of positive numbers in routing, the storage at the end of 1940 was assumed to be 12 million acre feet. All figures for other years were determined from this one, based on computed changes in storage.

(3) Broken line represents extrapolation below the lowest recorded water level.

EDWARDS UNDERGROUND RESERVOIR

ESTIMATED
STORAGE VS ELEVATION

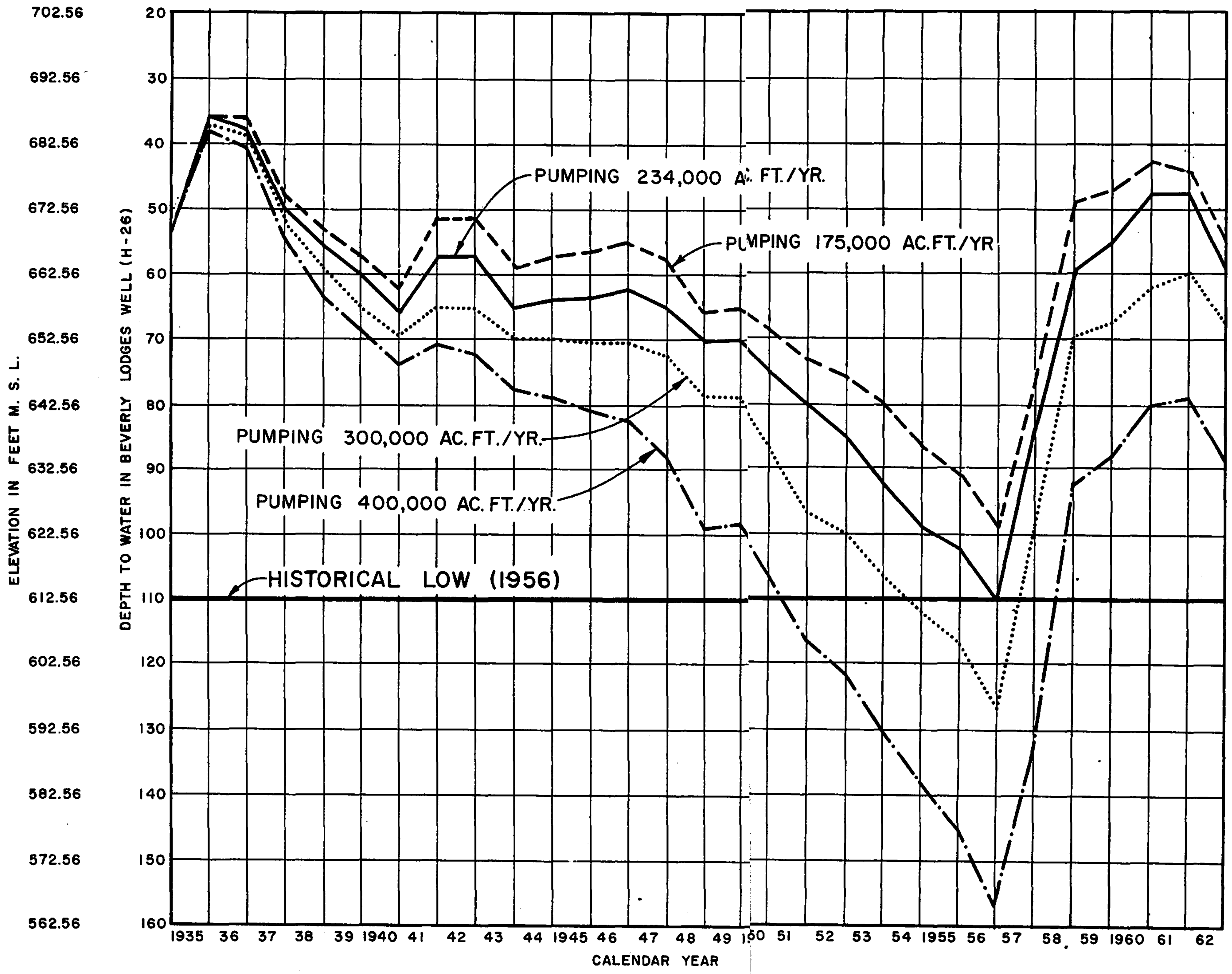
DEC 1964 PLATE 42

"is reversed. If part of the reservoir becomes contaminated in this manner, it will be made useless as a source of fresh water in the future."

It is not known to what level the reservoir would have to be lowered before the intrusion of the water of poor quality would begin. The volume of water which would move from the bad water area is unknown, and consequently the overall effect of the lowering of the water level cannot be predicted. However, it is considered that in view of the possible consequences of the contamination of the reservoir, the level should not be lowered appreciably beyond its historic low point.

76. METHOD OF UNDERGROUND RESERVOIR ROUTING.- For purposes of analysis, the underground reservoir may be thought of as a large surface reservoir with several controlled and uncontrolled outlets at varying levels. The inflow to the reservoir is largely derived by seepage from streams that cross the outcrop of the aquifer in the Blacones Fault zone. The uncontrolled outflow takes place as springflow and the controlled outflow is in the form of pumpage. The reservoir level fluctuates in reponse to the imbalances in inflow and outflow in a manner somewhat similar to that of a surface reservoir. In order to determine the yield of the Edwards Reservoir which might be associated with varying levels of drawdown, routings were made utilizing the storage curve shown on plate 40, the inflow (recharge) given in table 45, the elevation-springflow relation shown on plate 41, and several constant pumpage rates. In view of the estimated nature of the inflows, the inherent inaccuracies in the relations between storage, springflow, and elevation, annual rather than monthly routings were made. Based upon the relations noted above, a check routing wherein historic pumpage was used indicated reasonably good results.

77. RESULTS OF ROUTINGS UNDER EXISTING CONDITIONS.- A number of routings were made under existing conditions to determine the yield of the Edwards Reservoir if the pumpage were constant during the period 1935-1962. Plate 43 presents the computed levels for the Edwards Reservoir based upon constant annual pumpage rates of 175,000 acre-feet, 234,000 acre-feet, 300,000 acre-feet, and 400,000 acre-feet with no new upstream surface reservoirs constructed. Table 47 presents the computed average annual springflow and the low point of elevation for each of the above pumpage rates.



NOTE:

Existing conditions assuming pumpage at constant rate through period 1935-1962.

EDWARDS UNDERGROUND RESERVOIR

COMPARISON OF UNDERGROUND WATER LEVELS EXISTING CONDITIONS

DEC. 1964 PLATE 43

TABLE 47

COMPARISON OF THE EFFECT OF
VARYING PUMPAGE RATES

Pumpage (ac. ft./annum)	Average annual springflow (1) (ac. ft./annum)	Elevation of lowest water level (2) (ft. msl)
	EXISTING CONDITIONS	
175,000	335,700	624
234,000	292,900	612
300,000	251,000	596
400,000	196,000	566

(1) Average annual springflow based on period 1935 through 1956.
(2) Level at Well H-26 (Beverly Lodges Well).

The above routings cover a period of record from 1935 through 1962; however, the period of record that is used to evaluate the differences in average annual recharge, springflow, and pumpage is from 1935 through 1956. This interval includes a period of high rainfall and resulting runoff, and the most critical drought of record.

78. METHODS OF OPERATING SURFACE WATER RESERVOIRS FOR RECHARGE.- The provision of surface storage reservoirs upstream from the fault zone enables the storage of flood flows, which, because of the high rates involved, would flow across the fault zone. The plans of operation that were considered for the surface reservoirs are as follows:

a. Releasing the yield of the reservoirs at a constant rate to the underground reservoir, assuring a supply even during the critical period.

b. Holding the water in storage until the underground reservoir reaches some predetermined level and then releasing sufficient water to maintain the reservoir at that level.

c. Releasing the stored water from the reservoirs at rates equal to or less than the recharge rates, assuring that all of the runoff would be introduced into the underground reservoir as quickly as possible following runoff.

79. COMPARISON OF METHODS OF OPERATION.- Table 48 presents a comparison of the average annual pumpage and springflow from the Edwards Reservoir for the period 1935-1956 based upon the three different plans of operation.

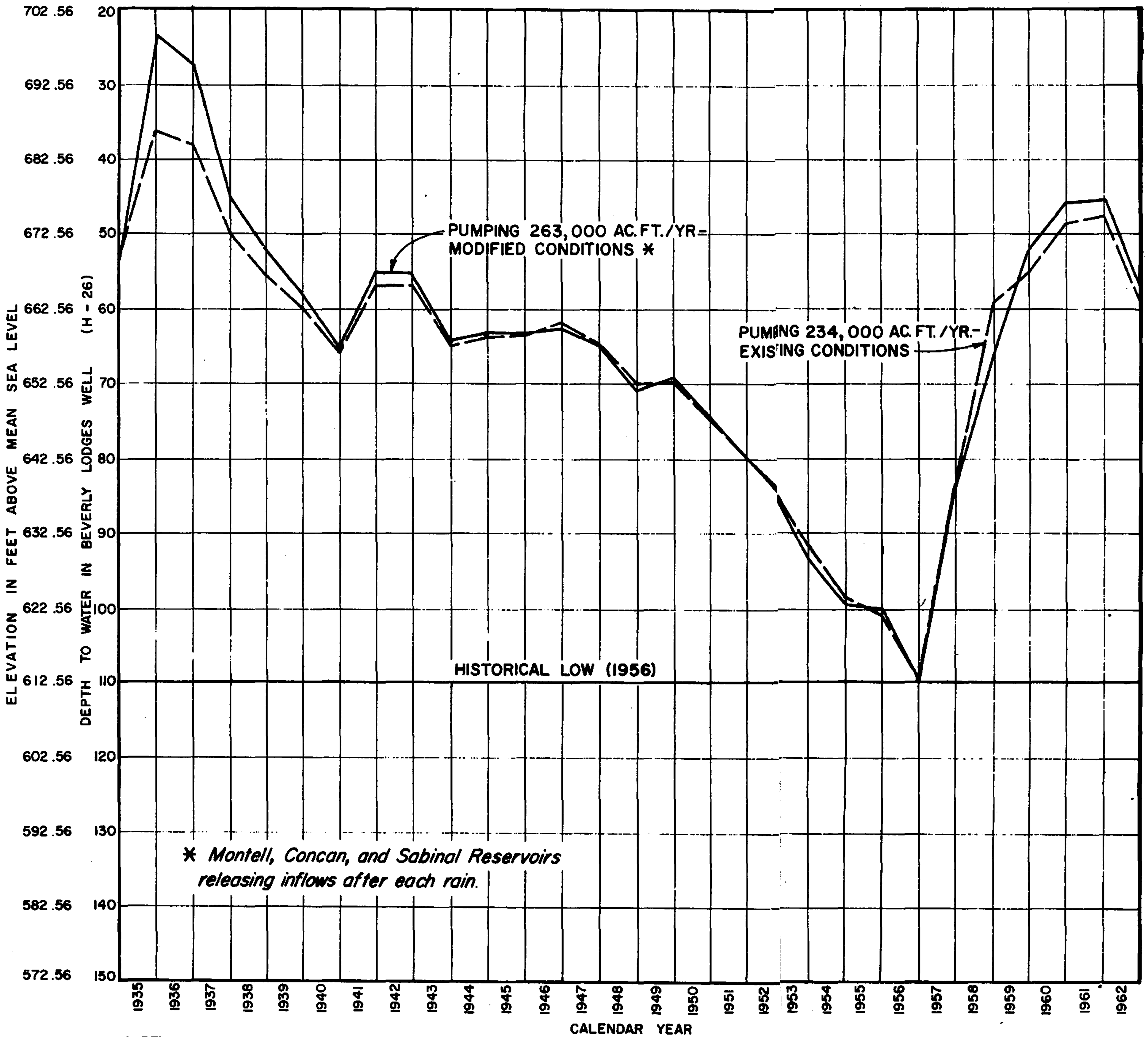
TABLE 48

COMPARISON OF THE EFFECT OF SELECTED OPERATION PLANS

Pumpage (ac. ft./annum)	Method of Operation	Average annual springflow (1) (ac. ft./annum)	Total springflow and pumpage (ac. ft./annum)	Elevation of lowest water level (2) (ft. msl
234,000	Existing conditions	292,900	526,900	612
278,000	Release dependable yield	271,700	549,700	612
307,000	Release during drought period to maintain 612 elevation	233,000	540,000	612
263,000	Immediate recharge	327,800	590,800	612

(1) Average annual springflow based on period 1935 through 1956.
(2) Level at Well H-26 (Beverly Lodges Well).

In each case, Montell, Concan, and Sabinal Reservoirs are considered as the system of reservoirs modifying the natural recharge. As indicated in table 48, the high evaporation rate in this region prevents the efficient and effective recharge of the Edwards Reservoir by storage of floodwaters in permanent conservation pools thereby eliminating the first two plans listed in paragraph 78. The third method of operation would enable the development of maximum water resources at the dam sites with a minimum loss of the resources to evaporation. Studies were made of the effect on the underground water level of various systems of surface reservoirs to be constructed above the fault zone. The locations of the investigated surface reservoirs are shown on plate 4. Analyses of the benefits and costs of the investigated projects resulted in the recommendation of only three reservoirs for the modification of the recharge to the Edwards Reservoir. These projects, which are located on plate 13, are Montell Reservoir on the Nueces River, Concan Reservoir on the Frio River, and Sabinal Reservoir on the Sabinal River. Plate 44 indicates the effect



NOTE:
Both routings assume pumpage at constant rate through period 1935 - 1962.

EDWARDS UNDERGROUND RESERVOIR

COMPARISON OF UNDERGROUND WATER LEVELS RESERVOIR IN OPERATION

DEC. 1964 PLATE 44

on the Edwards Reservoir of this system of reservoirs by comparing underground reservoir levels and pumpage rates for the period 1935-1962. Several rates of constant pumpage were used in preliminary routings both with and without the recharge reservoirs in the system. The comparison presented, however, is only for those rates of pumpage which, for natural and modified conditions, reproduced the historic low level (elevation 612) for the underground reservoir. The plate indicates that under the stated conditions, the increase in average annual pumpage is 29,000 acre-feet. In addition, flow from the major springs was increased by an average of 34,900 acre-feet annually. Water levels in the underground reservoir will be higher with the surface reservoirs in the system for recharge purposes. Under the modified recharge conditions the water levels would range from 1 to 13 feet higher and would average 2 feet higher during the 1935-1956 period. Table 49 shows an estimated geographical distribution of the average annual recharge under natural conditions and the additional average annual recharge creditable to the recommended plan of improvement.

TABLE 49

PHYSICAL EFFECTS OF THE PLAN

Stream***	Estimated average annual resources above lower edge of Edwards outcrop (ac-ft)*	Estimated average annual recharge (ac-ft)*: Existing conditions	Modified conditions	Increase due to reservoir projects	Average annual runoff at lower edge of Edwards outcrop*: Existing conditions	Modified conditions	Drainage area** (sq. mi.): Total	Controlled
GUADALUPE RIVER BASIN								
Blanco River and adjacent area	99,500	25,400	25,400	0	74,100	24,200(1)	514	307
Guadalupe River	246,000	0	0	0	246,000	74,100(2)	1,510	1,425
Dry Comal Creek	28,900	20,500	20,500	0	8,400	8,400	98	--
SUBTOTAL - Guadalupe River Basin	374,400	45,900	45,900	0	328,500	106,700		
SAN ANTONIO RIVER BASIN								
Cibolo Creek	58,900	54,100	54,100	0	4,800	4,800	258	--
Salado Creek	24,400	21,400	24,400(3)	3,000(3)	3,000	0	118	118
Leon and San Geronimo Creeks	29,300	27,600	27,600	0	1,700	1,700	152	--
Medina River	94,300	42,700	42,700	0	6,400(4)	6,400(4)	630	613
SUBTOTAL - San Antonio River Basin	206,900	145,800	148,800	3,000(3)	15,900	12,900		
NUECES RIVER BASIN								
Verde Creek	18,700	14,600	14,600	0	4,100	4,100	108	--
Hondo Creek	23,500	18,300	18,300	0	5,200	5,200	136	--
Tributary areas	13,700	10,700	10,700	0	3,000	3,000	79	--
Seco Creek	15,400	12,000	12,000	0	3,400	3,400	89	--
Sabinal River	33,900	17,600	33,400	15,800	16,300	500	214	210
Blanco and Hackberry Creeks	4,100	2,100	2,100	0	2,000	2,000	26	--
Little Blanco Creek	2,500	1,300	1,300	0	1,200	1,200	16	--
Frio River	65,000	40,000	61,500	21,500	25,000	3,500	432	391
Two Tributaries	2,700	1,700	1,700	0	1,000	1,000	18	--
Dry Frio River	27,000	17,100	17,100	0	9,900	9,900	140	--
Leona River	6,800	4,300	4,300	0	2,500	2,500	35	--
Deep Creek	3,500	2,200	2,200	0	1,300	1,300	18	--
Nueces River	98,700	64,400	91,000(5)	26,600(5)	34,300	3,400	784	707
Indian Creek	6,400	4,200	4,200	0	2,200	2,200	51	--
Four Tributaries	7,700	5,000	5,000	0	2,700	2,700	61	--
West Nueces River	29,800	16,000	16,000	0	13,800	13,800	905	--
SUBTOTAL - Nueces River Basin	359,400	231,500	295,400(5)	63,900(5)	127,900	59,700		
TOTAL - Edwards Reservoir Area	940,700	423,200	490,100(3)(5)	66,900(3)(5)	472,300	179,300		

* The annual resources, recharge and runoff (exclusive of springflow) at the lower edge of the Edwards outcrop are averages for the period 1935-56.
** The drainage area at lower edge of the Edwards outcrop, as indicated on plates 2 and 3.
*** Location of dam sites shown on plate 13.
(1) Reduced by estimated net inflow of 49,900 ac-ft/yr to Cloptin Crossing.
(2) Reduced by estimated net inflow of 171,90 ac-ft/yr to Dam No. 7 - Canyon Reservoir system.
(3) Using 16 SCS detention structures on Salado Creek (1962 Work Plan), for increase of 3,000 ac-ft/yr.
(4) Does not include approximately 45,200 ac-ft/yr combined loss to evaporation and use for irrigation.
(5) Does not include 4,300 ac-ft/yr (4 mgd) to be delivered to downstream areas.

EFFECTS OF PLAN ON DOWNSTREAM RESERVOIRS

80. NUECES RIVER BASIN.

a. The master plan prepared by the Nueces River Conservation and Reclamation District includes the proposed construction of Concan and Sabinal Reservoirs on the Frio and Sabinal Rivers, respectively, for recharge of the Edwards Underground Reservoir. The District has indicated that these recharge projects would have only a negligible effect on downstream water rights. The master plan also recommends construction of the Tom Nunn Hill and the Cotulla Reservoirs and the enlargement of Wesley Seale Reservoir. It was recommended in the master plan that Tom Nunn Hill and Cotulla Reservoirs be constructed with conservation capacities of 50,000 and 300,000 acre-feet, respectively, and that the conservation storage capacity in the existing Wesley Seale Reservoir be enlarged from 300,000 to 500,000 acre-feet. The reservoirs included in the master plan are located on plate 1.

b. The plan of development for the Edwards Reservoir area has been formulated in consonance with the improvements proposed in this master plan. Although Montell Reservoir is proposed in lieu of Tom Nunn Hill Reservoir, storage in the Montell project, with the channel dam and pipeline facilities included, would furnish to the Reclamation District the dependable yield of the Tom Nunn Hill project. The dependable yield for Tom Nunn Hill Reservoir has been estimated to be 4,300 acre-feet per year (6 second-feet). To obtain a yield of 4,300 acre-feet per year from Montell Reservoir a net conservation storage of 1,000 acre-feet has been recommended. In addition, substituting Montell Reservoir in the Tom Nunn Hill-Cotulla-Wesley Seale Reservoir system for Tom Nunn Hill Reservoir would not have an adverse effect on the yield of Wesley Seale Reservoir.

c. Examination of the resources of the Cotulla Reservoir indicates that under natural conditions the Nueces River loses large quantities of water to the Edwards Underground Reservoir as the stream crosses the outcrop of the Edwards limestone in the Balcones Fault zone. In addition, the river loses flow to the alluvial gravels and sand formations downstream from the fault zone. It is estimated that under existing conditions, flow occurring at the Montell Dam site at the rate of 14,000 acre-feet per month would be lost in transit through the fault zone and the gravel and sand formations downstream from the fault zone, and no part of such flow would reach the Cotulla Reservoir. Similarly, it is estimated that under natural conditions a flow of 60,000 acre-feet per month at the Montell Dam site would be reduced to only 10,000 acre-feet at the Cotulla site. It is estimated that if Tom Nunn Hill Reservoir had been in operation during the critical drought period, 1947-1956, the September 1955 storm would have produced the only runoff in the upper basin during this period which would have reached the Cotulla Reservoir. It is estimated that the flow reaching Cotulla Reservoir would have been approximately 16,100 acre-feet. If Montell Reservoir were constructed in lieu of Tom Nunn Hill Reservoir, this flow would not have reached the Cotulla Reservoir. It is considered, however, that the probability of the recurrence of a flood of the magnitude of the September 1955 flood (largest for peak discharge since 1854) during some future critical drought period is so remote that it should be disregarded in establishing reservoir size or yield. This flood was produced from a storm centered over a small area in the upper Nueces River Basin. If this flood were disregarded, construction of Montell Reservoir in lieu of Tom Nunn Hill Reservoir would not have an adverse effect on the yield of either of the two downstream reservoirs as presented in the master plan.

81. GUADALUPE RIVER BASIN.

a. The plan of development for the Guadalupe River Basin is set forth in the "Supplement to the Initial Plan of Development of the Guadalupe-Blanco River Authority," dated May 1961. This master plan provides for the construction of Cloptin Crossing Reservoir, but at a smaller size than that recommended in this report. The master plan also provides for construction of Dam No. 7 Reservoir in case excessive leakage is experienced at Canyon Reservoir; however, it would provide less storage than the project recommended in this report. The locations of the reservoirs included in the master plan are shown on plate 1.

b. Yield studies were made for the two sizes of projects at each of the Cloptin Crossing and Dam No. 7 Reservoir sites and for Canyon and Cuero Reservoirs. These studies indicated that the critical drought period at each of the above reservoirs occurred during the period from June 1947 through February 1957. During this period there would be no reservoir spills from the Cloptin Crossing and Dam No. 7 projects as recommended in the master plan and, consequently, the increase in size of the upstream projects could not decrease the inflow to Cuero Reservoir during its critical period. For this reason the yield of the Cuero Reservoir as presented in the master plan would not be affected by the increase in the conservation capacity of the Cloptin Crossing and Dam No. 7 Reservoirs as recommended in this report.

c. If the Montell, Concan, and Sabinal Reservoirs in the Nueces River Basin were constructed and operated to recharge the Edwards Underground Reservoir, and if the plan were adopted to limit the pumping from the aquifer to 263,000 acre-feet per year, the additional springflow from the Comal, Hueco, and San Marcos Springs in the Guadalupe River Basin would increase the resources of Cuero Reservoir by about 17,600 acre-feet annually.

82. GENERAL.- A study was made of the Edwards Underground Reservoir watershed to determine the hydraulic characteristics under existing conditions, and for various plans of improvement which would alleviate flooding and increase ground water recharge and water conservation.

83. WATER-SURFACE PROFILES - EXISTING CONDITIONS.- Backwater studies of selected water courses in the survey area were made to establish water-surface profiles, limits of flooding, and channel capacities under existing conditions. The backwater computations were based on the Manning formula in accordance with paragraph 10 of EM 1110-2-1409, 7 Dec 1959, using coefficients of roughness, n, of 0.035 to 0.050 for the existing channels and 0.060 to 0.100 for the existing overbanks. The studies were correlated with high-water data and stream-gaging station records. Plates 45 through 52 show the profiles of the major rivers and creeks in the Edwards area and their historical high-water profiles, which are based on high-water marks, stream-gaging records, and available historical information.

84. PLAN OF IMPROVEMENT.- Possible damsites, individually and in conjunction with other sites, and related pipeline distribution systems were investigated. The recommended plan of improvement would consist of two multiple-purpose reservoirs, Montell and Cloptin Crossing; two recharge and flood-control reservoirs, Concan and Sabinal, to be constructed by the Federal Government, and one conservation-only reservoir, Dam No. 7, to be constructed by local interests. Also in conjunction with Montell Dam, there would be a channel dam and pipeline to convey low-flow discharges from Montell Reservoir across a downstream loss zone.

85. MONTELL DAM-SPILLWAY.- The Montell Dam would be located on the Nueces River at river mile 401.6, with the spillway in the left bank. The spillway would consist of a 960-foot uncontrolled broadcrested weir with crest at elevation 1331.0. Details of the dam and spillway are shown on plate 53. Under conditions of the spillway design discharge (570,600 second-feet), the reservoir would be at elevation 1366.0. The spillway rating curve, adjusted for approach losses, is shown on figure 2, plate 54.

86. MONTELL DAM-OUTLET WORKS.- The flood-control outlet works would consist of a 15-foot diameter conduit controlled by three 5-foot, 8-inch by 12-foot tractor-type gates. The conduit would be located in the main embankment, with inlet invert at elevation 1216.0 and outlet invert at elevation 1214.0, as shown on plate 53. The outlet works would be used for diversion during construction, for the passage of flood releases, and for the passage of low-flow discharges. The capacity of the conduit with the reservoir water surface level at

top of conservation pool, elevation 1237.0, and at maximum design water surface, elevation 1366.0, would be about 3,400 second-feet and 10,400 second-feet, respectively. Figure 1, plate 54 shows the rating curve for the outlet works.

87. MONTELL DAM - TAILWATER RATING CURVE.- The tailwater rating curve at the Montell Dam site is shown on figure 3, plate 54. This rating curve was developed by slope-area computations at the dam site.

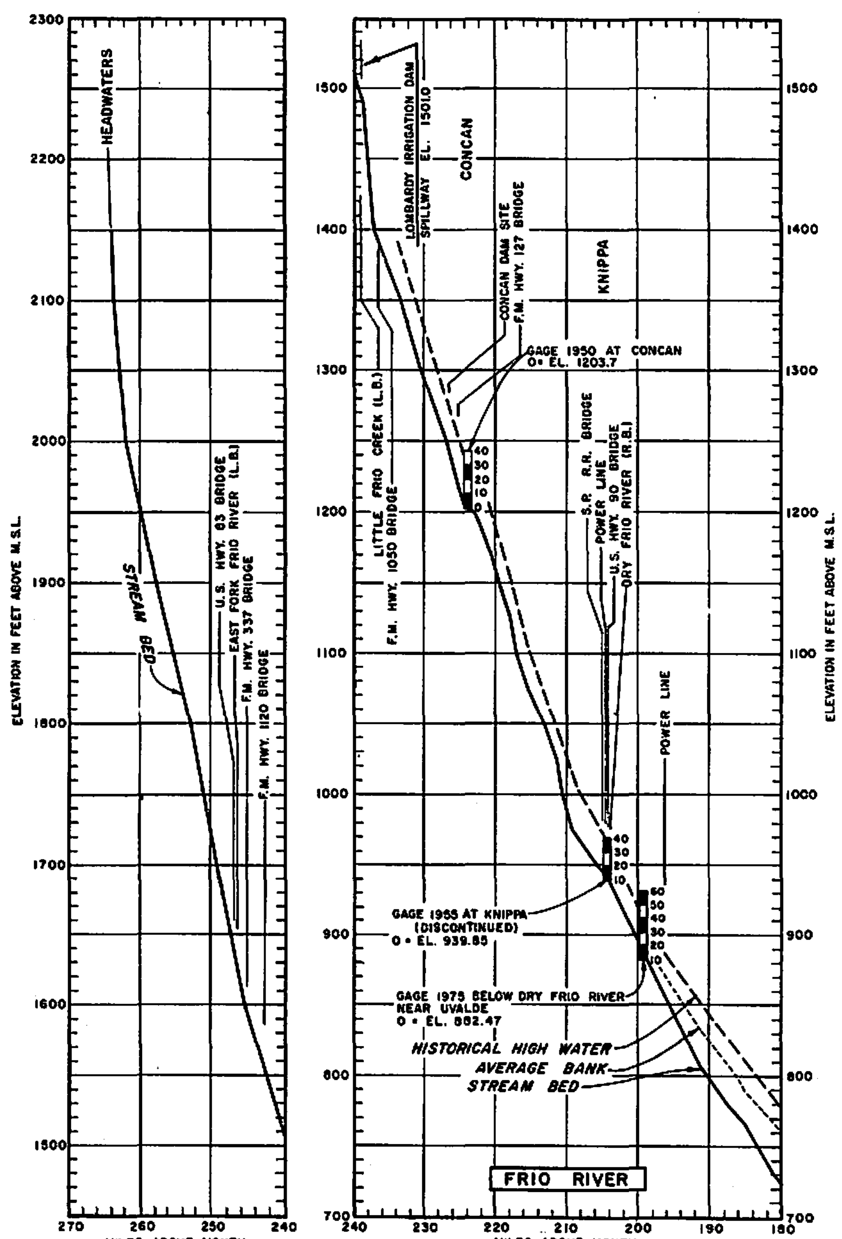
88. CONCAN DAM - SPILLWAY.- The Concan Dam would be located on the Frio River at river mile 226.2, with the spillway in a saddle on the right bank. The spillway would consist of a 1,030-foot uncontrolled broadcrested weir with crest at elevation 1366.5. Details of the dam and spillway are shown on plate 55. Under conditions of the spillway design discharge (425,300 second-feet), the reservoir would be at elevation 1394.2. The spillway rating curve, adjusted for approach losses, is shown on figure 2, plate 56.

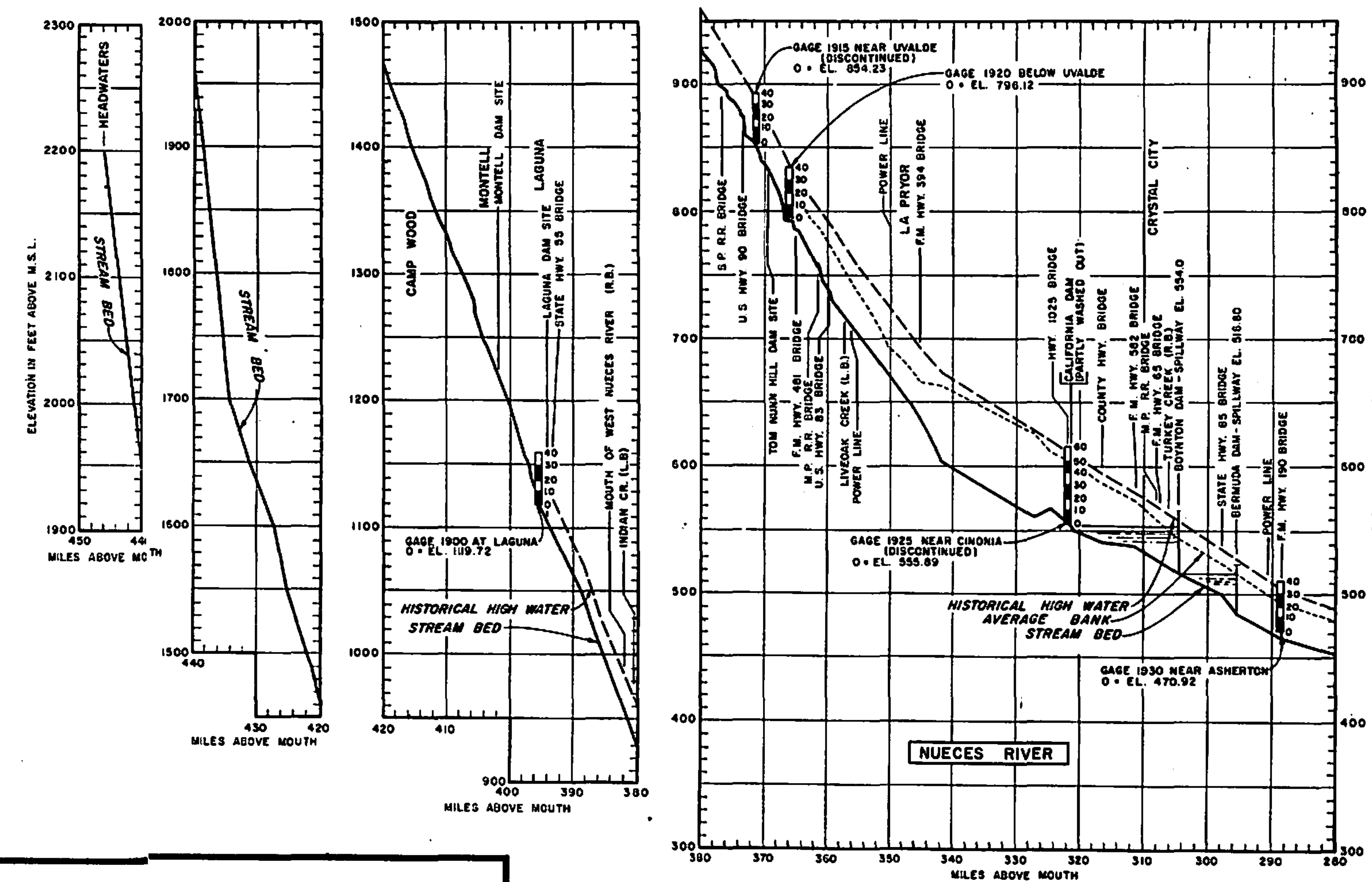
89. CONCAN DAM - OUTLET WORKS.- The outlet works would consist of a 13-foot diameter conduit controlled by two 6-foot by 13-foot tractor-type gates. The conduit would be located in the main embankment, with inlet invert at elevation 1240.0 and outlet invert at elevation 1238.0, as shown on plate 55. The outlet works would be used for diversion during construction and for passage of flood-control releases. The capacity of the conduit with reservoir water surface level at spillway crest, elevation 1366.5, and at maximum design water surface, elevation 1394.2, would be about 8,000 second-feet and 7,700 second-feet, respectively. The outlet works rating curve is shown on figure 1, plate 56.

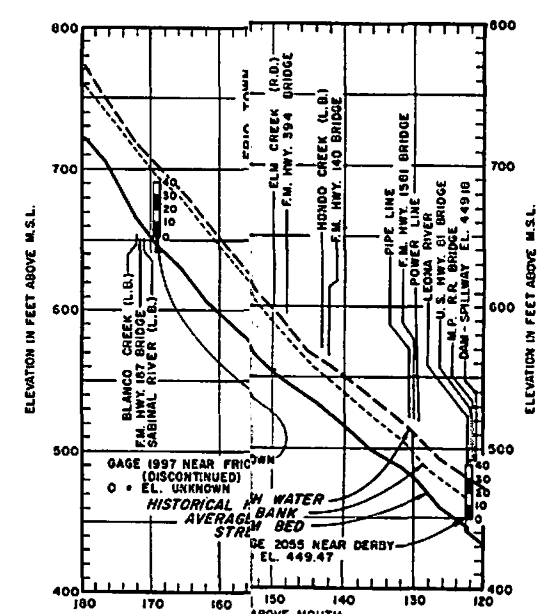
90. CONCAN DAM - TAILWATER RATING CURVE.- The tailwater rating curve at the damsite is shown on figure 3, plate 56. The tailwater rating curve was developed by backwater methods from the U. S. Geological Survey stream-gaging station Number 081950 on the Frio River at Concan, Texas, 2.1 miles downstream from the dam site, and extended by slope-area computations to encompass the spillway design discharge.

91. SABINAL DAM - SPILLWAY.- The Sabinal Dam would be located on the Sabinal River at river mile 42.3, with a gated spillway adjacent to the river channel. The spillway would consist of a 240-foot ogee weir with crest at elevation 1196.5, controlled by six 40- by 30-foot tainter gates separated by five 8-foot piers. Details of the dam and spillway are shown on plate 57. Under conditions of the spillway design discharge (270,600 second-feet), the reservoir water surface level would be at elevation 1238.8. Figure 2, plate 58 shows the rating curve for the spillway.

92. SABINAL DAM - OUTLET WORKS.- The outlet works would consist of two 3-foot by 6-foot conduits located in two gate piers.







NOTES:

Abbreviations L.B. and R.B. refer to left and right bank, respectively.
High-water profiles depict maximum known water surface levels.
Gage numbers refer to U.S.G.S. permanent numbering system.
Add prefix 08. to gage number to obtain complete number.
Profile data from Corps of Engineers survey.

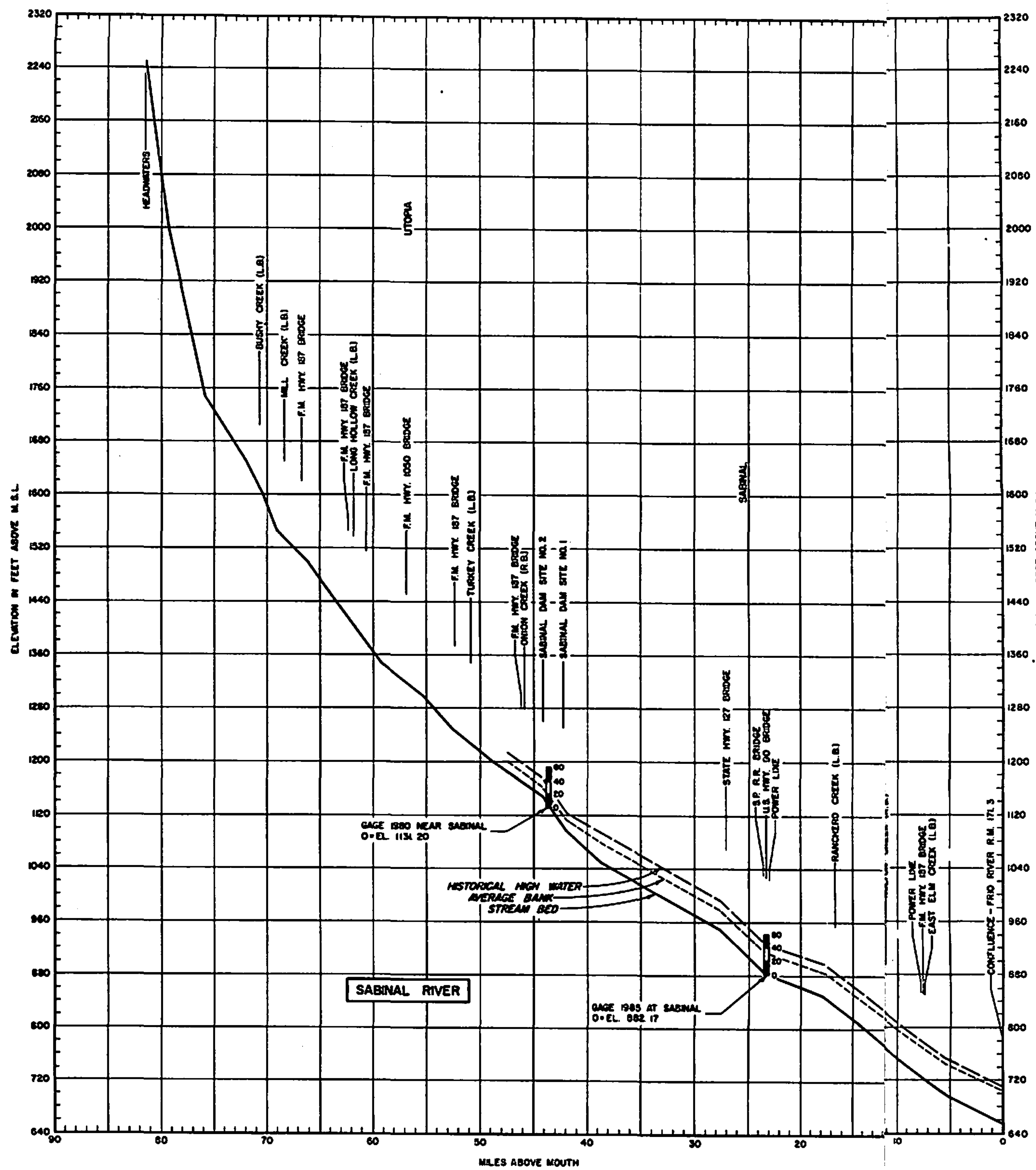
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR

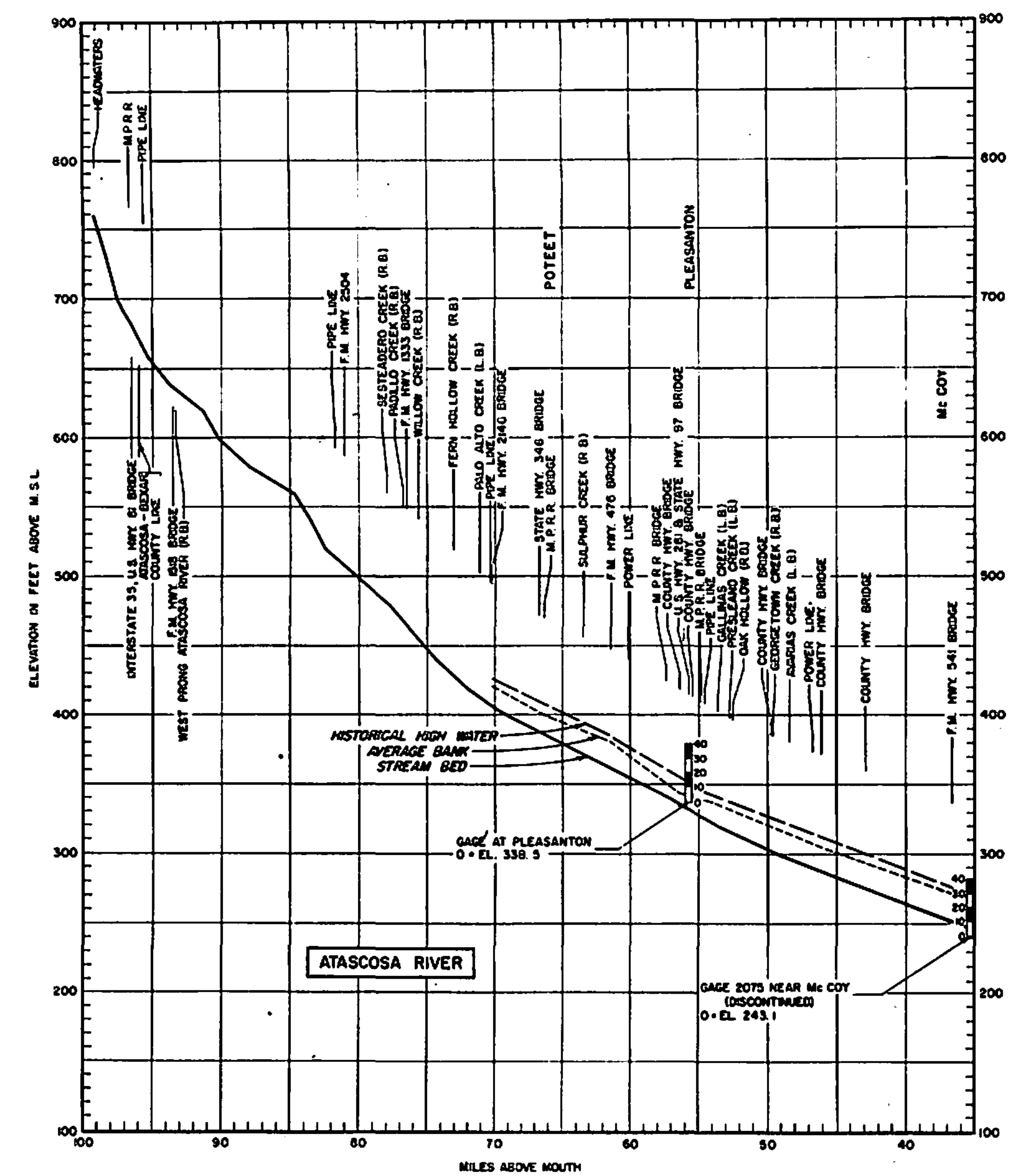
NUECES RIVER AND TRIBUTARIES

PROFILES

SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH		DEC. 1964
SUBMITTED: [signature] CHIEF, PROJECT PLANNING BRANCH	APPROVAL RECOMMENDED: [signature] CHIEF, ENGINEERING DIVISION	APPROVED: [signature] DISTRICT ENGINEER
PREPARED: [signature] CHIEF, H&H INVESTIGATIONS SECTION	DRAWN BY: B.G.S. / CHECKED BY: D.T.K.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR / FILE: GUAD. 707-2





NOTES:

Abbreviations L.B. and R.B. refer to left bank, and right bank, respectively.
High-water profiles depict maximum known water surface levels.
Gage numbers refer to U.S.G.S. permanent numbering system.
Add prefix 08. to number to obtain complete gage number.
Sabinal River profile data obtained from A.M.S. maps, and stream gaging stations. Atascosa River data obtained from C. of E. Survey.

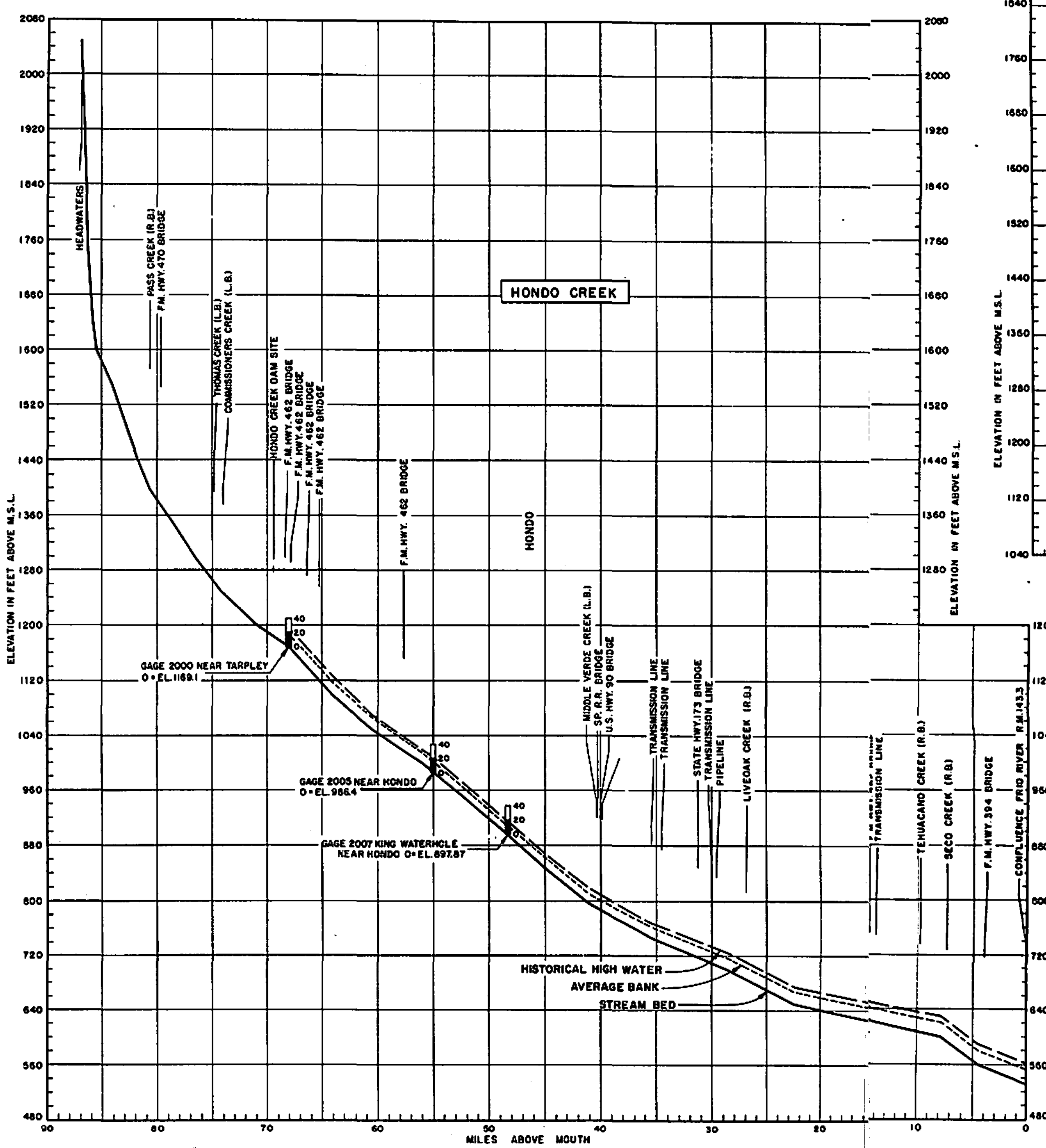
GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
NUECES RIVER TRIBUTARIES

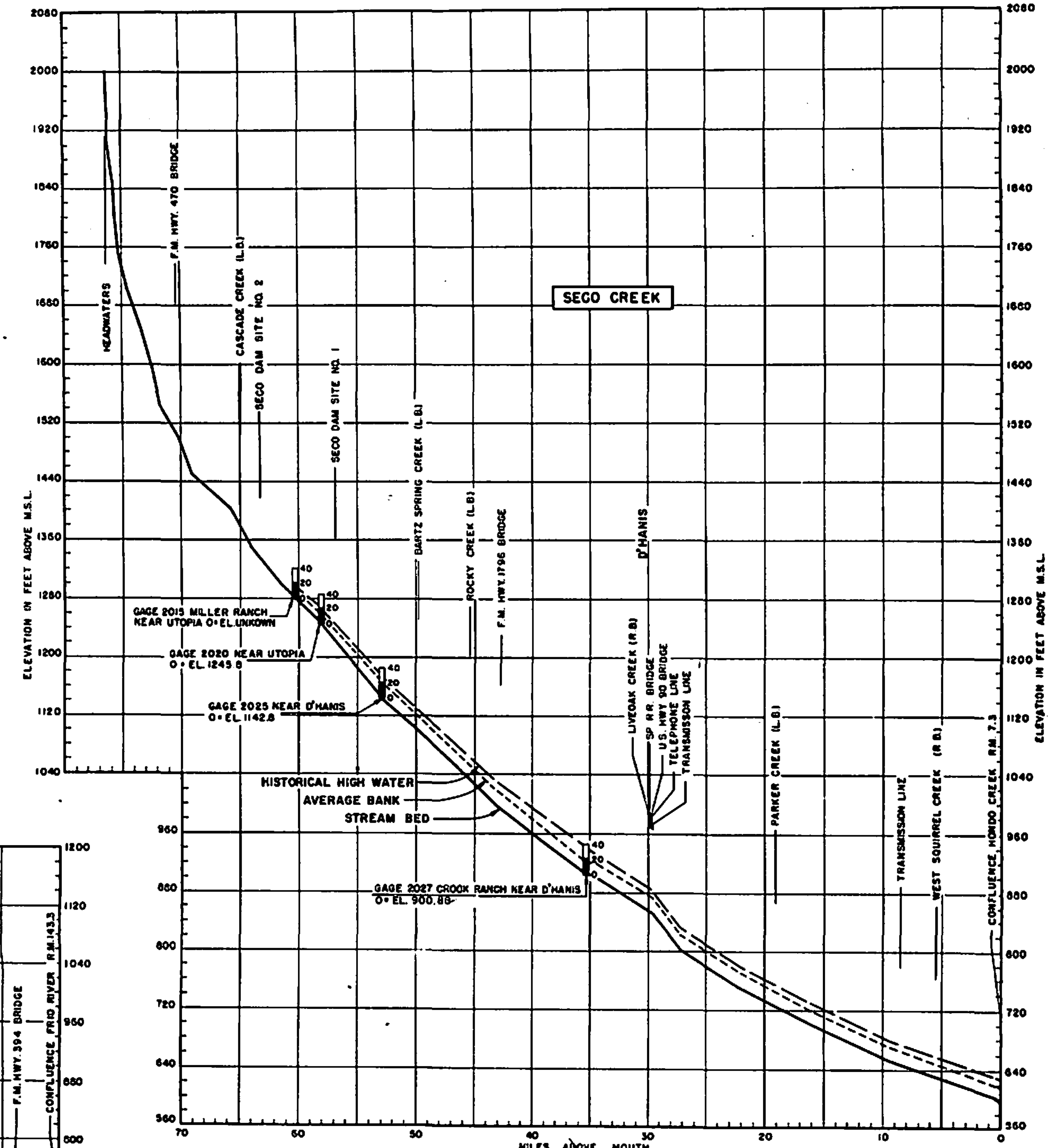
PROFILES

SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED: W. E. Wood, Chief, Project Planning Branch
APPROVAL RECOMMENDED: Chief, Engineering Division
APPROVED: Col. Corps of Engineers, District Engineer
PREPARED: Chief, Geo. Investigation Section
DRAWN BY: T.L.W.
CHECKED BY: D.T.K.
TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
FILE: GUAD. 707-2





NOTES:

Abbreviations L.B. and R.B. refer to left bank and right bank, respectively.

High-water profiles depict maximum known water surface levels. Gage numbers refer to U.S.G.S. permanent numbering system.

Add prefix 08. to number to obtain complete Gage number. Profile data obtained from A.M.S. maps and stream gaging stations.

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

EDWARDS UNDERGROUND RESERVOIR

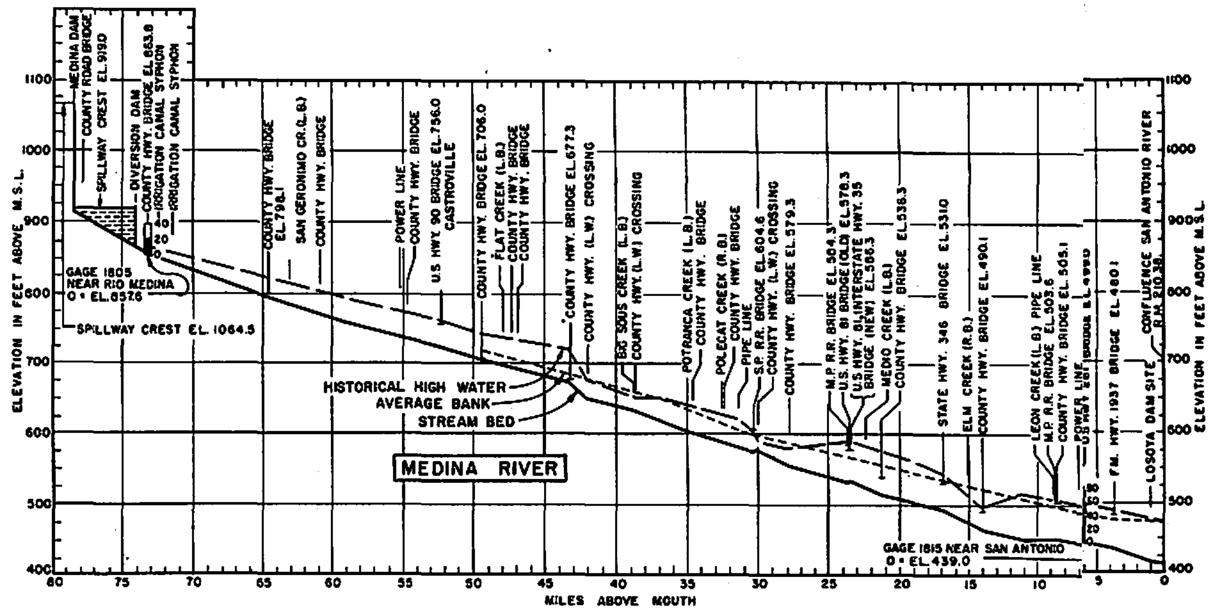
NUECES RIVER TRIBUTARIES

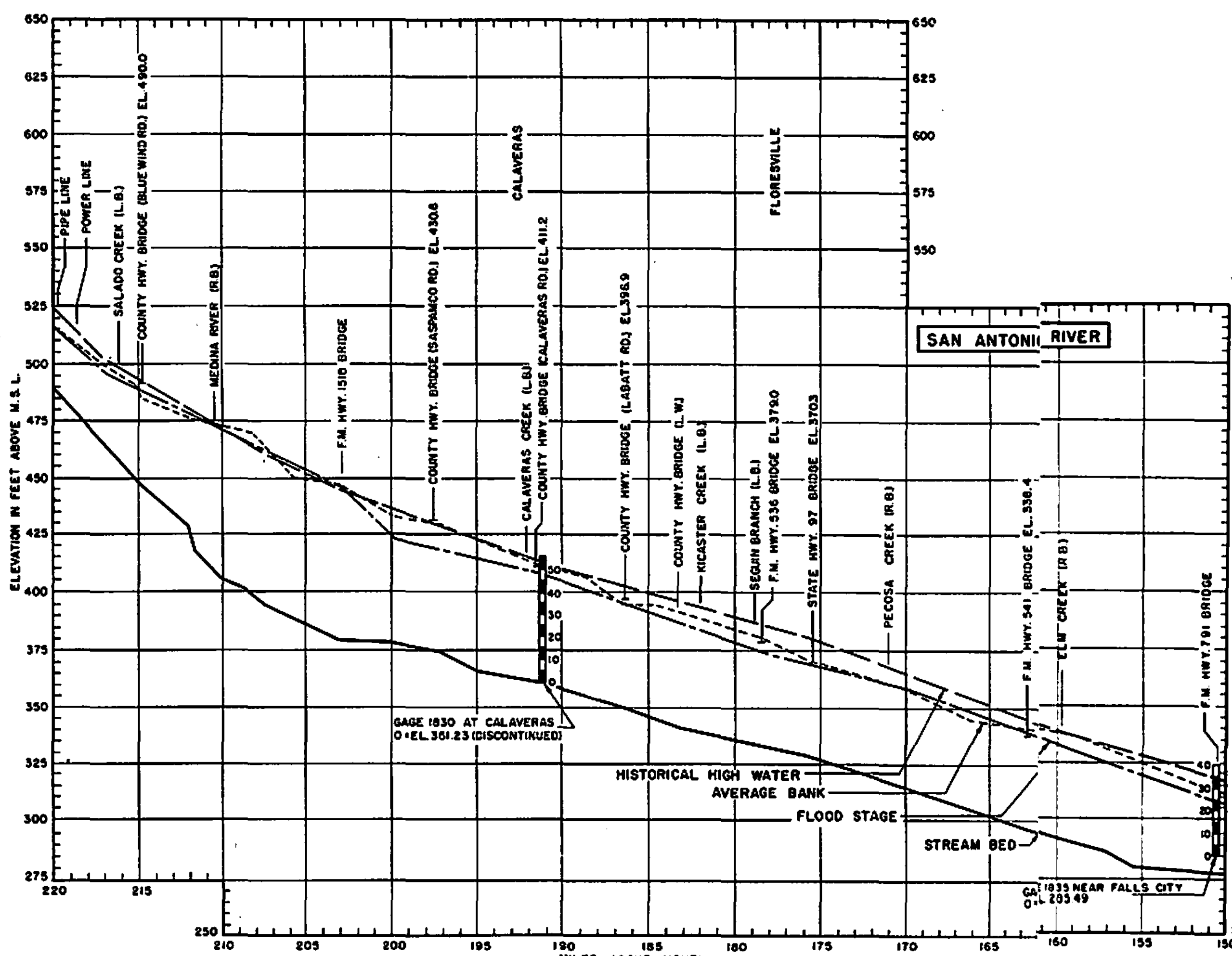
PROFILES

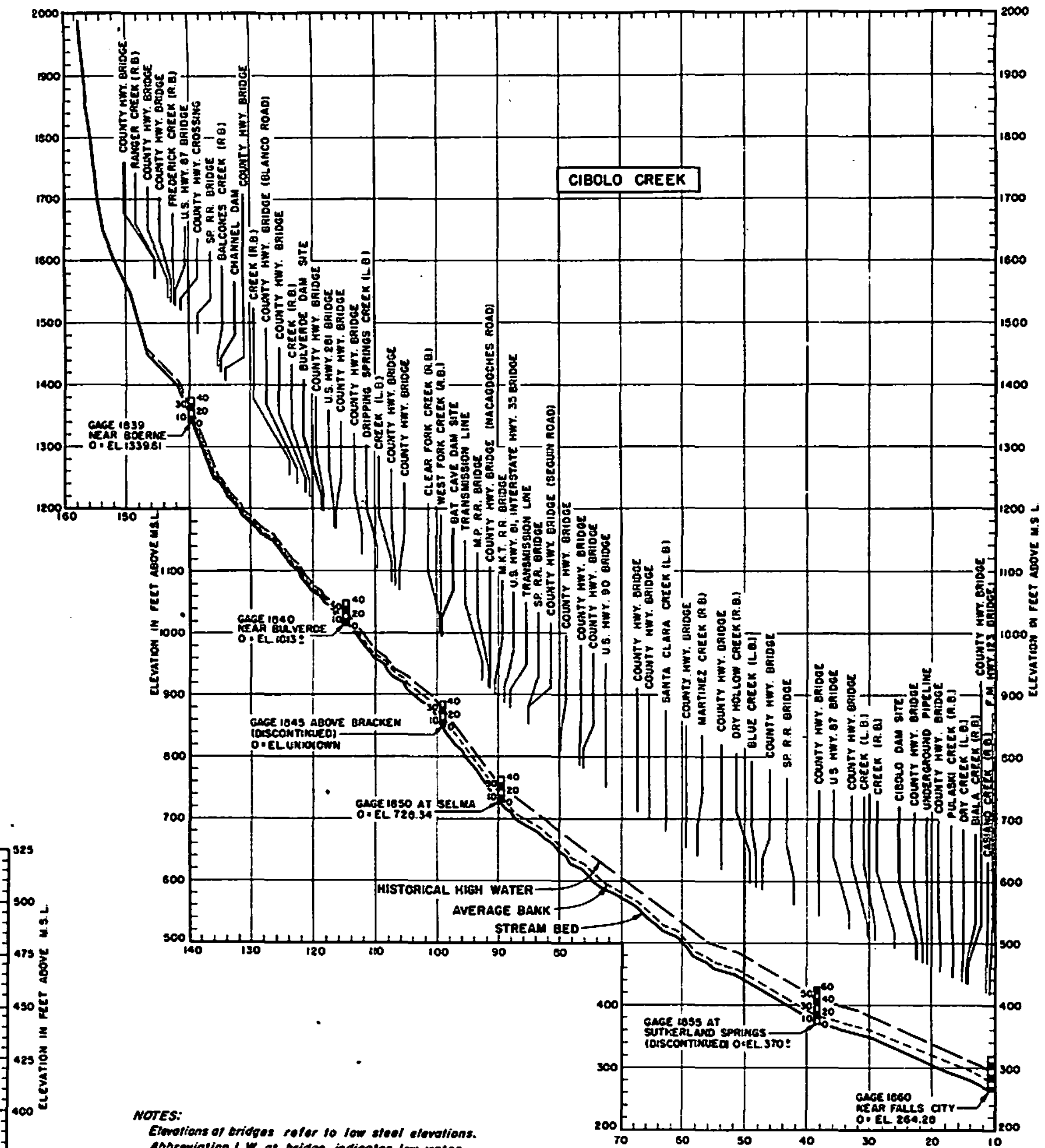
SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED:	APPROVAL RECOMMENDED:	APPROVED:
W. E. Wood, Engineer, Chief, Project Planning Branch	Engineer, Chief, Engineering Division	Col., Corps of Engineers, District Engineer
PREPARED: Chief, Gen. Investigations Section	DRAWN BY: J.L. CHECKED BY: D.T.K.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR. FILE: GUAD. 707-2







NOTES:

Elevations at bridges refer to low steel elevations.

Abbreviation L.W. at bridge indicates low water bridge.

Abbreviations L.B. and R.B. refer to left bank and right bank, respectively.

High-water profiles depict maximum known water surface levels.

Gage numbers refer to U.S.G.S. permanent numbering system. Add prefix 08. to number to obtain complete number.

San Antonio and Medina River profiles are from C. of E. surveys.

Cibolo Creek profile data are from U.S.G.S. and A.M.S. maps, and stream gaging stations.

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR

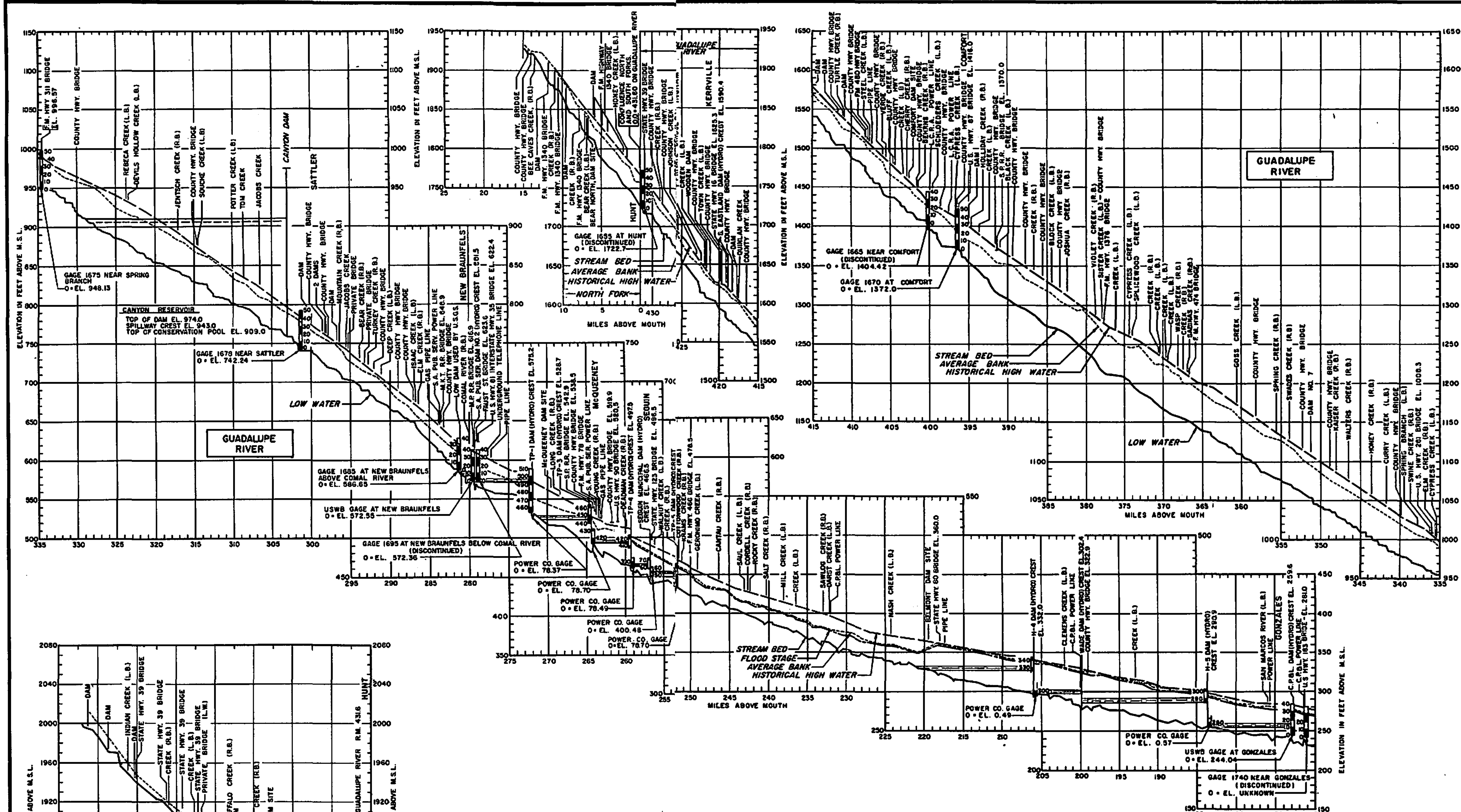
SAN ANTONIO RIVER AND TRIBUTARIES

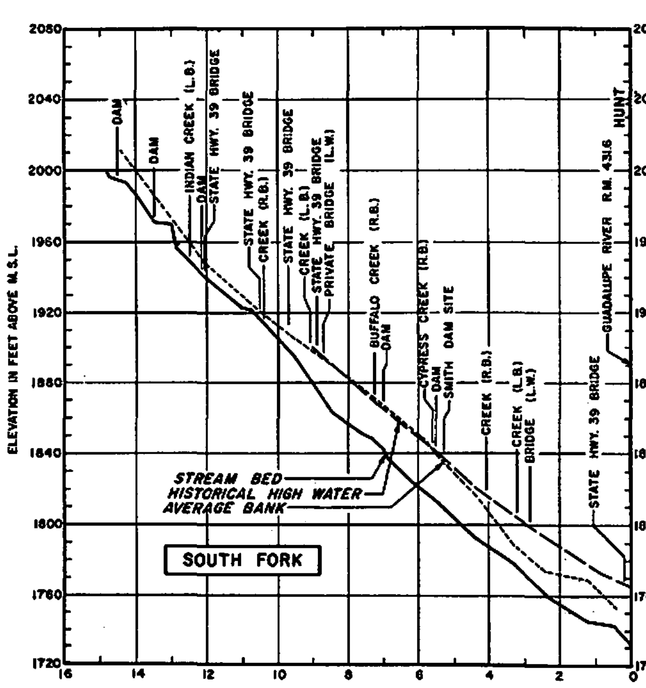
PROFILES

SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED: W. E. Wood, Engineer, Chief, Project Planning Branch	APPROVAL RECOMMENDED: Engineer, Chief, Engineering Division	APPROVED: Col., Corps of Engineers, District Engineer
PREPARED: Engineer, Chief, Gen. Investigations Section	DRAWN BY: J.L. CHECKED BY: D.T.K.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR. FILE: GUAD. 707-2





NOTES:

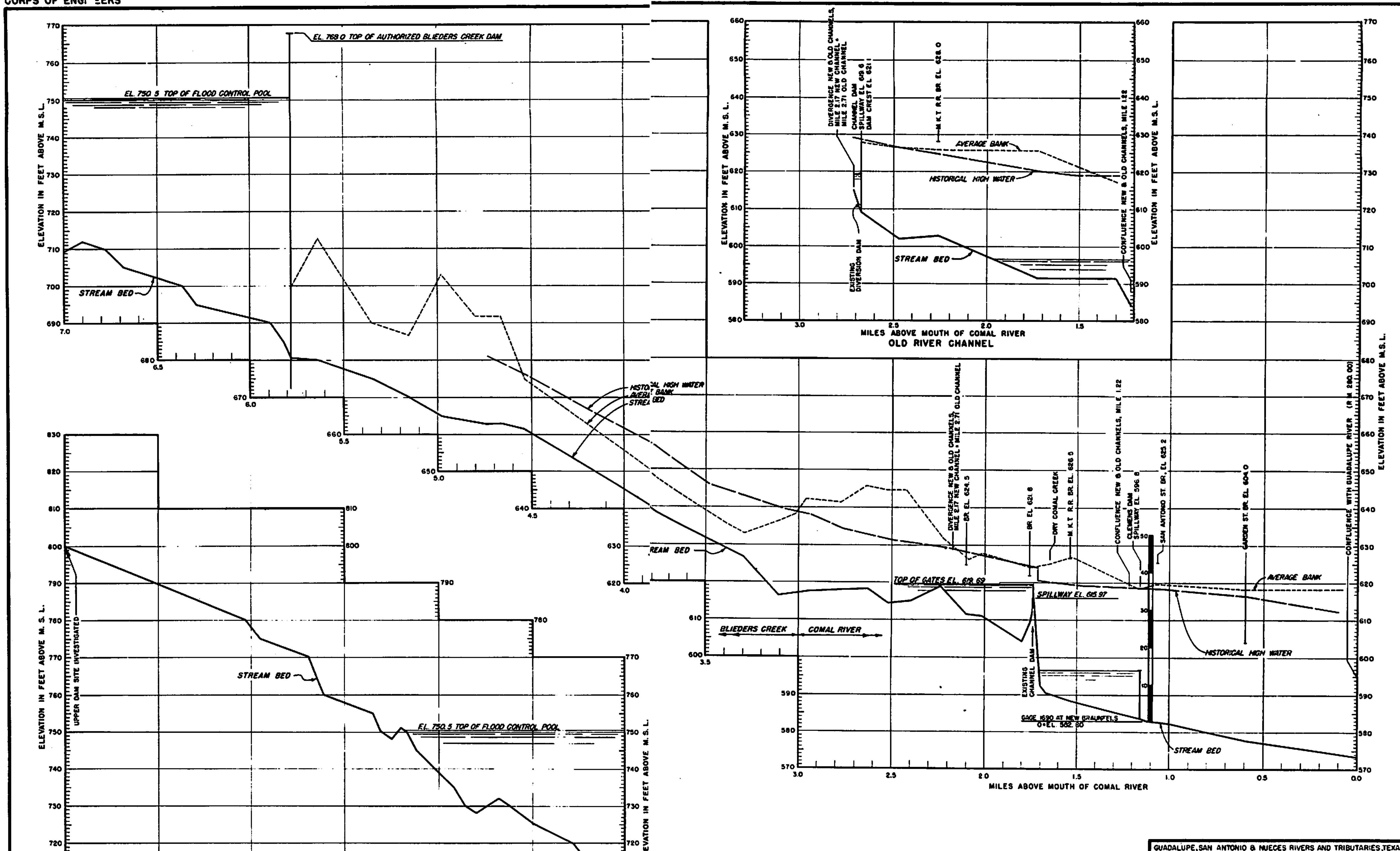
Elevations of bridges refer to low steel elevations.
L.W. at bridge indicates low water bridge L.B and RB are abbreviations for left bank and right bank, respectively
High-water profiles depict maximum known water surface levels,
Gage numbers refer to U.S.G.S. permanent numbering system.
Add prefix 08. to number shown to obtain complete gage number.
Mile 170.00 to mile 281.05 & mile 367.46 to mile 14.92 (North Fork), show stream bed profile.
Mile 281.06 to mile 367.46, show low water profile.
Corps of Engineers - 1935 and 1939 survey data, Central Power & Light Company Data.
Texas Power & Light Co. - 1928 survey data was used to supplement the water surface data obtained by the Corps of Engineers field party from miles. 367.0 to miles 419.0.

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE RIVER

PROFILES

SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH		DEC. 1964
SUBMITTED: W. E. Wood, CHIEF, PROJECT PLANNING BRANCH	APPROVAL RECOMMENDED: C. L. [signature], CHIEF, ENGINEERING DIVISION	APPROVED: [signature], COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: [signature], CHIEF, BASIN INVESTIGATIONS SECTION	DRAWN BY: B.O.S. CHECKED BY: D.T.W.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR. FILE: GUAD. 707-2



GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR

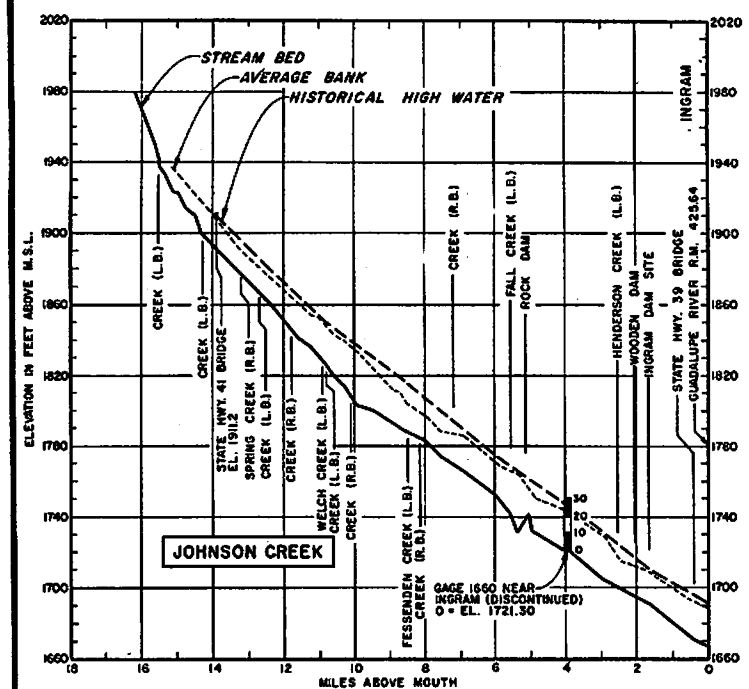
COMAL RIVER AND BLIEDERS CREEK

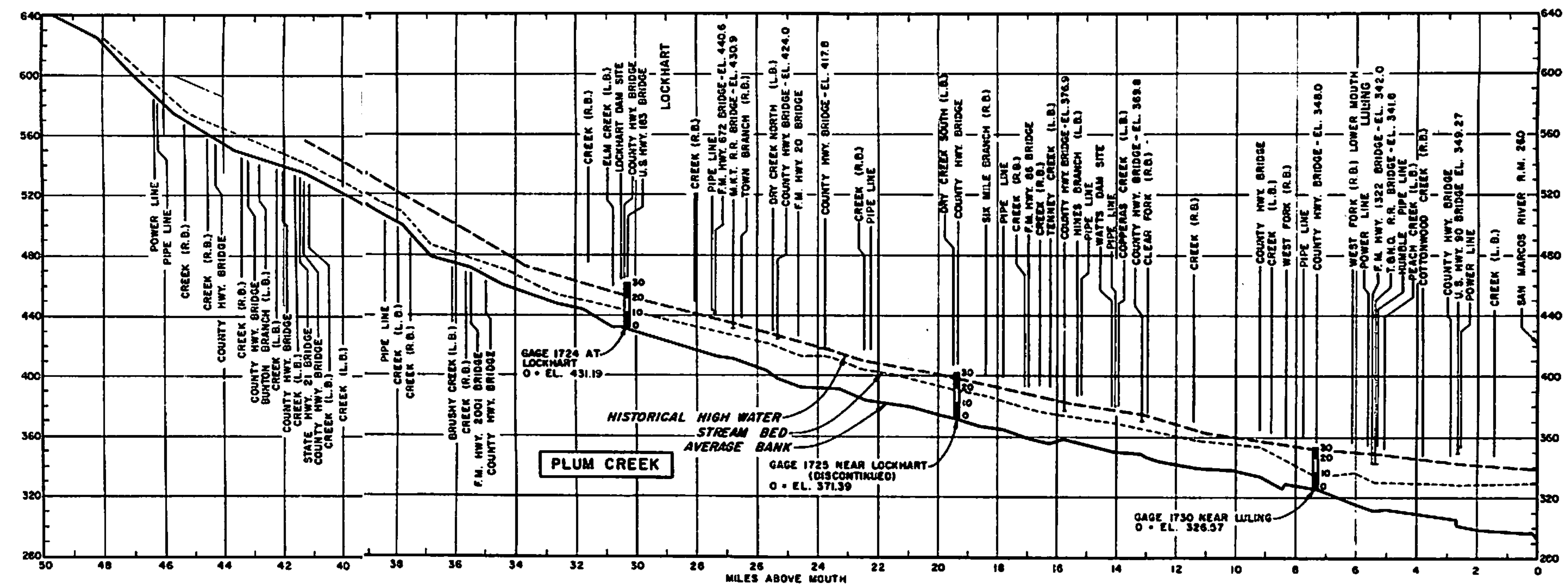
PROFILES

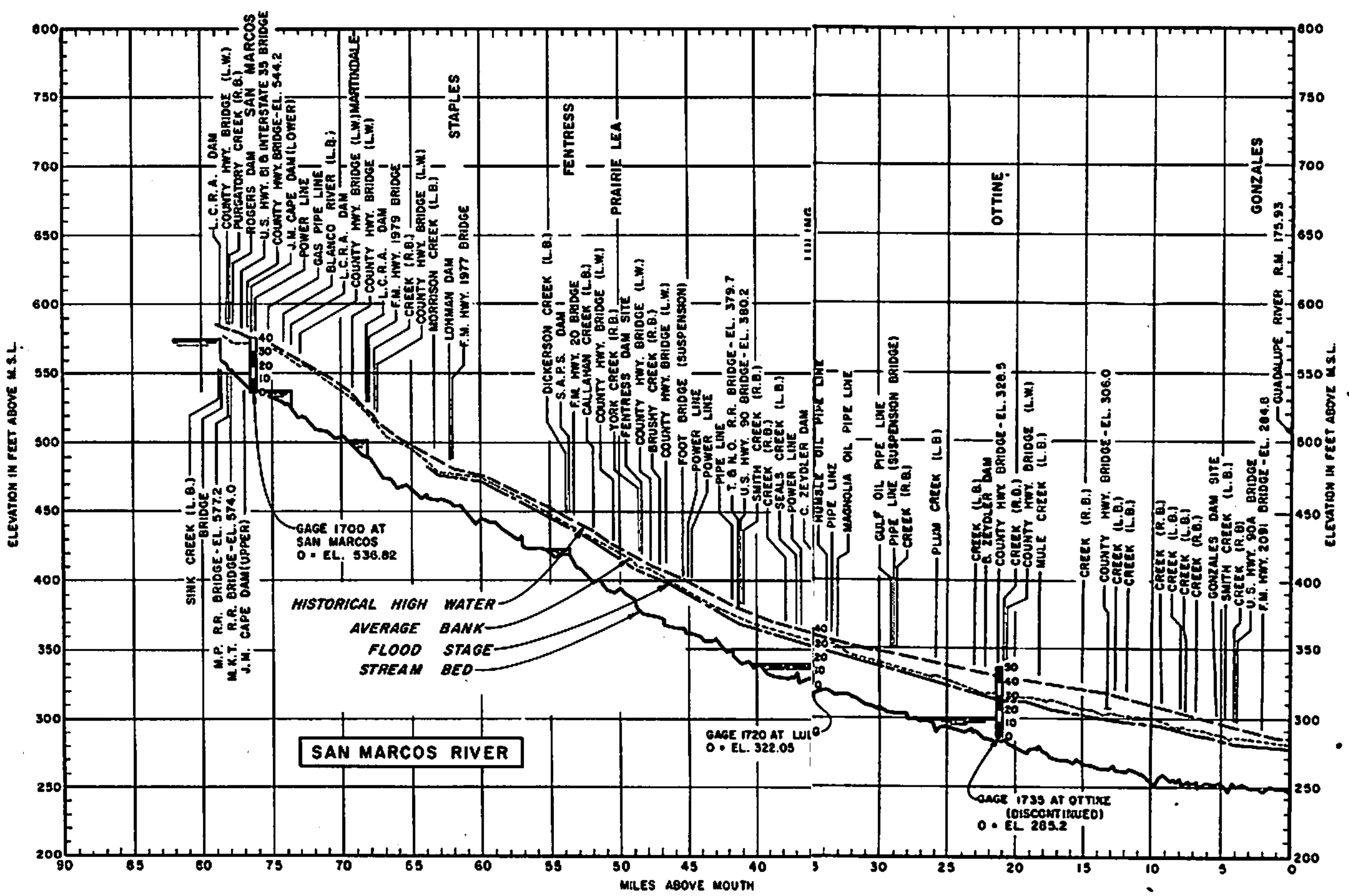
SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
CHIEF, PROJECT PLANNING BRANCH	CHIEF, ENGINEERING DIVISION	COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: CHIEF, GENERAL INVESTIGATIONS SECTION	DRAWN BY: T.L.W. / CHECKED BY: R.H.S.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR / FILE GUAD 707-2







NOTES:

Elevations at bridges refer to low steel elevations.
Abbreviation L.W. at bridge indicates low water bridge.
Abbreviations L.B. and R.B. refer to left bank and right bank respectively.
High-water profiles depict maximum known water surface levels.
Gage numbers refer to U.S.G.S. permanent numbering system. Add prefix 08. to number to obtain complete number.
Profile data from Corps of Engineers survey.

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR

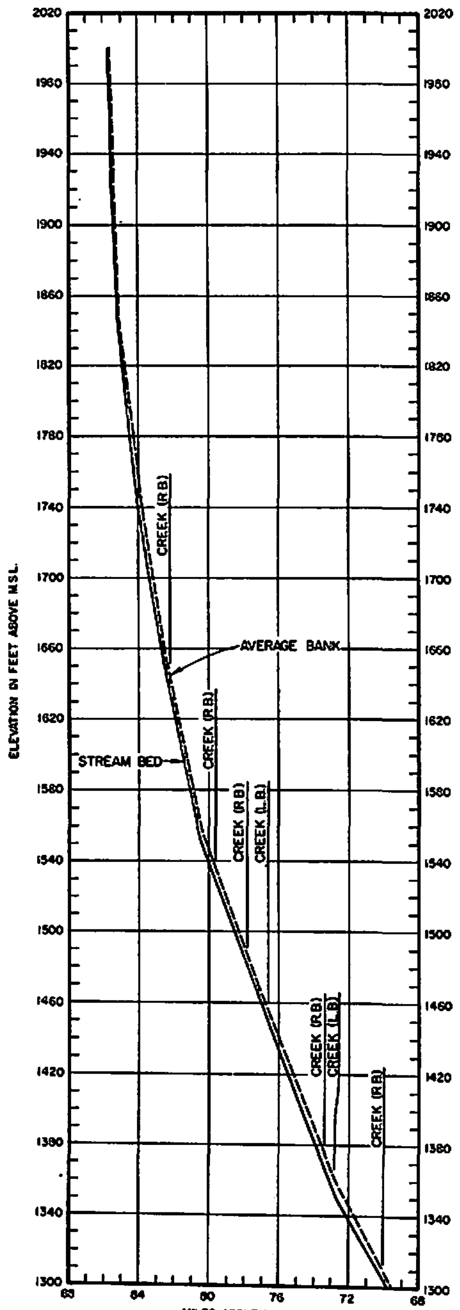
GUADALUPE RIVER TRIBUTARIES

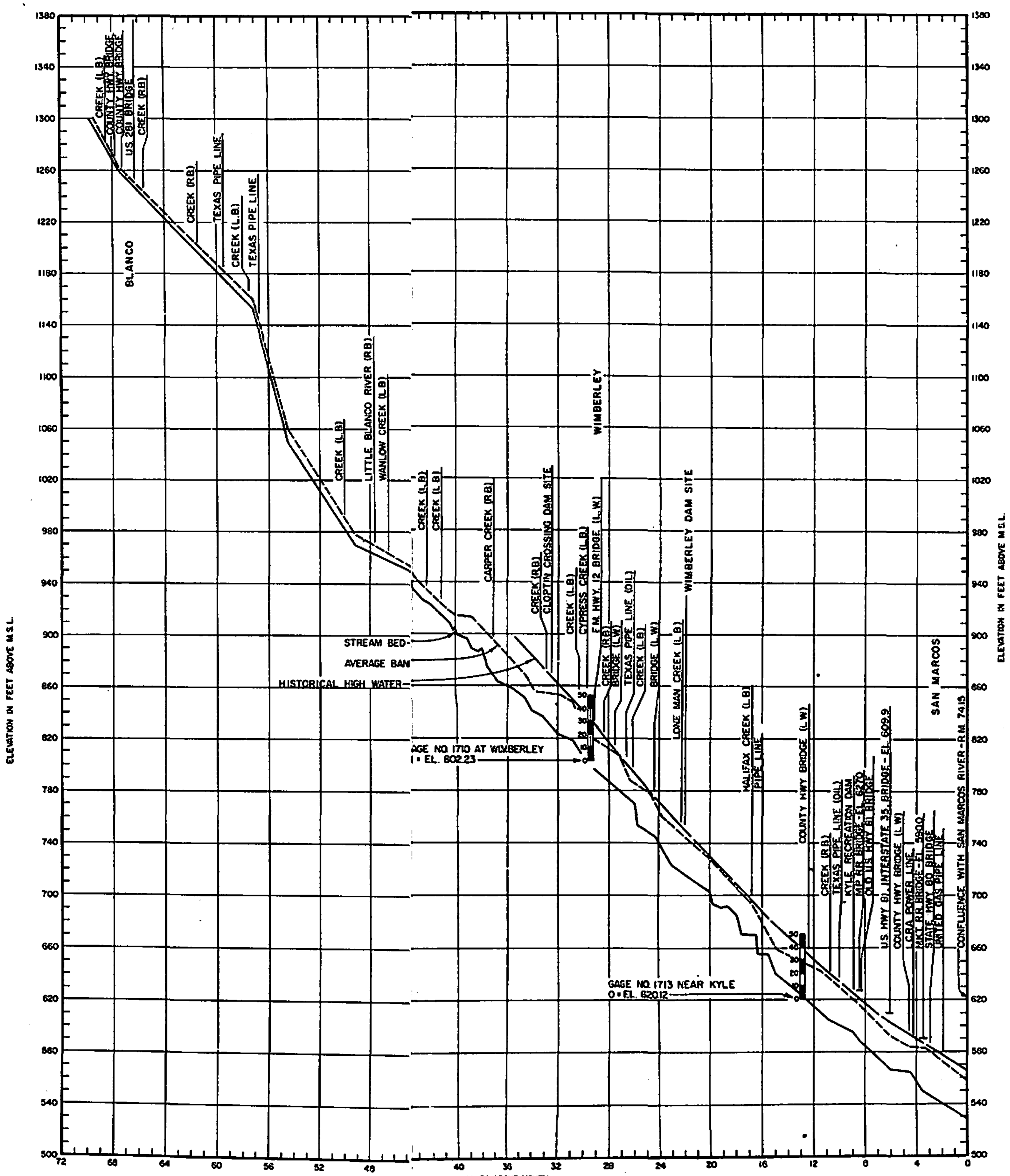
PROFILES

SCALE AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
CHIEF, PROJECT PLANNING BRANCH	CHIEF, ENGINEERING DIVISION	DISTRICT ENGINEER
PREPARED: CHIEF, GEN. INVESTIGATIONS SECTION	DRAWN BY: B.G.S. CHECKED BY: D.T.K.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR; FILE: GUAD. 707-2





NOTES

1. Abbreviation (L.W.) at bridge indicates low water bridge.
2. Elevations at bridges refer to low steel elevations.
3. High-water profile depicts maximum known water surface levels.
4. Abbreviations (L.B.) and (R.B.) refer to left bank, and right bank, respectively.
5. Profiles above mile 44 from U.S.G.S. quadrangle sheets.
6. Profiles below mile 44 from Corps of Engineer survey.

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

EDWARDS UNDERGROUND RESERVOIR

BLANCO RIVER

PROFILES

SCALES AS SHOWN

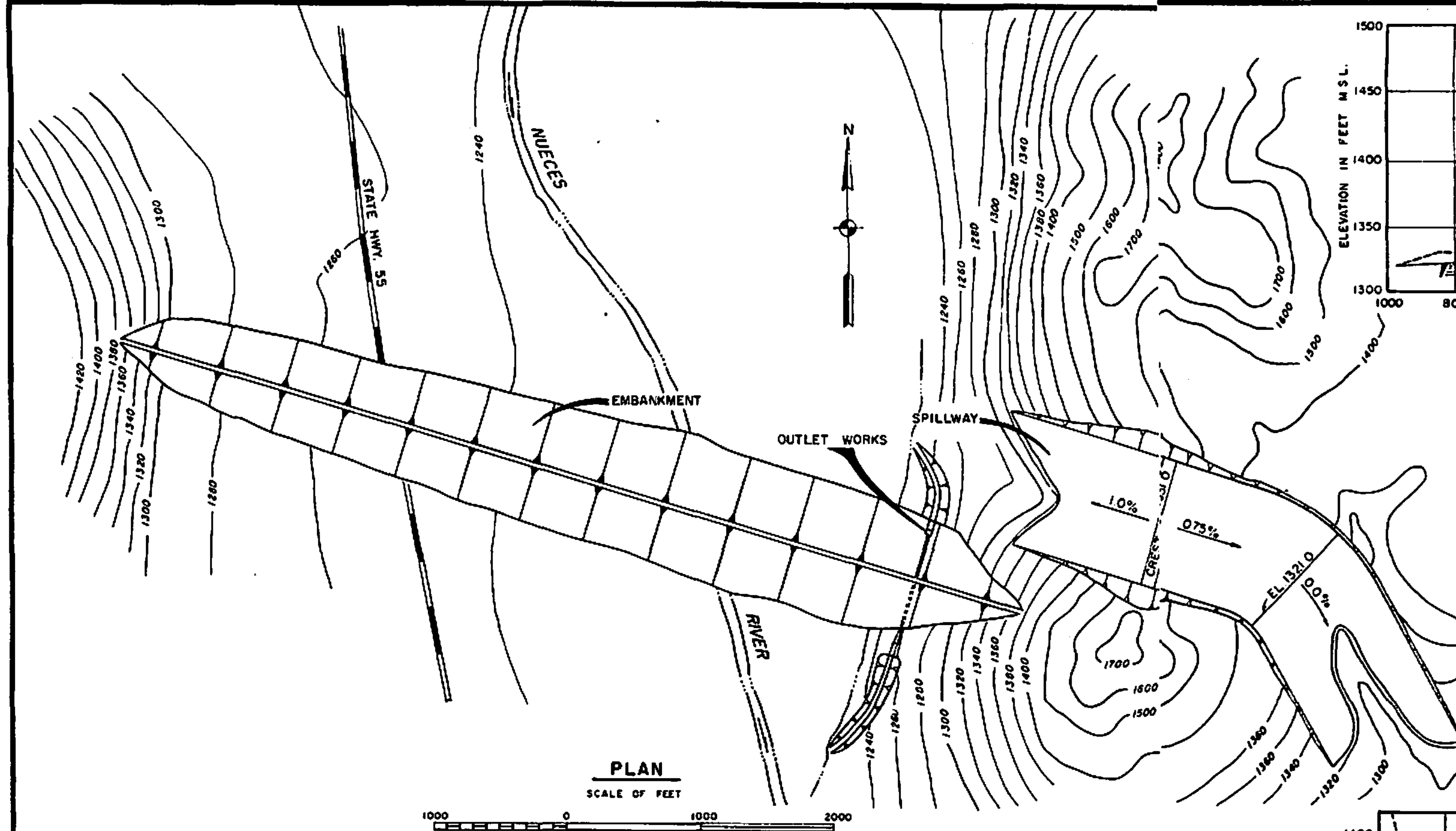
U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED: [signature] — APPROVAL RECOMMENDED: [signature] — APPROVED: [signature]

DRAWN BY: D.P. — CHECKED BY: O.T.E.

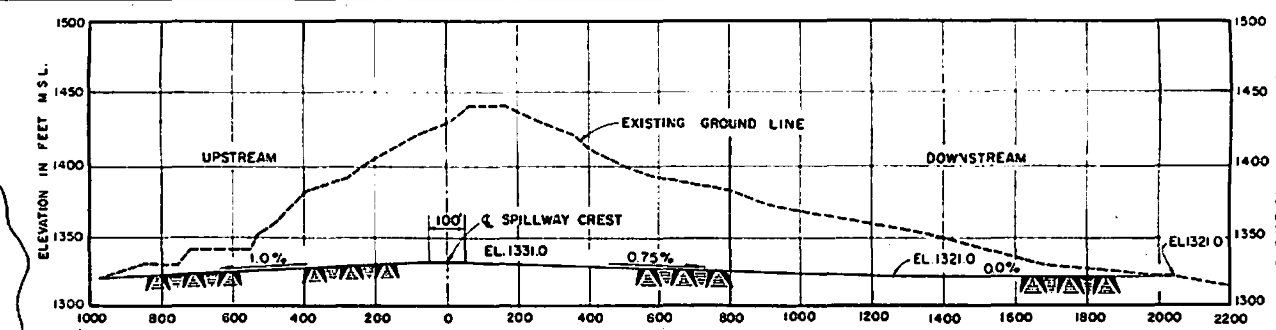
TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR

FILE: GUAD 707-2

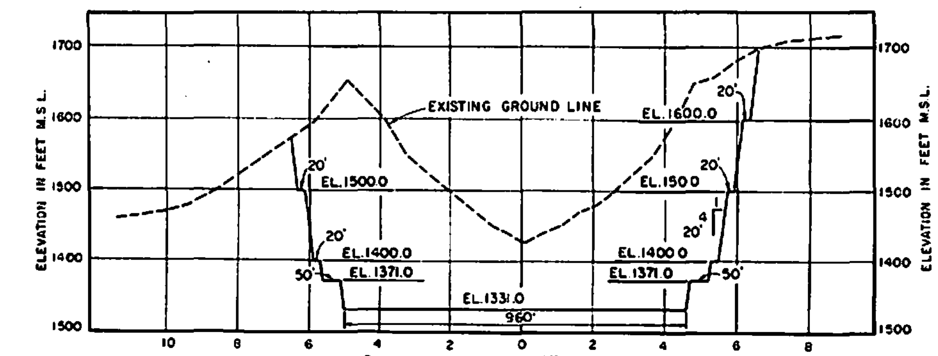


PLAN

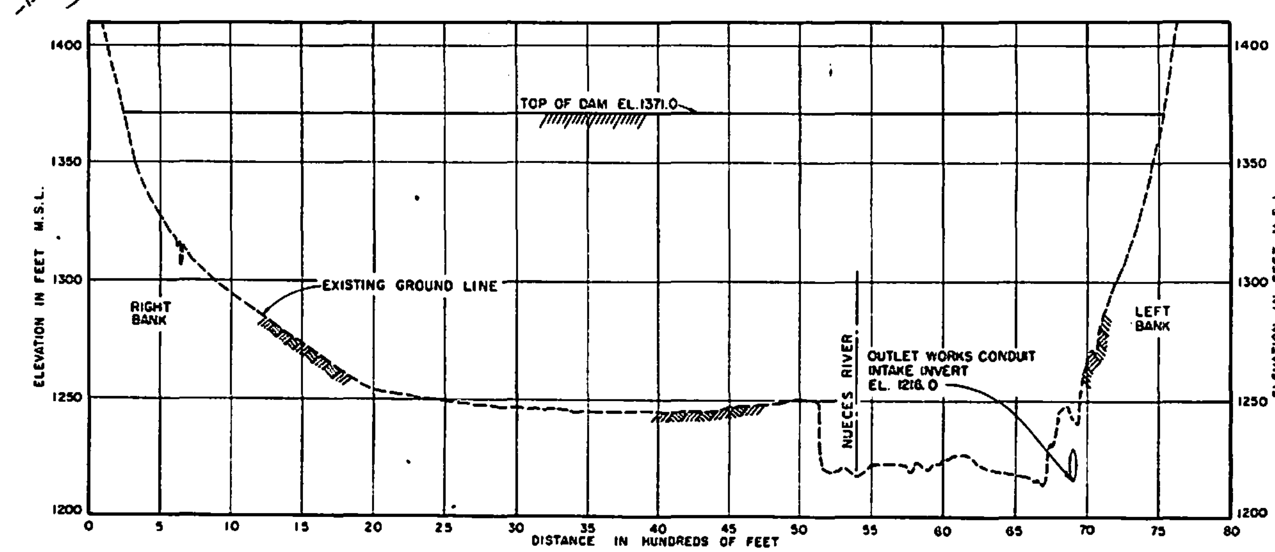
SCALE OF FEET



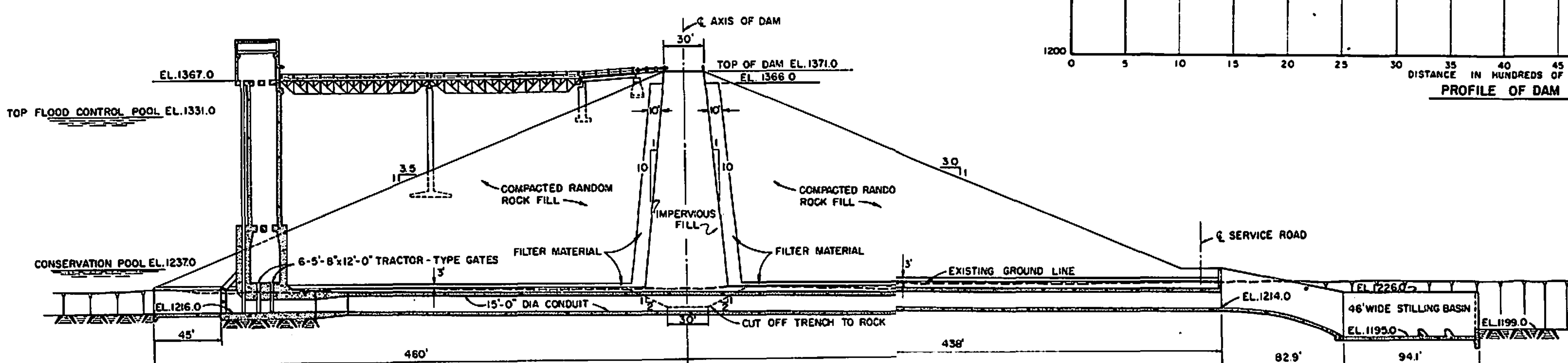
SPILLWAY PROFILE



SPILLWAY SECTION AT WEIR



PROFILE OF DAM



EMBANKMENT SECTION - OUTLET WORKS PROFILE

NOT TO SCALE

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

EDWARDS UNDERGROUND RESERVOIR

NUECES RIVER

PLAN, PROFILES AND SECTIONS

MONTELL DAM SITE

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
W. E. Wood	C. E. Seymour	[signature]
CHIEF, PLANNING & REPORTS BRANCH	CHIEF, ENGINEERING DIVISION	DISTRICT ENGINEER
PREPARED	DRAWN BY A.M.F.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
CHIEF, CIVIL ENGINEERING SECTION	CHECKED BY W.P.B.	FILE GUAD. 707-2

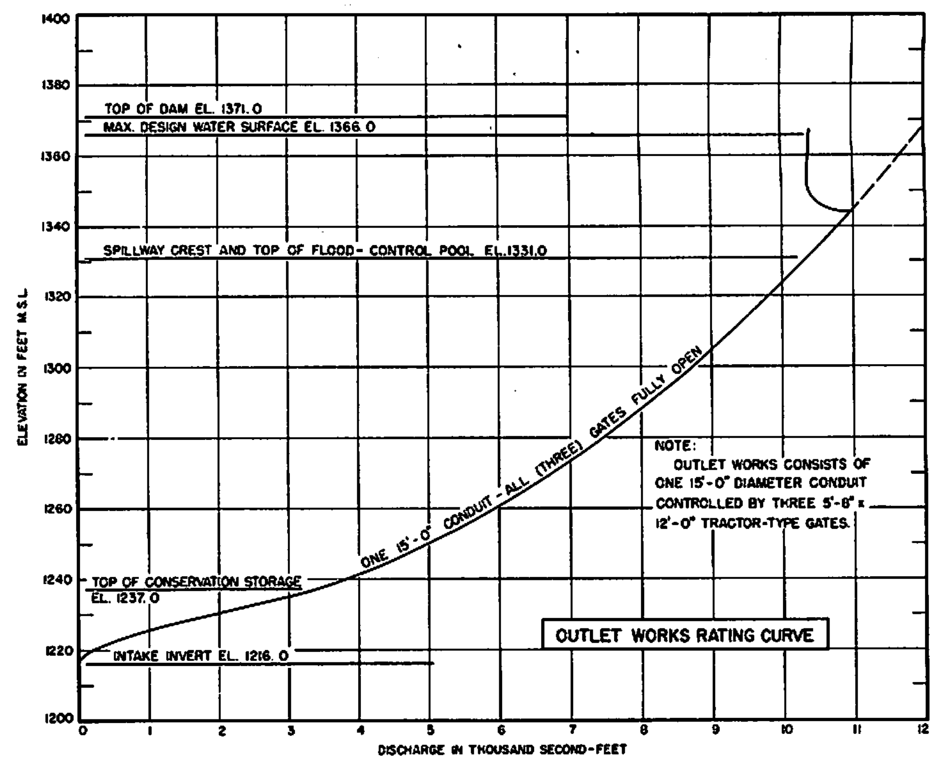


FIG. 1

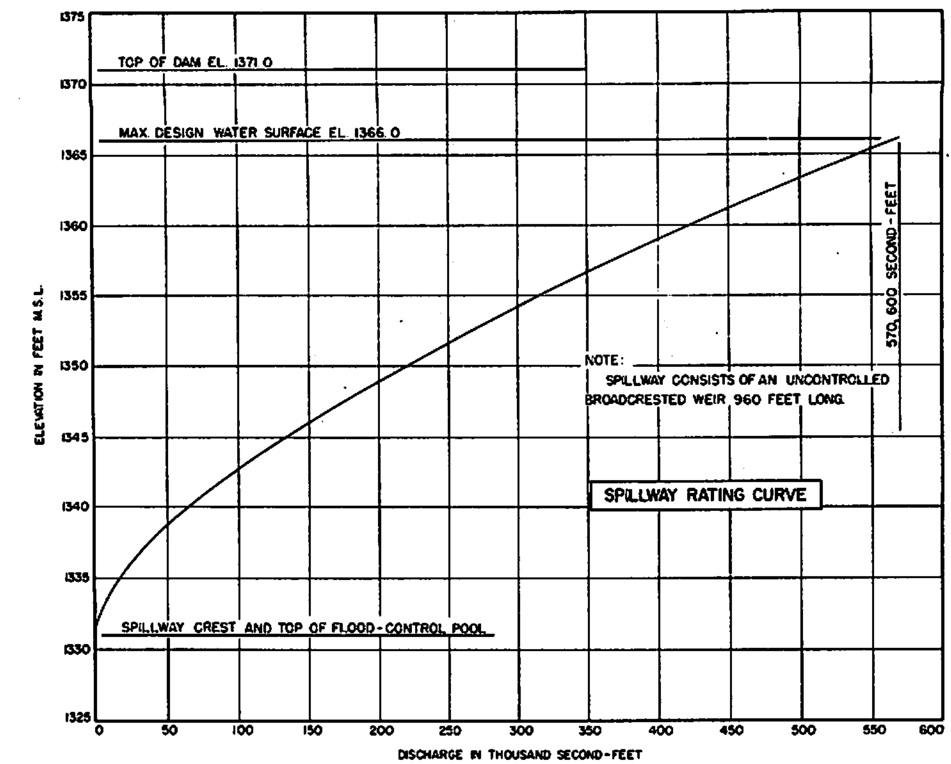


FIG. 2

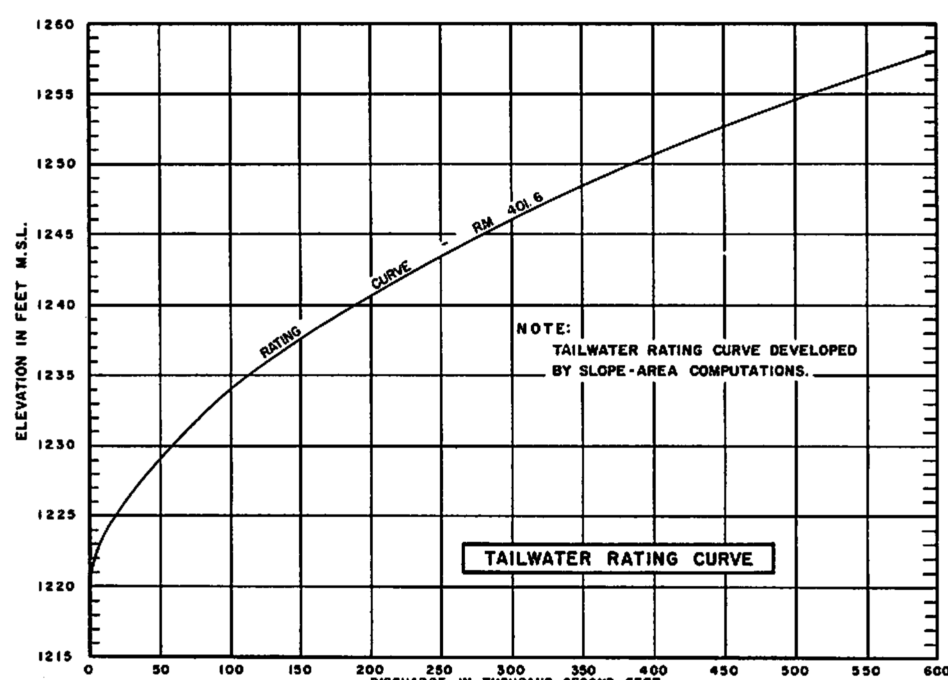
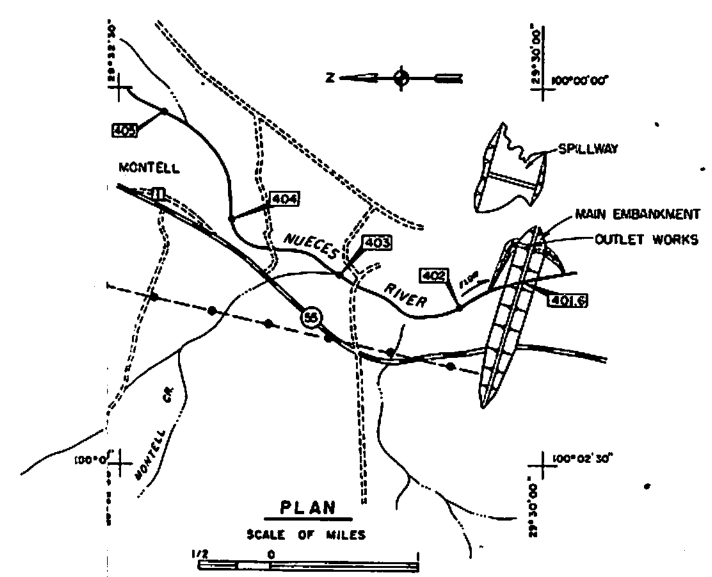


FIG. 3



GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

EDWARDS UNDERGROUND RESERVOIR

NUECES RIVER

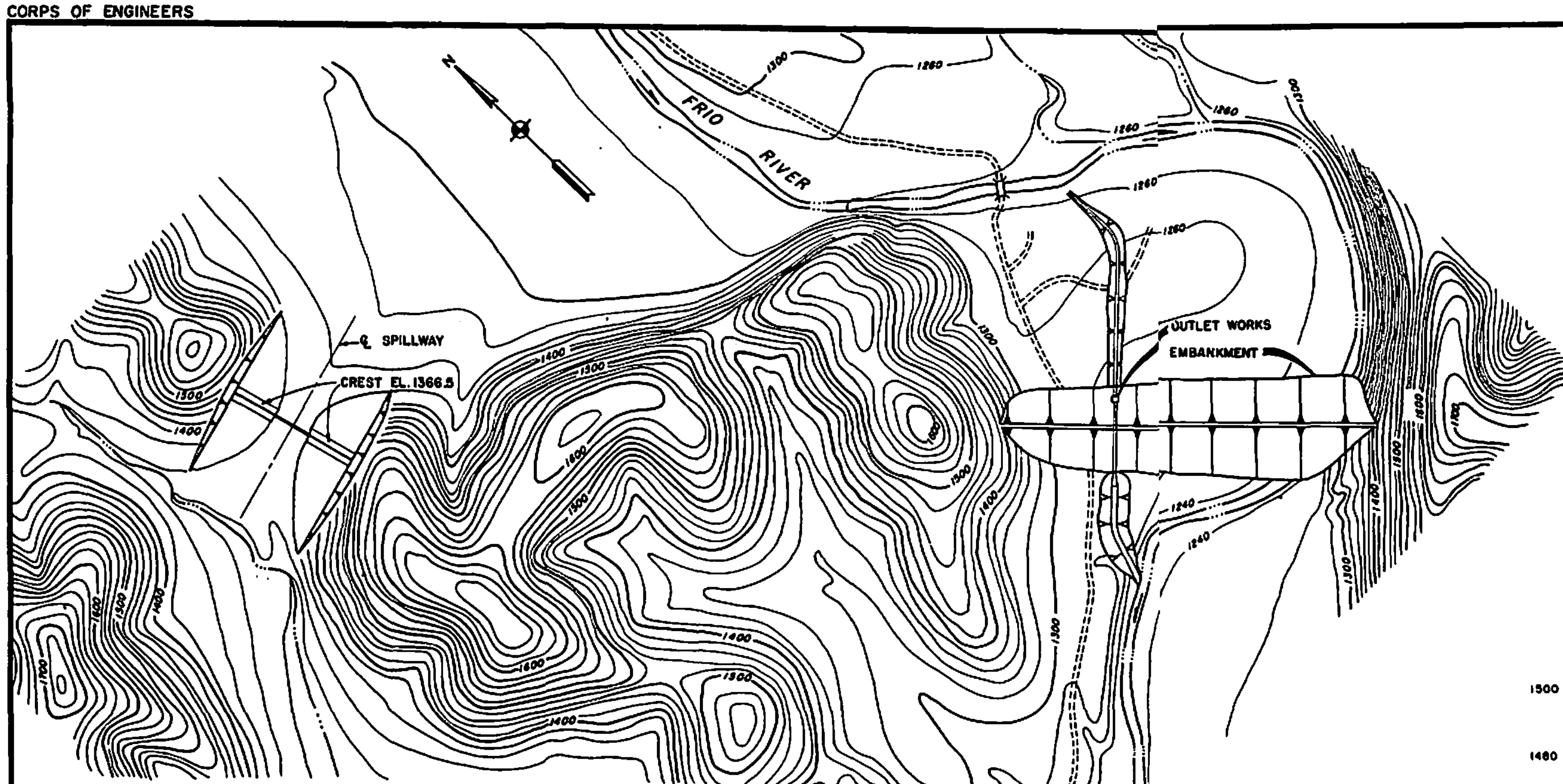
GENERAL HYDRAULIC DATA

MONTELL DAM AND RESERVOIR

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

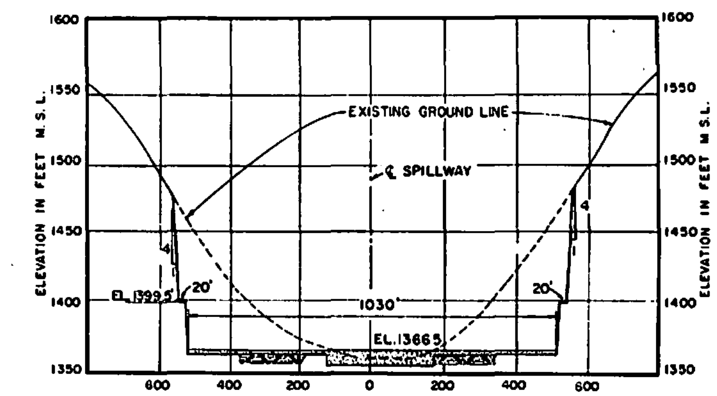
SUBMITTED	APPROVAL RECOMMENDED	APPROVED
W. E. Wood, ENGINEER, CHIEF, PROJECT PLANNING BR.	C. F. [signature], ENGINEER, CHIEF, ENGINEERING DIVISION	James H. Nash, Col. CofE, COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: [signature], ENGINEER, CHIEF, HYDRAULIC DESIGN SECT.	DRAWN BY: T.L.McM.B.; CHECKED BY: D.T.K.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR; FILE: GUAD 707-2



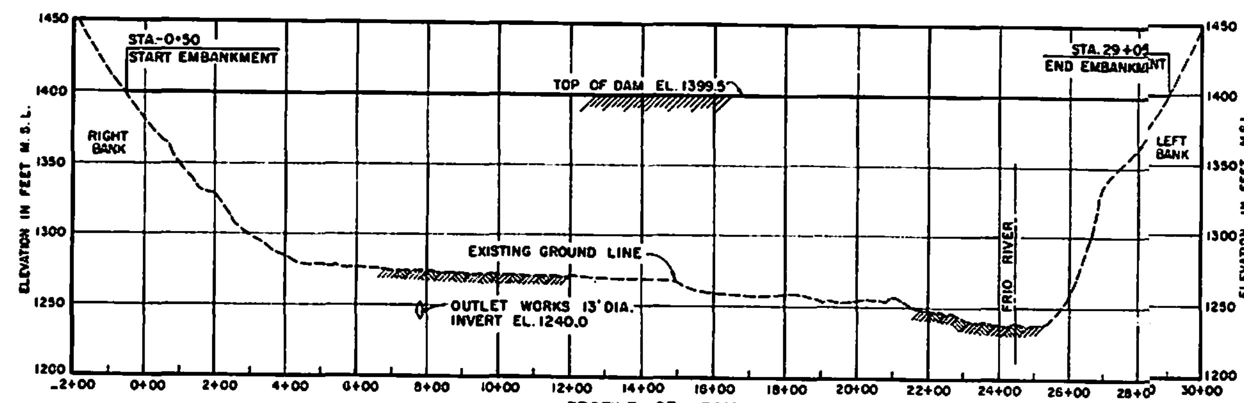
PLAN

SCALE OF FEET

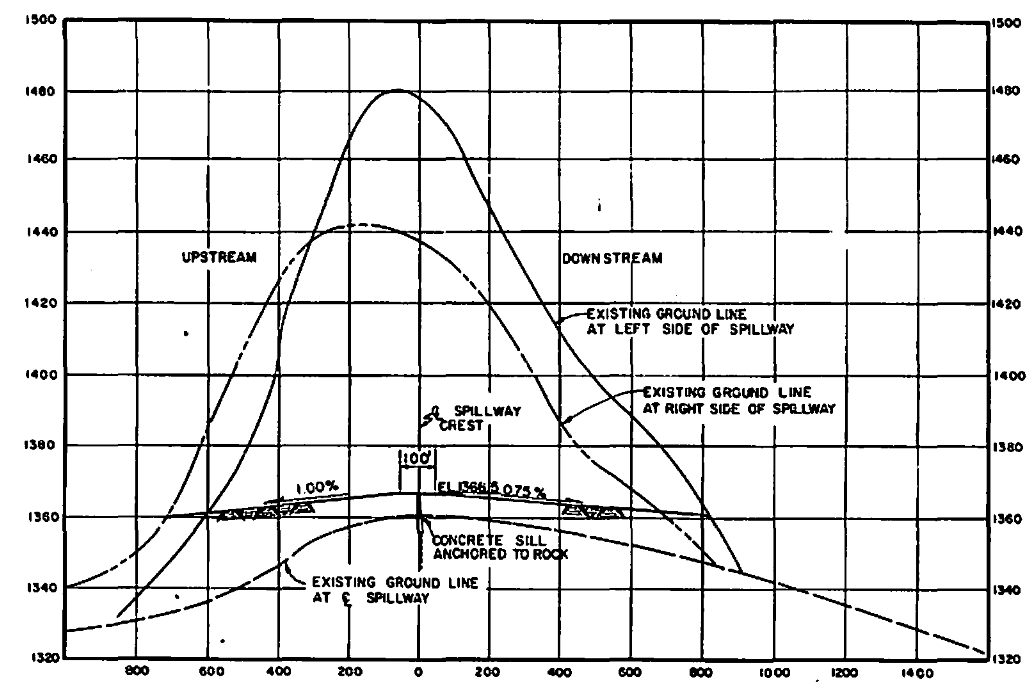
500 0 500 1000



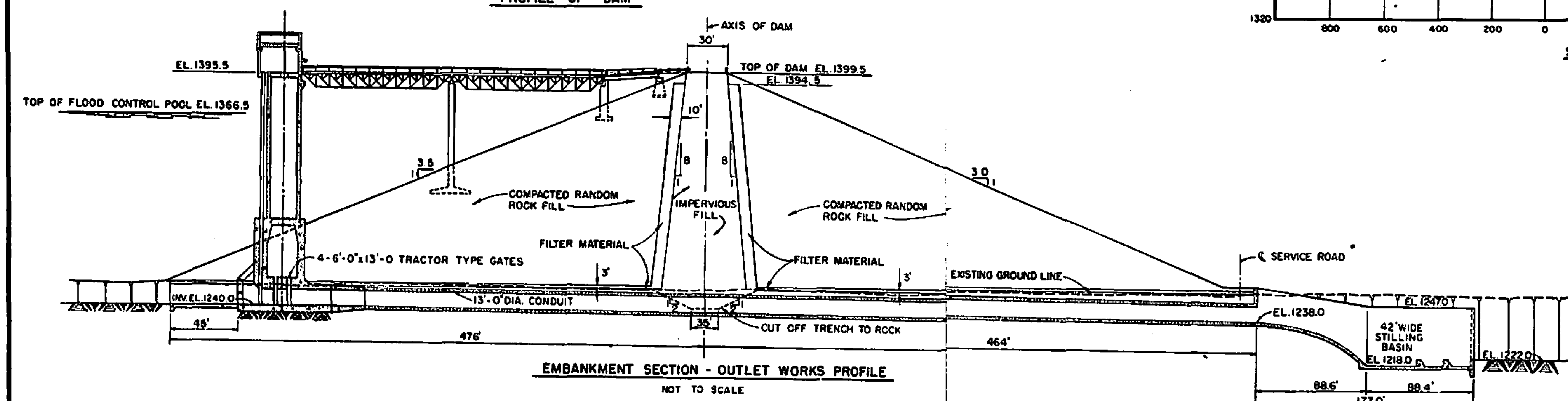
SPILLWAY SECTION AT WEIR



PROFILE OF DAM



SPILLWAY PROFILE



EMBANKMENT SECTION - OUTLET WORKS PROFILE

NOT TO SCALE

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

EDWARDS UNDERGROUND RESERVOIR

FRIO RIVER

PLAN, PROFILES AND SECTIONS

CONCAN DAM SITE

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH		DEC. 1964
SUBMITTED: W. E. Wood, CHIEF, PLANNING & REPORTS BRANCH	APPROVAL RECOMMENDED: C. J. Lusmann, CHIEF, ENGINEERING DIVISION	APPROVED: DISTRICT ENGINEER
PREPARED: CHIEF, CIVIL ENGINEERING SECTION	DRAWN BY: A.M.F. CHECKED BY: W.R.B.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR. FILE GUAD. 707-2

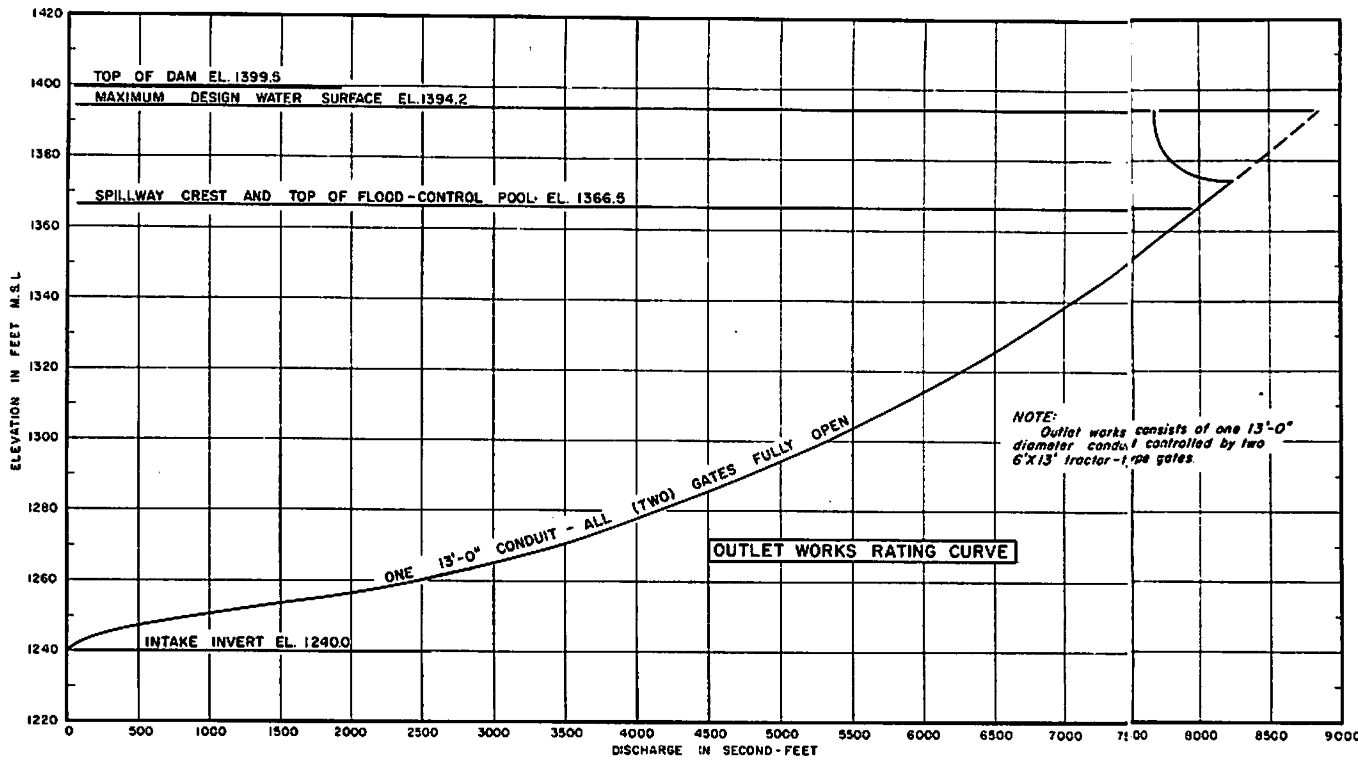
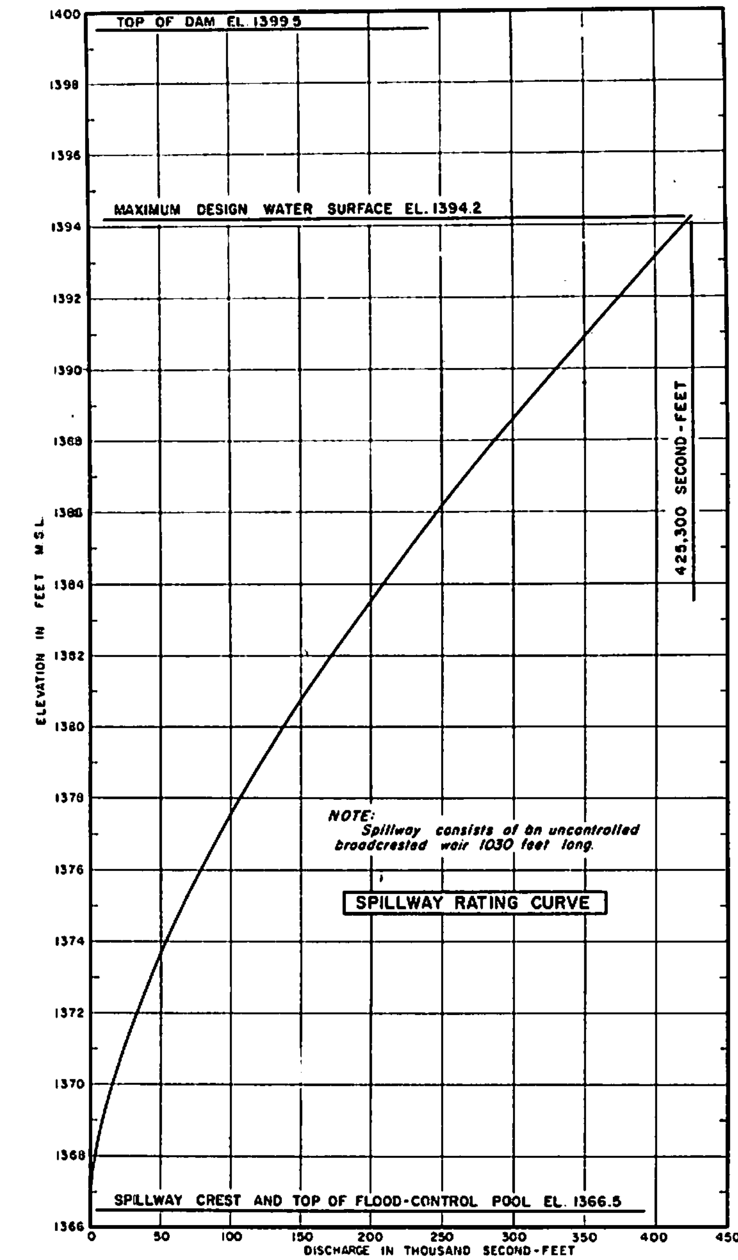


FIG. 1



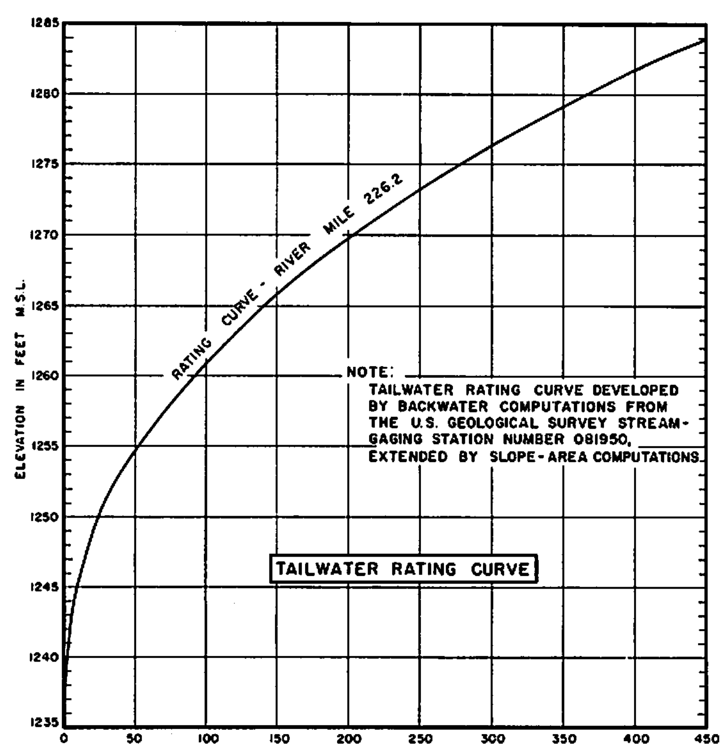
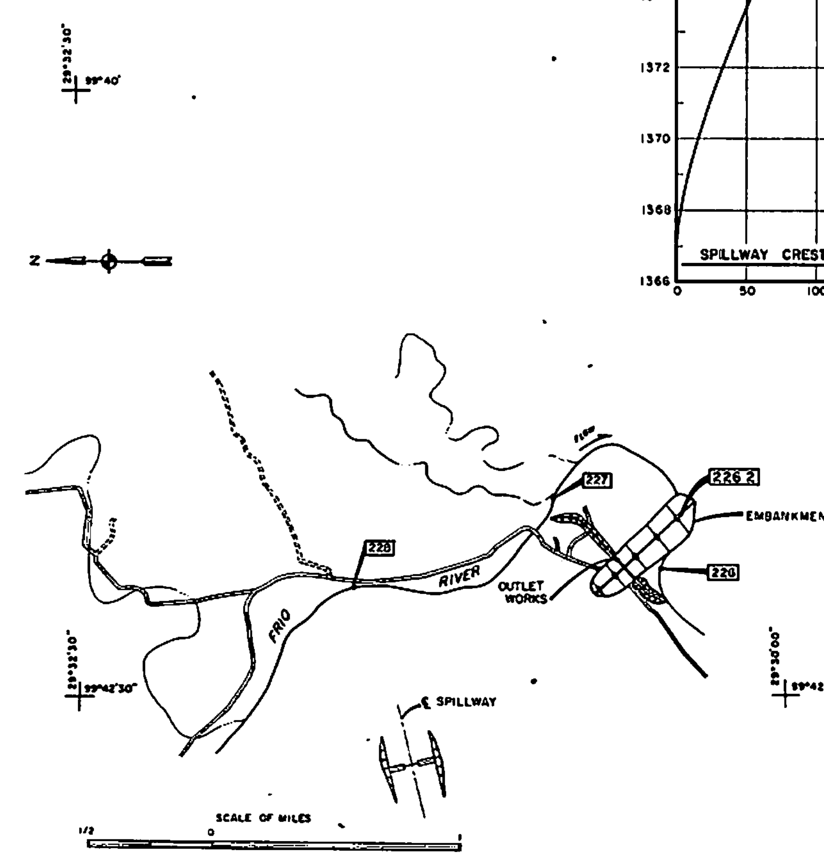


FIG. 3



PLAN

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
FRIO RIVER

GENERAL HYDRAULIC DATA
CONCAN DAM AND RESERVOIR

SCALES AS SHOWN

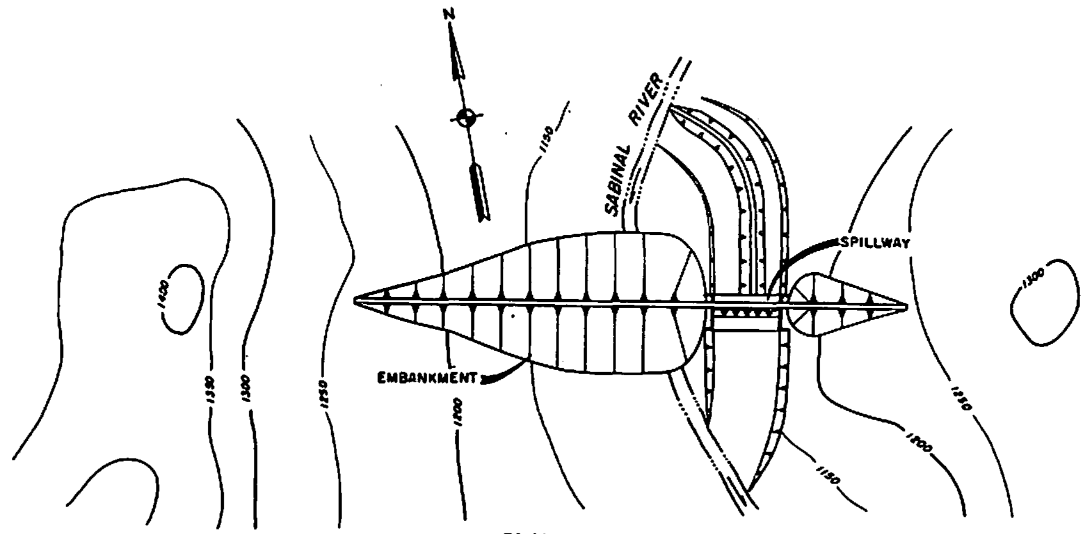
U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED: CHIEF, PROJECT PLANNING BR. — APPROVAL RECOMMENDED: CHIEF, ENGINEERING DIVISION — APPROVED: DISTRICT ENGINEER

PREPARED: CHIEF, HYDRAULIC DESIGN SECT. — DRAWN BY J.L.-A.M.F. — CHECKED BY D.T.K.

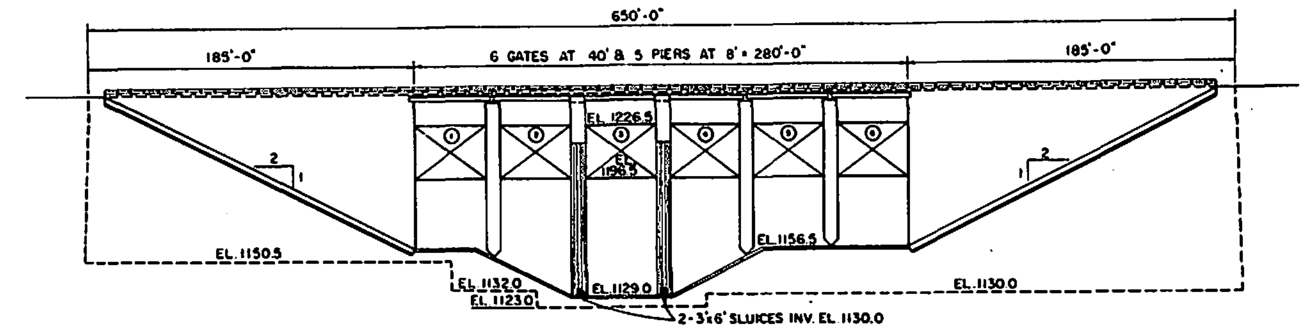
TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR

FILE GUAD 707-2



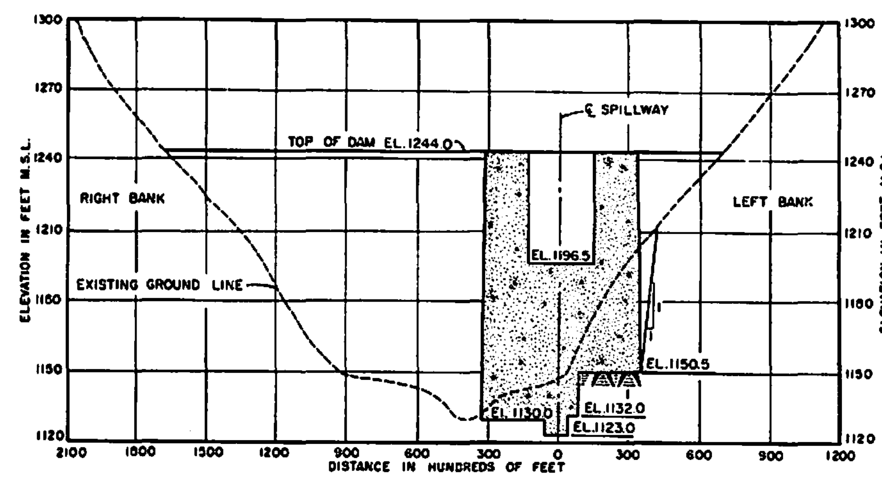
PLAN

SCALE OF FEET 300 0 300 600

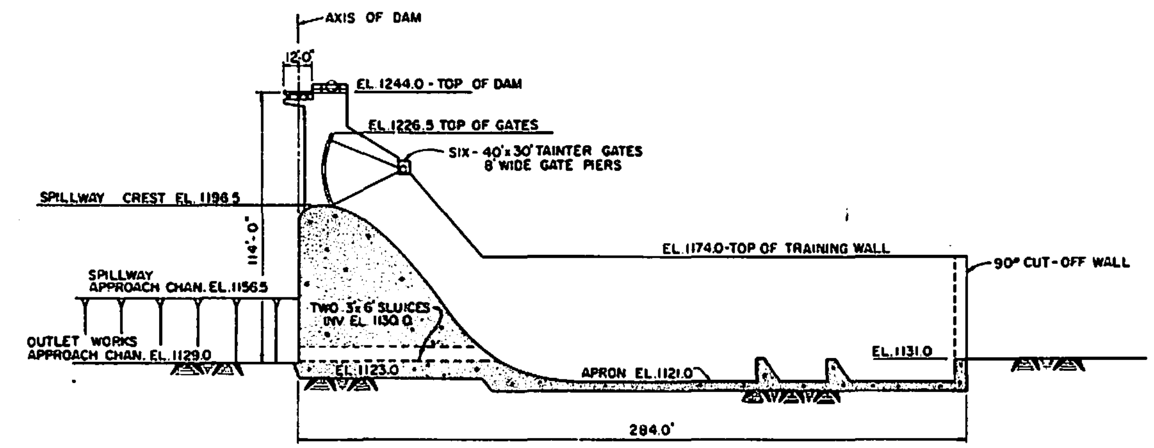


UPSTREAM ELEVATION OF SPILLWAY

SCALE: 1 INCH = 40 FEET

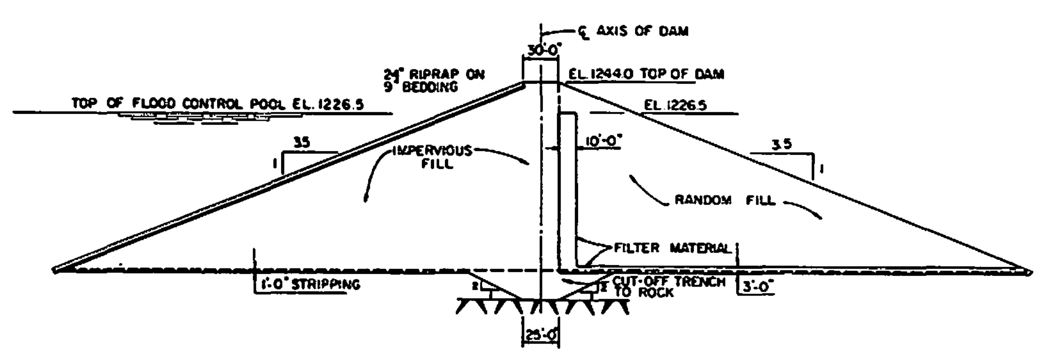


PROFILE OF DAM



SECTION THRU SPILLWAY

SCALE: 1 INCH = 30 FEET



SECTION THRU EMBANKMENT

NOT TO SCALE

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

EDWARDS UNDERGROUND RESERVOIR

SABINAL RIVER

PLAN, PROFILES AND SECTIONS

SABINAL DAM SITE

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH		DEC. 1964
SUBMITTED: W. E. Wood, ENGINEER, CHIEF, PLANNING & REPORTS BRANCH	APPROVAL RECOMMENDED: C. J. [signature], ENGINEER, CHIEF, ENGINEERING DIVISION	APPROVED: [signature], COL. CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED: [signature] Smith, ENGINEER, CHIEF, CIVIL ENGINEERING SECTION	DRAWN BY: A.M.F. CHECKED BY: W.R.B.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR; FILE: GUAD. 707-2

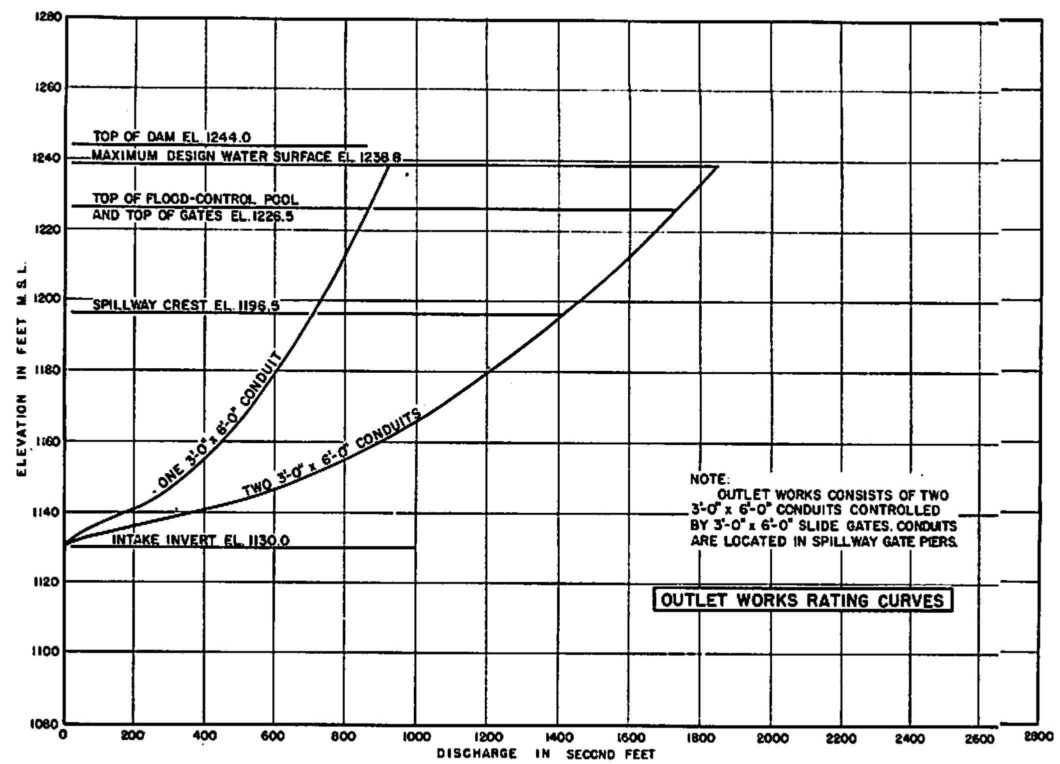


FIG. 1

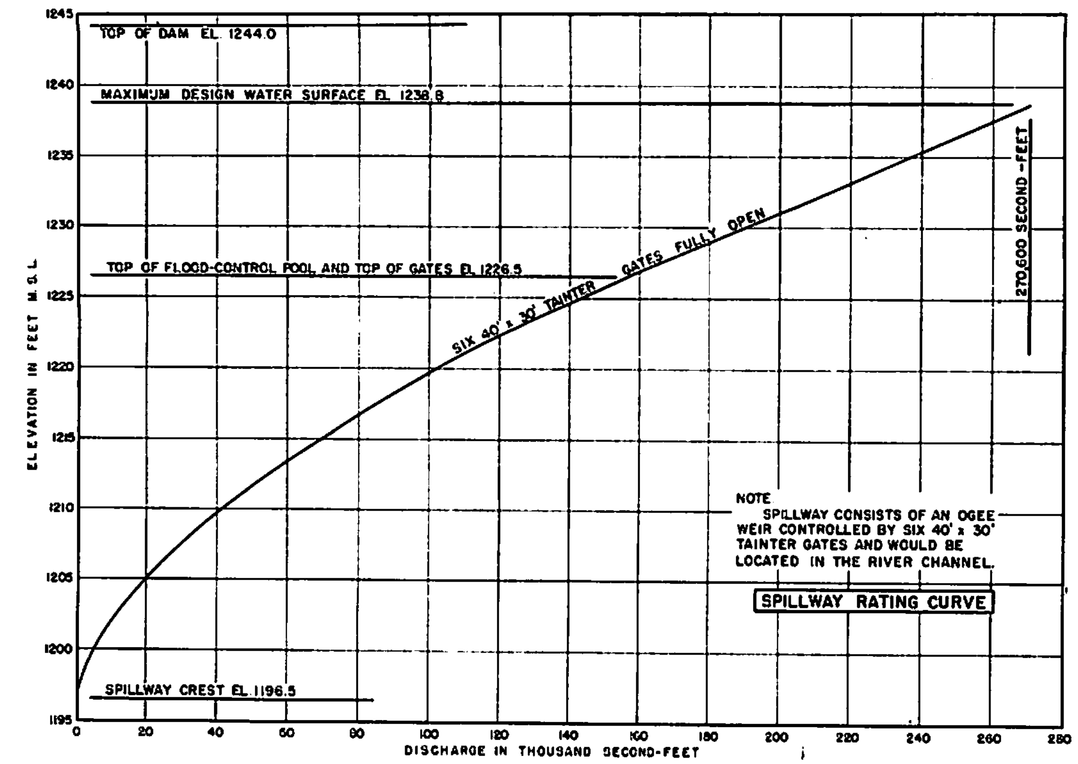


FIG. 2

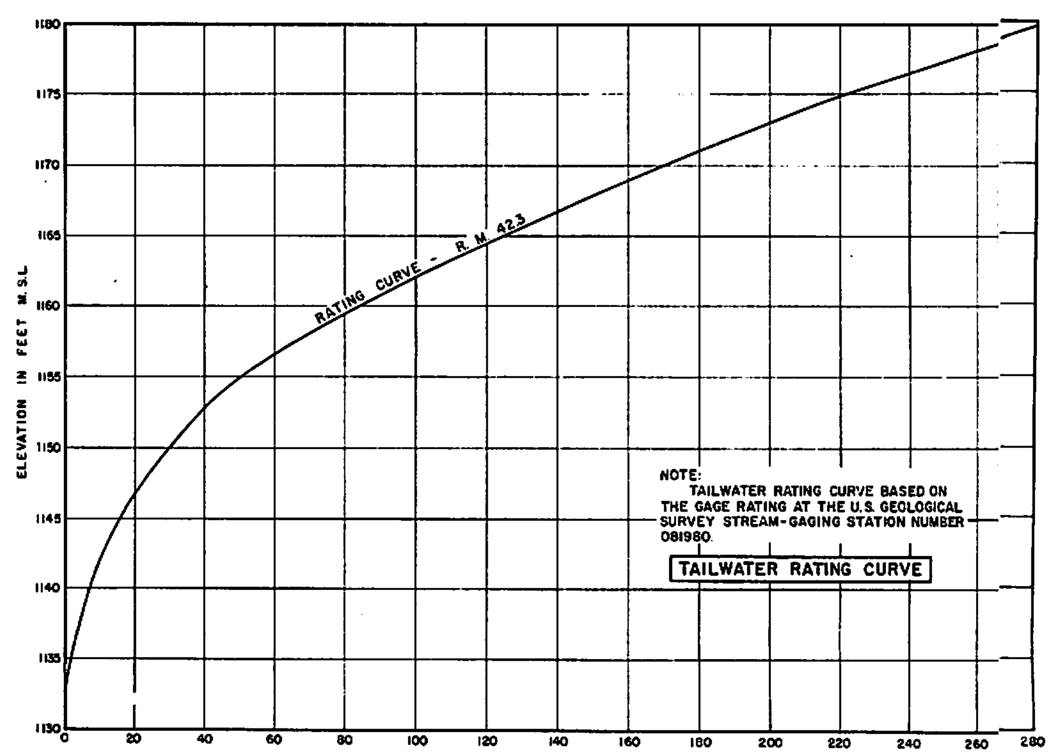
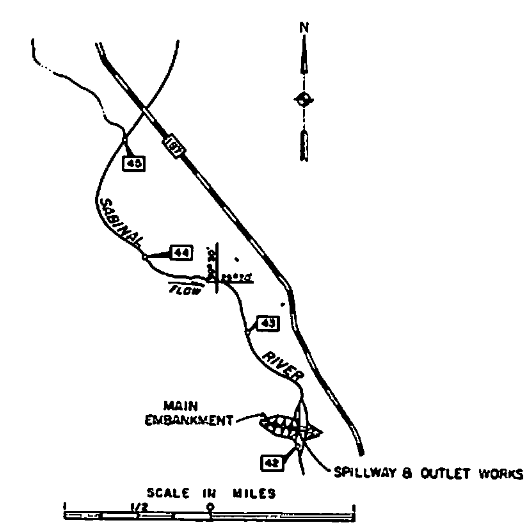


FIG. 3



PLAN

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
SABINAL RIVER

GENERAL HYDRAULIC DATA
SABINAL RESERVOIR

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
CHIEF, PROJECT PLANNING BRANCH	CHIEF, ENGINEERING DIVISION	DISTRICT ENGINEER
PREPARED: CHIEF, HYDRAULIC DESIGN SECT.	DRAWN BY: V.J.B. / CHECKED BY: O.T.K.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR
		FILE GUAD. 707-2

Each conduit would have intake invert at elevation 1130.0 and would be controlled by a 3-foot by 6-foot slide gate, as shown on plate 57. The outlet works would be used for diversion during construction and for passage of flood-control releases. The total capacity of the outlet works with reservoir water surface level at spillway crest, elevation 1196.5, and at maximum design water surface, elevation 1238.8, would be about 1,420 second-feet and 1,850 second-feet, respectively. The outlet works rating curves are shown on figure 1, plate 58.

93. SABINAL DAM - TAILWATER RATING CURVE.- The tailwater rating curve at the dam site is shown on figure 3, plate 58. This rating curve is based on the rating curve developed for the U. S. Geological Survey stream-gaging station Number 081980 on the Sabinal River near Sabinal, Texas, in the vicinity of the dam site.

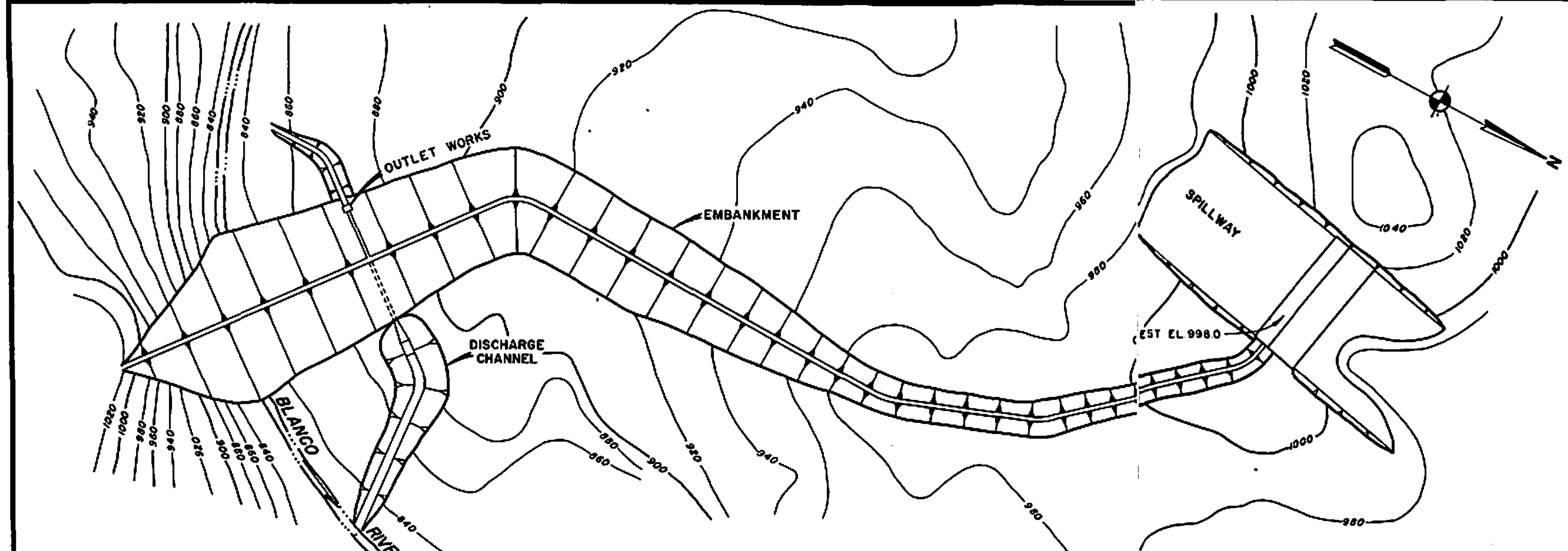
94. CLOPTIN CROSSING DAM - SPILLWAY.- The Cloptin Crossing Dam would be located on the Blanco River at river mile 32.5, with the spillway in a saddle on the left bank. The spillway would consist of a 760-foot uncontrolled broadcrested weir with crest at elevation 998.0. Details of the dam and spillway are shown on plate 59. Under conditions of the spillway design discharge (187,200 second-feet), the reservoir would be at elevation 1017.5. The spillway rating curve, adjusted for approach losses, is shown on figure 2, plate 60.

95. CLOPTIN CROSSING DAM - OUTLET WORKS.- The flood-control outlet works would consist of a 13-foot diameter conduit controlled by two 6-foot by 13-foot tractor type gates. The conduit would be located in the main embankment, with inlet invert at elevation 855.0 and outlet invert at elevation 852.0, as shown on plate 59. The outlet works would be used for diversion during construction, for the passage of flood releases, and for the passage of low-flow discharges. The capacity of the conduit with reservoir water surface at top of conservation pool, elevation 980.5, and at maximum design water surface, elevation 1017.5, would be about 8,100 second-feet and 9,200 second-feet respectively. Figure 1, plate 60 shows the rating curve for the outlet works.

96. CLOPTIN CROSSING DAM - TAILWATER RATING CURVE.- The tailwater rating curve at the dam site is shown on figure 3, plate 60. This rating curve was developed by backwater methods from the U. S. Geological Survey stream-gaging station Number 081710 on the Blanco River at Wimberley, Texas, 2.5 miles downstream from the dam site. Results of the backwater study were correlated with observed flood flow data.

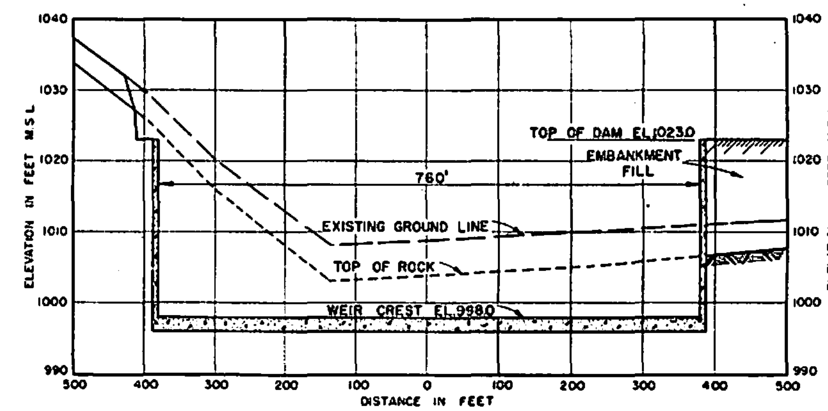
97. CHANNEL DAM AND PIPELINE.- A pipeline for conveying conservation water across an infiltration loss zone existing in the

Nueces River channel from about river mile 386.5 to 377.3 would be constructed adjacent to the river channel downstream from Montell Reservoir. The pipeline would have gravity flow and would consist of 24-inch diameter concrete pipe with an average grade of about 0.3 percent. A low channel dam would be constructed at Nueces River mile 387.0 to establish the necessary entrance conditions for the conduit. The pipeline would be about 8.5 miles long and would discharge back into the Nueces River channel at about river mile 376.5. The capacity of the pipeline would be from 6 to 12 second-feet and the average velocity in the conduit would be about 4 feet per second. The details for this pipeline are shown on plate 61.

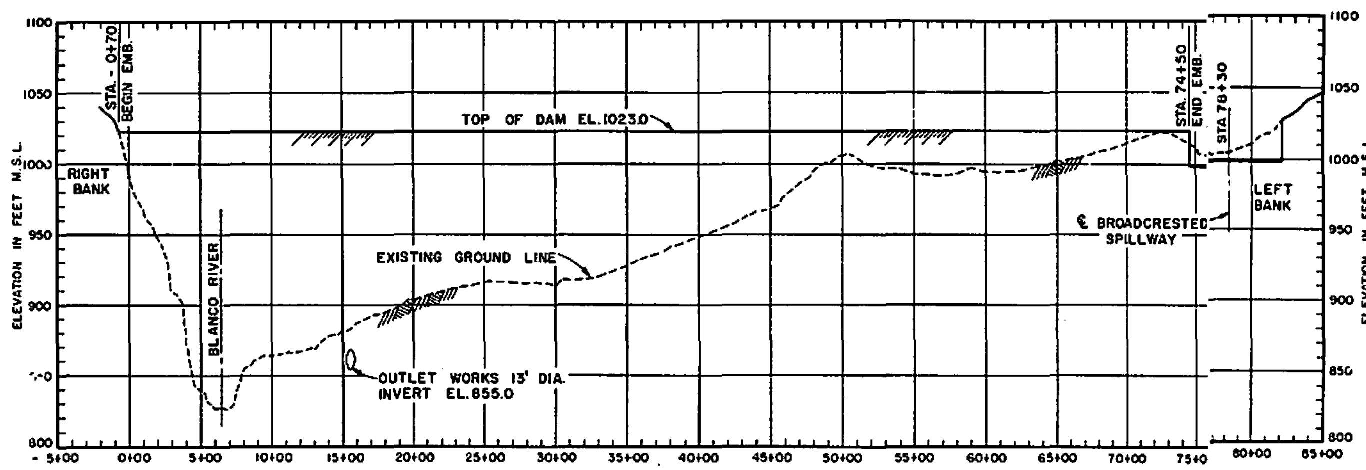


PLAN

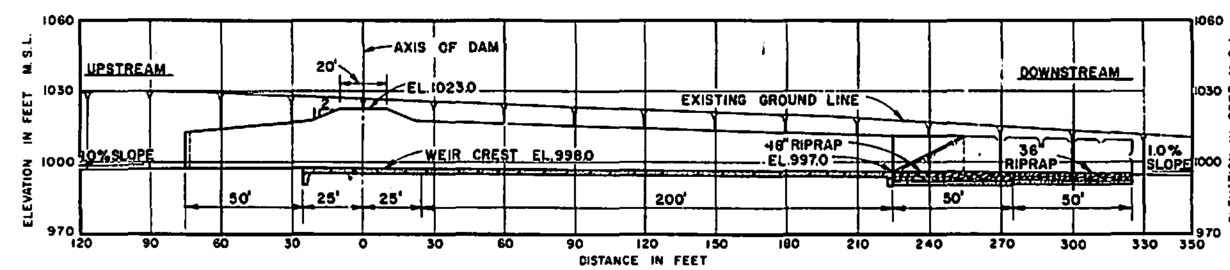
SCALE OF FEET



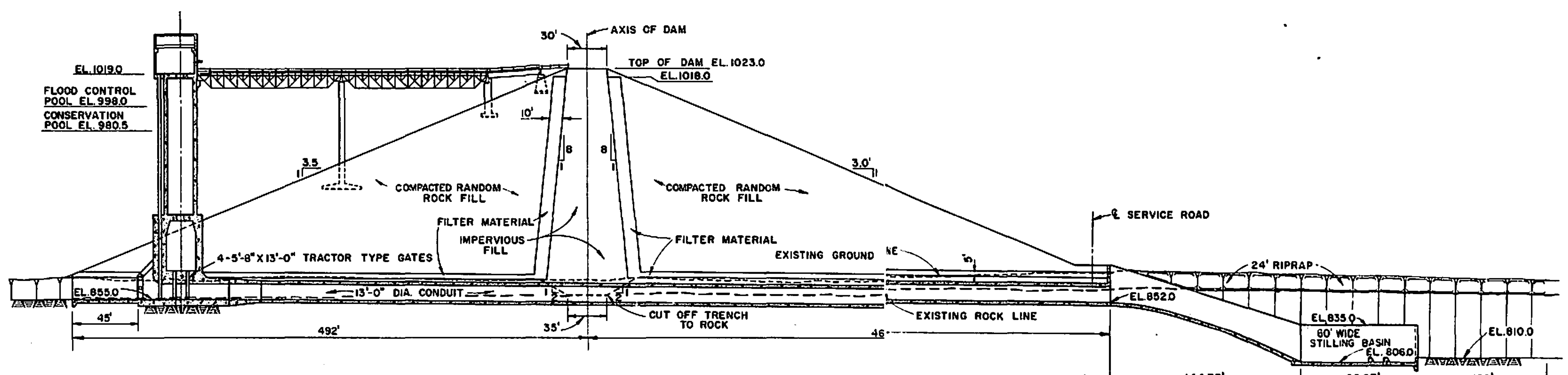
SPILLWAY SECTION AT WEIR



PROFILE OF DAM



SPILLWAY PROFILE



EMBANKMENT SECTION - OUTLET WORKS PROFILE

NOT TO SCALE

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS
EDWARDS UNDERGROUND RESERVOIR
BLANCO RIVER

PLAN, PROFILES AND SECTIONS
CLOPTIN CROSSING DAM

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC. 1964

SUBMITTED / APPROVAL RECOMMENDED / APPROVED

TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR

FILE GUAD 707-2

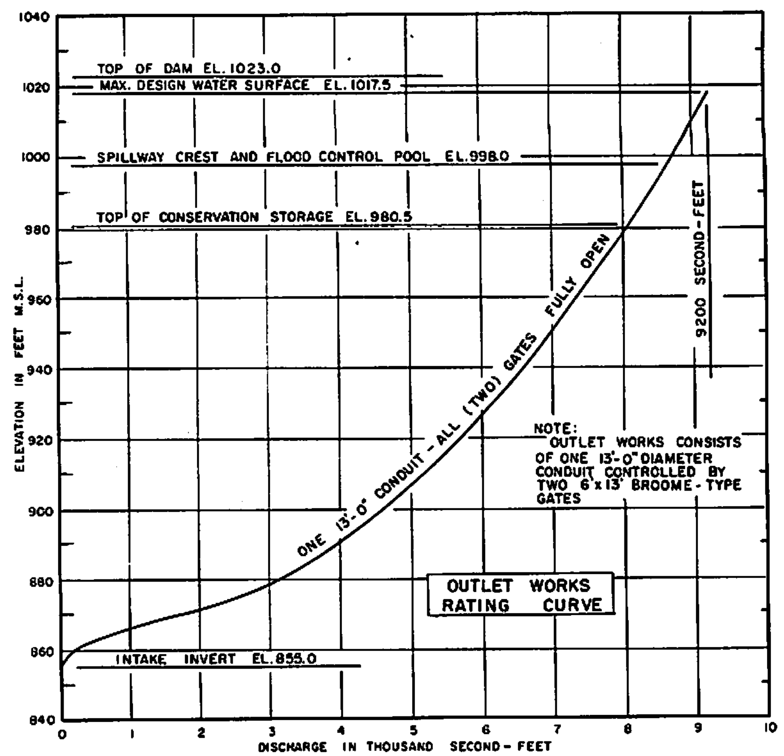


FIG. 1

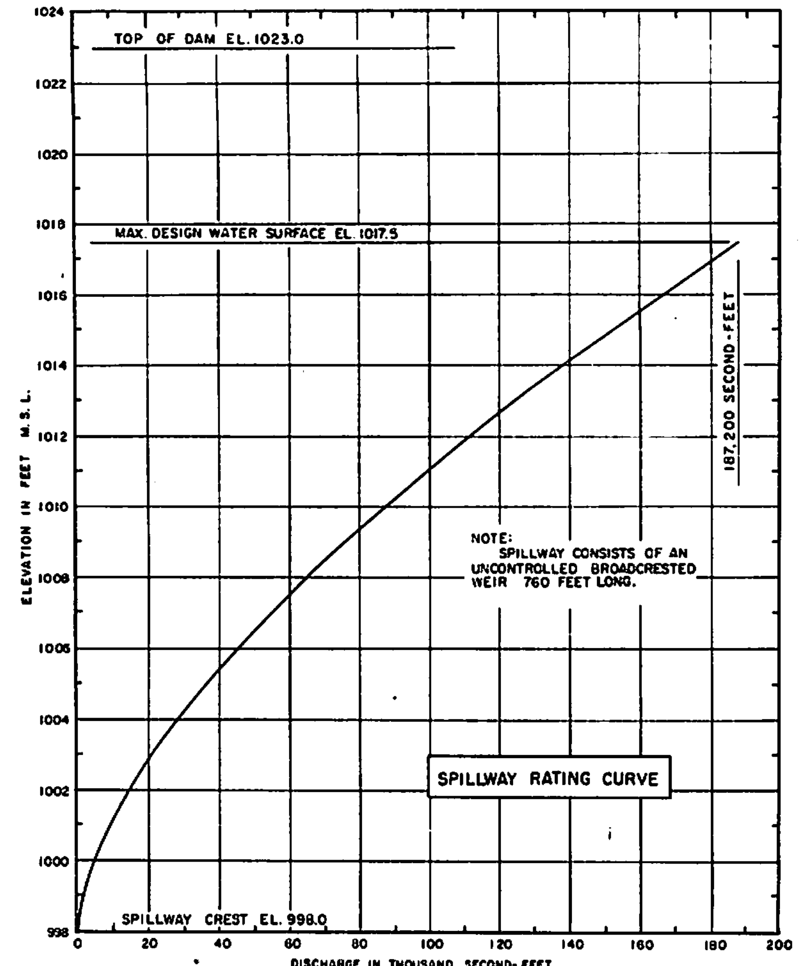


FIG. 2

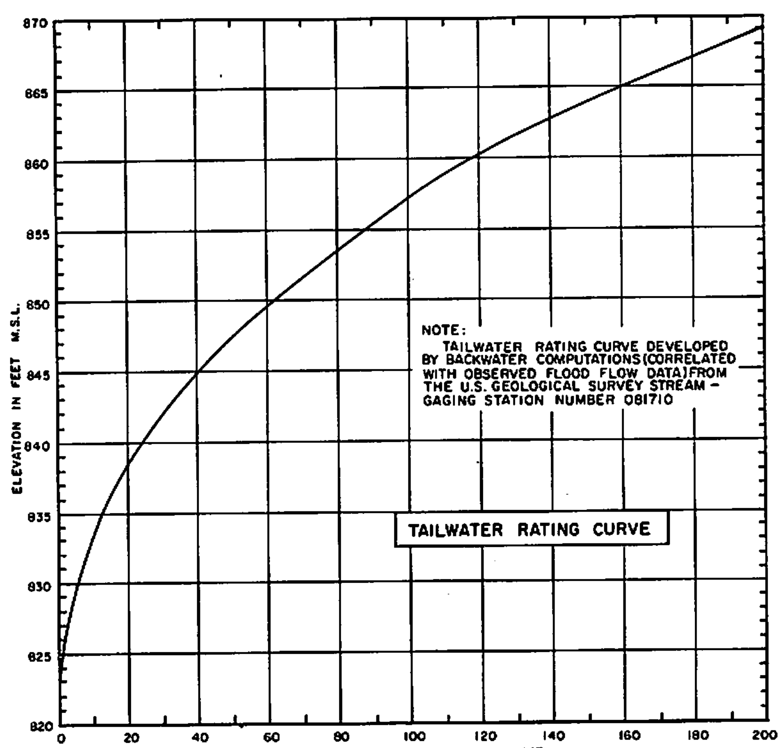
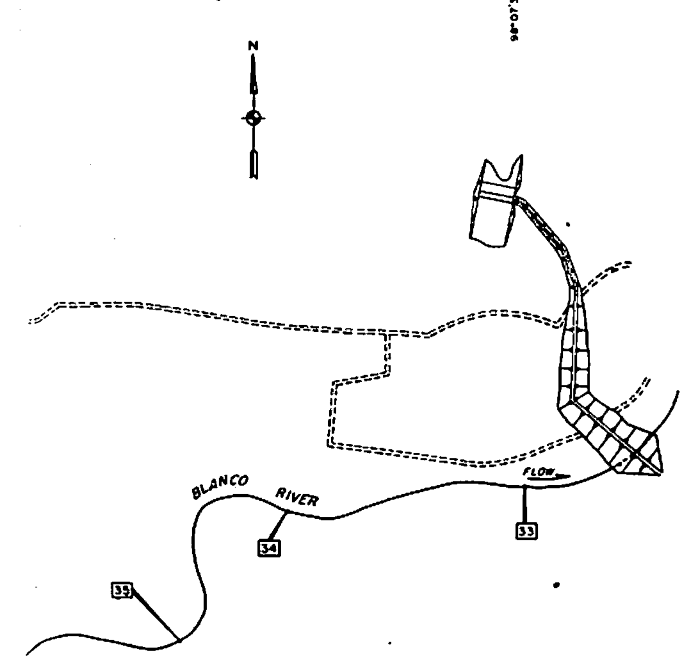


FIG. 3



PLAN

SCALE OF MILES

GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEX.

EDWARDS UNDERGROUND RESERVOIR

BLANCO RIVER

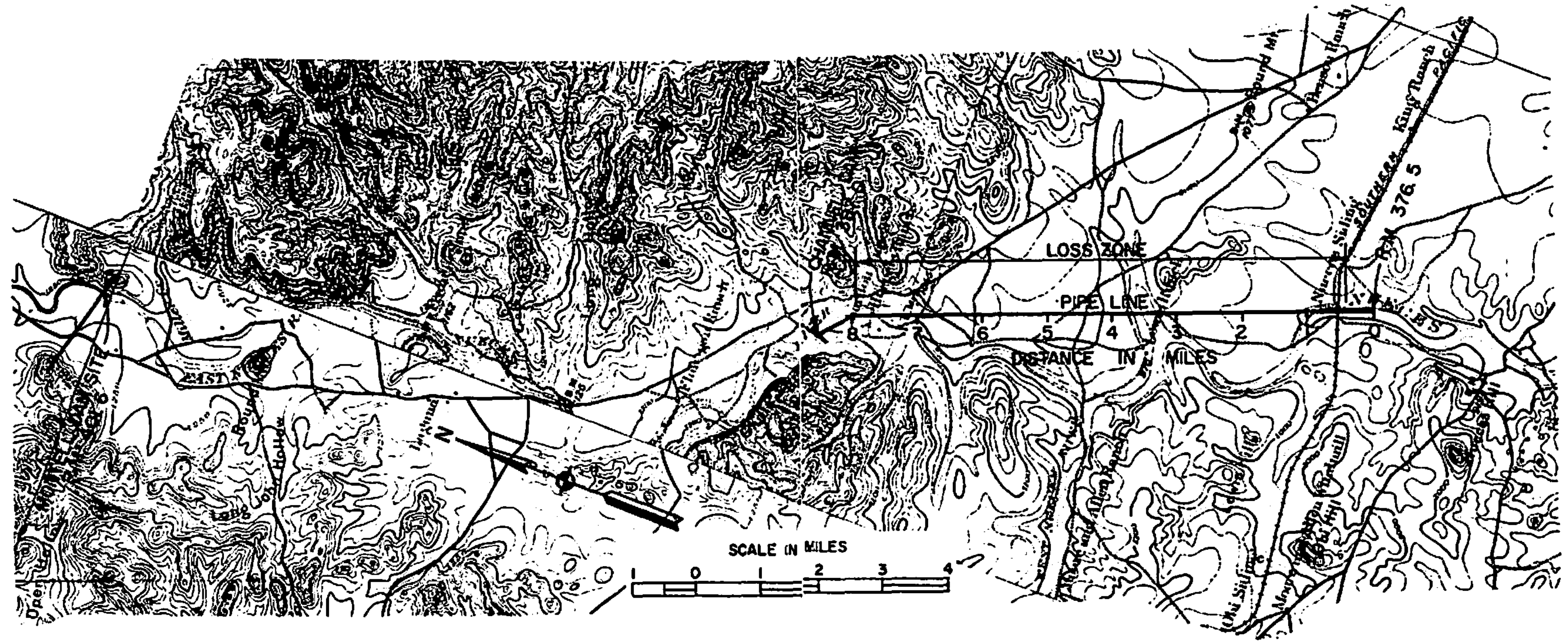
GENERAL HYDRAULIC DATA

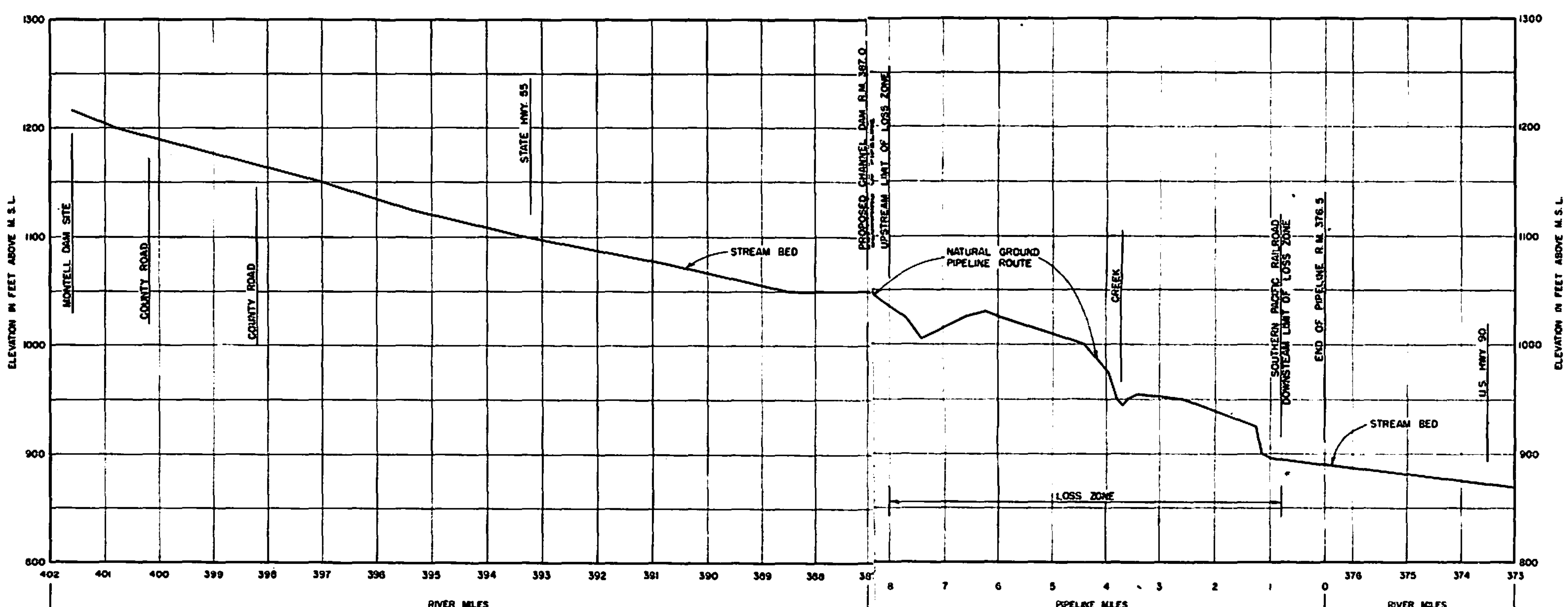
CLOPTIN CROSSING DAM & RESERVOIR

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH — DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
CHIEF, PROJECT PLANNING BRANCH	ENGINEER, CHIEF, ENGINEERING DIVISION	COL., CORPS OF ENGINEERS, DISTRICT ENGINEER
PREPARED	DRAWN BY A.M.F. CHECKED BY G.Y.H.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR — FILE GUAD. 707-2





GUADALUPE, SAN ANTONIO & NUECES RIVERS AND TRIBUTARIES, TEXAS

EDWARDS UNDERGROUND RESERVOIR

NUECES RIVER

PIPELINE FOR WATER SUPPLY

SCALES AS SHOWN

U.S. ARMY ENGINEER DISTRICT, FORT WORTH DEC. 1964

SUBMITTED	APPROVAL RECOMMENDED	APPROVED
W. E. Wood, Engineer, Chief, Project Planning Branch	C. F. Kunnemann, Engineer, Chief, Engineering Division	District Engineer
PREPARED: Chief, General Investigations Section	DRAWN BY: T.L.G. / CHECKED BY: B.H.S.	TO ACCOMPANY SURVEY REPORT COVERING EDWARDS UNDERGROUND RESERVOIR / FILE: GUAD. 707-2

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Volume II, Part I, "Records of Wells and Springs"
Volume II, Part II, "Records of Drillers' Logs"
Volume II, Part III, "Water Levels in Wells, Chemical Analyses of Water, Records of Stream Flow, and Reservoir Contents, Discharge Measurements, and Precipitation in the San Antonio Area, Texas"

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APPENDIX IV

FLOOD CONTROL ECONOMICS

SURVEY REPORT
ON
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE, SAN ANTONIO, AND NUECES RIVERS
AND TRIBUTARIES, TEXAS

APPENDIX IV

FLOOD CONTROL ECONOMICS

CONTENTS

FIGURES

TABLES

CONTENTS (Continued)

TABLES (Continued)

SURVEY REPORT
ON
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE, SAN ANTONIO AND NUECES RIVERS
AND TRIBUTARIES, TEXAS

APPENDIX IV

FLOOD CONTROL ECONOMICS

1. SCOPE.- This appendix is devoted to the evaluation of flood-control benefits which would accrue through operation of the proposed improvements in the Edwards Underground Reservoir area to determine whether flood control could be added as a justified increment. This appendix presents the flood problems; the area subject to flooding; tables of values, damages, and benefits; and description of the methods used to determine average annual flood damages.

2. FLOOD PROBLEMS.- The principal river basins partially contained in the Edwards Underground Reservoir area are the Guadalupe, the San Antonio, and the Nueces Basins. While there is known to be a definite flood problem in all these basins, only those portions of the basins which would be influenced by projects in the Edwards Underground Reservoir area have been considered to be within the scope of this report. In the Nueces River Basin, the portion studied includes the Nueces River below the Montell site, the Frio River below the Concan site, the Sabinal River below the Sabinal site, Hondo Creek below Hondo site, and Seco Creek below Seco site. In the Guadalupe River Basin, the portion studied includes the Guadalupe River below the Cloptin Crossing site. It has been determined that no flood control projects can be justified at this time for the San Antonio River Basin within the Edwards Underground Reservoir area.

3. In the Nueces River Basin, agricultural damages account for approximately 73 percent of the total flood damages in the portion of the flood plain studied in this report. The urban damages, which occur at the city of Crystal City on the Nueces River, the city of Three Rivers on the Nueces and Frio Rivers, and the city of D'Hanis on Seco Creek, account for about 3 percent of the total damages. The remaining 24 percent of the total losses is due principally to damages to transportation facilities, plus some damages to utilities and rural nonagricultural installations. The principal crops grown in the flood plain of the Nueces Basin consist of winter vegetables, cotton, grain sorghums, corn, and hay, with a considerable acreage in improved pasture.

4. In the Guadalupe River Basin, agricultural damages account for approximately 71 percent of the total flood damages in the portion

of the flood plain studied in this report. The urban damages, which occur at the city of San Marcos on the San Marcos and Blanco Rivers and the cities of Gonzales and Victoria on the Guadalupe River, account for about 15 percent of the total damages. The remaining 14 percent of the total losses is due principally to damages to transportation facilities, utilities, and the rural nonagricultural property. The principal crops grown in the flood plain of the Guadalupe Basin consist of cotton, grain sorghums, corn, wheat, oats, and hay, with a considerable acreage in improved pasture.

5. AREA SUBJECT TO FLOODING.- The flood plain areas investigated in detail for the preparation of this report consist of areas subject to overflow from the maximum flood of record under the conditions as modified by existing improvements in the Guadalupe and Nueces River Basins. The proposed Cuero Dam (Stage II) has also been assumed to be in operation on the Guadalupe River. The limits of the areas investigated are shown on tables 1 and 2.

6. CHARACTER OF FLOOD PLAIN AREAS.- The flood plain areas investigated total 692,715 acres, 157,441 acres of which are in the Guadalupe River Basin and 535,274 acres in the Nueces River Basin. Of this total acreage, 2,590 acres are urban, suburban, or rural development, 1,184 acres in the Guadalupe River Basin and 1,406 acres in the Nueces River Basin. The acreage and classification for each reach of the Guadalupe River Basin are shown in table 1, and the corresponding data for the Nueces River Basin in table 2.

7. DETERMINATION OF VALUES AND DAMAGES.- In 1959, a field reconnaissance was made of the Nueces River Basin in connection with the preparation of the report by the U. S. Study Commission-Texas. This reconnaissance and the resulting office studies were for the purpose of updating flood-damage data previously obtained for the entire Nueces River Basin. In 1963, new economic field surveys were conducted along the reaches immediately downstream from the reservoir sites investigated in the Edwards Underground Reservoir study. In 1959, an economic field survey was made of the Guadalupe River downstream from Canyon Dam in connection with a study of the Cuero (Stage II) site made at the request of the U. S. Bureau of Reclamation. In 1963, a detailed economic field survey was made of the Blanco River below the Cloptin Crossing Dam site and a reconnaissance was made of the San Marcos River and the Guadalupe River between the Comfort Site and Canyon Reservoir for the purpose of updating data available from previous economic surveys. During the economic field surveys outlined above, 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

TABLE 1

LAND AREAS IN FLOOD PLAIN - GUADALUPE RIVER BASIN

Stream	Reach	River Mile From	River Mile To	Agricultural: Improved (acres)	Agricultural: Unimproved grazing (acres)	Urban, Suburban and Rural Development (acres)	Total (acres)
Guadalupe River	1	0.0	37.8	4,335	40,922		45,257
	L-2	37.8	64.4	10,490	9,008	(Victoria) 123	19,621
	U-2	64.4	107.2	15,691	6,713	(Cureo) 238	22,642
	3A-1	107.2	110.9	403	1,155		1,558
	3A-2	110.9	118.2)				(-
	3B	118.2	152.2)	Inundated by Cuero Reservoir			(-
	4A	152.2	165.0)				(-
	4B	165.0	180.5	4,547	2,698	96	7,341
	5	180.5	303.0	11,998	9,694		21,692
	6	303.0	332.6)	Inundated by Canyon Reservoir			(-
	L-7A	332.6	351.1	173	1,296		1,469
	L-7B	351.1	376.0	731	2,075		2,806
	L-7C	376.0	402.8	3,326	2,803	47	6,176
Total Guadalupe River				51,694	76,364	504	128,562
San Marcos River	1	2.1	5.4	921	618		1,539
	2	5.4	31.9	7,780	2,736		10,566
	3	31.9	74.2	7,398	4,283	14	11,695
	4	74.2	79.5	188	88	401	677
Total San Marcos River				16,287	7,775	415	24,477
Blanco River	1	0.0	21.7	1,186	859	208	2,253
	2	21.7	32.5	1	300	57	358
Total Blanco River				1,187	1,159	265	2,611
Sandies Creek	1	1.8	6.7	880	911		1,791
BASIN TOTAL				70,048	86,209	1,184	157,441

TABLE 2

LAND AREAS IN FLOOD PLAIN - NUECES RIVER BASIN

Stream	Reach	River Mile From	River Mile To	Agricultural: Improved (acres)	Agricultural: Unimproved grazing (acres)	Urban, Suburban and Rural Development (acres)	Total (acres)
Nueces River	1B	380.0	402.6	544	6,826		7,370
	1A	369.6	380.0	476	5,100		5,576
	1-1	357.0	369.6	1,683	5,147		6,830
	1-2	339.7	357.0	3,285	7,814		11,099
	1-3	307.0	339.7	24,502	24,173	206	48,881
	1-4	273.0	307.0	23,106	23,107		46,213
	2	250.2	273.0	2,960	26,293		29,253
	3	197.1	250.2	12,436	22,968		35,404
	4	105.5	197.1	9,698	78,615		88,313
	5&5A	47.6	105.5	20,702	14,944	460	36,106
	6	0.0	47.6	14,348	22,735		37,083
Total Nueces River				113,740	237,722	666	352,128
Frio River	1A	172.3	226.4	2,705	5,651		8,356
	1B	144.2	172.3	7,435	18,243		25,678
	2	109.3	144.2	7,983	26,664		34,647
	3	98.1	109.3	1,226	6,211		7,437
	4	60.6	98.1	4,928	24,084		29,012
	5	8.0	60.6	12,195	24,619	145	36,959
Total Frio River				36,472	105,472	145	142,089
Sabinal River	1	2.9	42.2	2,025	5,160		7,185
Hondo Creek	1	2.3	14.9	2,521	5,507		8,028
	2	14.9	67.1	1,661	3,774		5,435
Total Hondo Creek				4,182	9,281		13,463
Seco Creek	1	1.65	20.1	587	5,081		5,668
	2	20.1	41.0	6,521	5,821	595	12,937
	3	41.0	56.8	154	1,650		1,804
Total Seco Creek				7,262	12,552	595	20,409
BASIN TOTAL				163,681	370,187	1,406	535,274

flood damages.

8. VALUE OF PHYSICAL PROPERTY IN THE FLOOD PLAINS.- The total value of the physical property in the flood plain reaches as considered herein is estimated at about $230,076,600, of which $128,841,500 is in the Guadalupe River Basin and $101,235,100 is in the Nueces River Basin. These valuations are summarized in tables 3 and 4.

9. 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 $19,244,100, of which $4,833,800 is in the Guadalupe River Basin and $14,410,300 is in the Nueces River Basin. These damages are based on July 1964 price levels and 1964 conditions of development. Tables 5 and 6 show these damages by reaches and by principal property classification.

10. DETERMINATION OF AVERAGE ANNUAL DAMAGES.- For each flood plain reach, discharge-damage curves and discharge-frequency curves were developed. From these curves a computation of average annual damages was made. Figures 1, 2, and 3 of this appendix show a discharge-frequency curve, a discharge-damage curve, and computations of average annual damages, respectively, for river reach 1 - 3 a typical reach on the Nueces River. These curves and computations, together with the following discussion, are furnished as being representative of the methods used to determine the average annual damages for the investigated reaches of the Edwards Underground Reservoir area. 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 1. The flood damage data obtained through an economic survey in the field during 1963 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 2. By use of the discharge-frequency and discharge-damage curves, average annual damages were then computed for the various types of damage under existing and proposed

conditions of modification, the difference representing the damages prevented. 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.

11. APPLICATION OF ECONOMIC INDICATORS.- The economic base study presented in appendix V established indicators and trends of future development for the base study area. In order to apply these indicators to flood control, it was necessary to select the indicators pertinent to the different property classifications and to modify the indicators for use in the various reaches under study. Inspection of the damages under existing conditions disclosed that damages to agricultural property and crops constitute the major portion of the damages, with lesser damage to rural nonagricultural property and damage to urban and suburban property in four reaches. The indicators selected for the property classifications are as follows: Agricultural development; value of farm products sold and population; nonagricultural development; population, value of mineral production, retail sales, bank deposits, and disposable personal income; urban and suburban development; urban population, value added by manufacture, new construction, retail sales, bank deposits and disposable income.

12. Projection of the selected indicators was constructed for each of the reaches under study. The values of retail sales and bank deposits were estimated by relationship with personal income.

13. The difficulty in determining the proportion of the damages affected by each development factor was circumvented by deriving a proxy indicator which could be used in connection with the value of each category. The proxy indicators were computed as follows:

a. The values of the proxy indicators for the year 1975, 2000, and 2025 were found by computing the geometric mean of the factors of increase of the individual indicators which were selected for use with each property classification. The computed factors define the development curve to year 2025.

b. The increase in the factors from year 2025 to 2050 and from 2025 to 2075 are assumed to be the same as the increases in the factors from 2000 to 2025 and from 1975 to 2025, respectively, in order to define the final 50 years of the development curve. The completed development curve closely approximates a normal growth curve.

c. Since the damage computations are based on 1964 conditions the factors of increase are reduced by the value for 1964, which is read from the curve in order to achieve factors of increase with 1964 equal to one. An annual equivalent factor is then computed

TABLE 3

SUMMARY OF VALUE OF PHYSICAL PROPERTY IN THE FLOOD PLAIN - GUADALUPE RIVER BASIN
(1964 PRICE LEVELS - 1964 CONDITIONS OF DEVELOPMENT)

Stream	Reach	Agricultural Property	Rural Non-Agricultural Property	Transportation Facilities	Utilities	Urban and Suburban Property	Total
Guadalupe River	1	$ 3,011,400	$ 102,600	$ 2,776,100	$ 3,886,000	$	$ 9,776,100
	2	6,465,300	1,392,900	4,839,500	988,300	29,141,500	42,827,500
	3A-1	167,200	730,800	48,500	21,800	-	968,300
	3A-2)					-	
	3B)	Inundated by Cuero Reservoir					
	4A)						
	4B	1,265,900	-	681,200	122,000	2,224,800	4,293,900
	5	2,699,600	28,876,900	4,830,900	120,800	2,713,700	39,241,900
	6	Inundated by Canyon Reservoir					
	L-7A	145,600	11,200	770,300	800	-	927,900
	L-7B	312,500	-	28,400	-	-	340,900
	L-7C	831,400	13,400	2,018,000	70,200	101,500	3,034,500
Total Guadalupe River		14,898,900	31,127,800	15,992,900	5,209,900	34,181,500	101,411,000
San Marcos River	1	262,800	-	674,700	11,100	-	948,600
	2	2,024,800	186,100	249,000	6,900	-	2,466,800
	3	2,115,900	1,182,900	2,092,700	56,700	62,200	5,510,400
	4	67,200	121,600	3,001,200	345,600	10,331,800	13,867,400
Total San Marcos River		4,470,700	1,490,600	6,017,600	420,300	10,394,000	22,793,200
Blanco River	1	412,300	150,100	2,019,200	215,600	809,500	3,606,700
	2	18,200	338,800	112,000	4,900		473,900
Total Blanco River		430,500	488,900	2,131,200	220,500	809,500	4,080,600
Sandies Creek	1	289,100	-	256,500	11,100	-	556,700
BASIN TOTAL		$20,089,200	$33,107,300	$24,398,200	$5,861,800	$45,385,000	$128,841,500

TABLE 4

SUMMARY OF VALUE OF PHYSICAL PROPERTY IN THE FLOOD PLAIN - NUECES RIVER BASIN
(1964 PRICE LEVELS - 1964 CONDITIONS OF DEVELOPMENT)

Stream	Reach	Agricultural Property	Rural Non-Agricultural Property	Transportation Facilities	Utilities	Urban and Suburban Property	Total
Nueces River	1B	$ 948,500	$ -	$ 255,600	$ 10,000	$ -	$ 1,214,100
	1A	732,700	-	2,144,300	151,500	-	3,028,500
	1-1	765,200	-	925,000	6,000	-	1,696,200
	1-2	1,328,800	-	60,500	3,000	-	1,392,300
	1-3	9,240,900	690,000	1,819,500	198,600	1,006,000	12,955,000
	1-4	8,780,400	493,900	293,800	33,000	-	9,601,100
	2	3,056,400	-	38,800	-	-	3,095,200
	3	3,250,600	409,000	486,700	25,800	-	4,172,100
	4	5,732,900	251,200	1,016,000	222,100	-	7,222,200
	5&5A	3,298,100	6,446,300	3,177,300	402,500	6,029,700	19,353,900
	6	4,282,400	787,800	2,980,300	353,400	-	8,403,900
Total Nueces River		41,416,900	9,078,200	13,197,800	1,405,900	7,035,700	72,134,500
Frio River	1A	959,900	30,000	739,400	13,500	-	1,742,800
	1B	2,409,600	-	295,000	14,000	-	2,718,600
	2	4,079,400	-	559,000	35,400	-	4,673,800
	3	788,100	-	-	-	-	788,100
	4	2,347,900	-	381,500	6,400	-	2,735,800
	5	2,757,600	246,300	191,000	112,800	940,000	4,247,700
Total Frio River		13,342,500	276,300	2,165,900	182,100	940,000	16,906,800
Sabinal River	1	661,300	-	238,000	14,000	-	913,300
Hondo Creek	1	1,030,200	-	204,000	6,000	-	1,240,200
	2	656,400	-	577,000	10,000	-	1,243,400
Total Hondo Creek		1,686,600	-	781,000	16,000	-	2,483,600
Seco Creek	1	371,400	-	31,000	1,400	-	403,800
	2	1,740,800	-	2,127,700	66,200	3,868,400	7,803,100
	3	195,800	230,300	151,800	12,000	-	589,900
Total Seco Creek		2,308,000	230,300	2,310,500	79,600	3,868,400	8,796,800
BASIN TOTAL		$59,415,300	$9,584,800	$18,693,200	$1,697,500	$11,844,100	$101,235,000

TABLE 5

DAMAGES FROM MAXIMUM FLOOD OF RECORD UNDER PRESENT STATE OF DEVELOPMENT
GUADALUPE RIVER BASIN
(1964 Price Levels)

Stream	Reach	Year of Maximum Flood	Estimated Damages: Agricultural	Estimated Damages: Nonagricultural	Estimated Damages: Total
Guadalupe River	1	1936	$ 101,200	$ 1,900	$ 103,100
	2	1936	323,000	106,600	429,600
	3A-1	1936	ND	ND	ND
	3A-2		(Inundated by Cuero Reservoir)		
	3B		(Inundated by Cuero Reservoir)		
	4A		(Inundated by Cuero Reservoir)		
	4B	1929	319,700	340,700	660,400
	L-5	1913	414,700	285,900	700,600
	U-5	1935	ND	ND	ND
	6		(nundated by Canyon Reservoir)		
	L-7A	1932	10,300	39,800	50,100
	L-7B	1932	36,200	3,300	39,500
	L-7C	1932	150,800	72,100	222,900
Total Guadalupe River			1,355,900	850,300	2,206,200
San Marcos River	1	1929	48,300	17,500	65,800
	2	1929	526,500	145,900	672,400
	3	1929	555,200	21,500	576,700
	4	1921	15,700	1,006,600	1,022,300
Total San Marcos River			1,145,700	1,191,500	2,337,200
Blanco River	1	1929	82,400	123,100	205,500
	2	1929	2,900	82,000	84,900
Total Blanco River			85,300	205,100	290,400
Sandies Creek	1	1936	ND	ND	ND
TOTAL INVESTIGATED			2,586,900	2,246,900	4,833,800

TABLE 6

DAMAGES FROM MAXIMUM FLOOD OF RECORD UNDER PRESENT STATE OF DEVELOPMENT
NUECES RIVER BASIN
(1964 Price Levels)

Stream	Reach	Year of Maximum Flood	Estimated Damages		
			Agricultural	Nonagricultural	Total
Nueces River	1B	1955	$ 165,800	$ 39,100	$ 204,900
	1A	1935	94,900	1,971,500	2,066,400
	1-1	1935	149,900	430,000	579,900
	1-2	1935	224,900	7,300	232,200
	1-3	1935	2,132,900	542,100	2,675,000
	1-4	1935	1,715,000	259,500	1,974,500
	2	1935	108,100	8,500	116,600
	3	1935	405,600	132,300	537,900
	4	1935	110,100	207,200	317,300
	5&5A	1919	459,200	634,200	1,093,400
	6	1919	175,400	88,700	264,100
Total Nueces River			5,741,800	4,320,400	10,062,200
Frio River	1A	1932	128,800	43,000	171,800
	1B	1932	478,800	74,000	552,800
	2	1932	152,400	128,300	280,700
	3	1932	23,400	-	23,400
	4	1932	66,000	114,500	180,500
	5	1958	138,800	156,500	295,300
Total Frio River			988,200	516,300	1,504,500
Sabinal River	1	1958	114,200	26,500	140,700
Hondo Creek	1	1935	156,800	25,000	181,800
	2	1958	105,200	40,000	145,200
Total Hondo Creek			262,000	65,000	327,000
Seco Creek	1	1935	163,500	9,900	173,400
	2	1935	923,700	1,023,800	1,947,500
	3	1935	211,400	43,600	255,000
Total Seco Creek			1,298,600	1,077,300	2,375,900
TOTAL INVESTIGATED			8,404,800	6,005,500	14,410,300

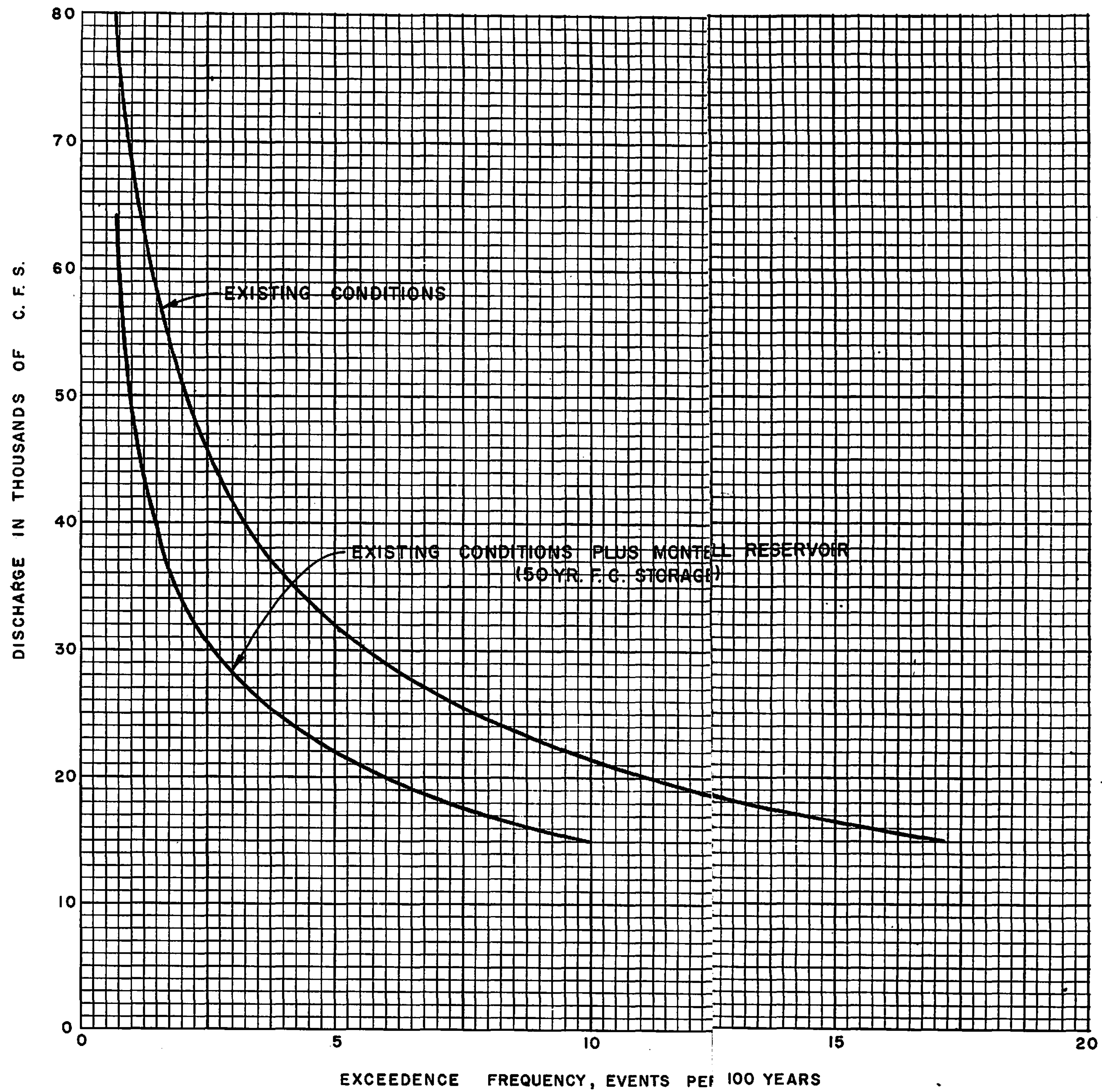

FIGURE I

DISCHARGE-FREQUENCY CURVES

NUECES RIVER - REACH I-3

SCALES AS SHOWN

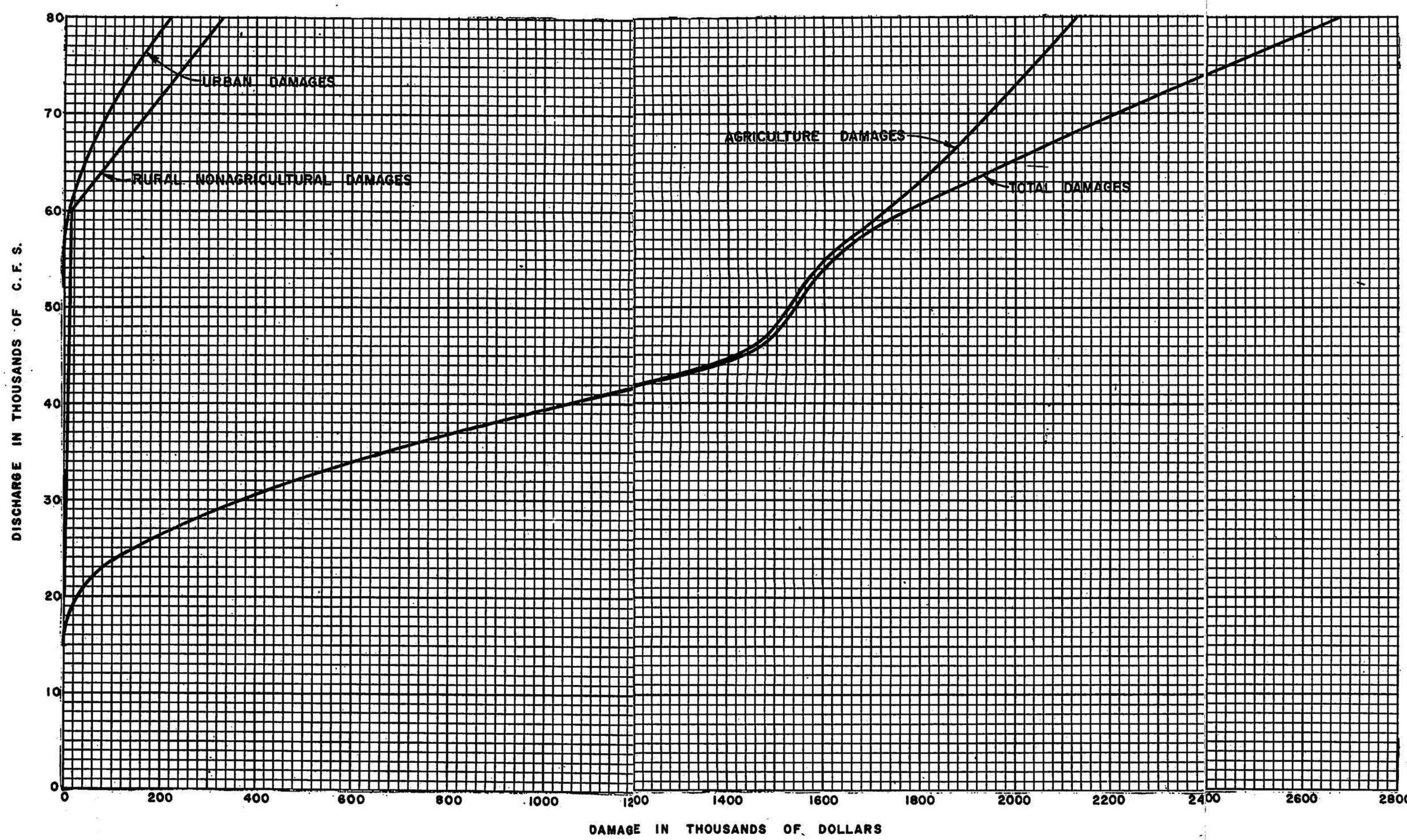

FIGURE 2

DISCHARGE - DAMAGE CURVES

NUECES RIVER-REACH I-3

SCALES AS SHOWN

Figure 3

COMPUTATION OF AVERAGE ANNUAL DAMAGES
NUECES RIVER - REACH 1-3

Existing Conditions

Total Damages: Frequency	Total Damages: Δ Frequency	Total Damages: Discharge (cfs)	Total Damages: Damage	Total Damages: Double Damage	Total Damages: Δ Double Damage	Nonagricultural Damages: Δ Frequency	Nonagricultural Damages: Damage	Nonagricultural Damages: Double Damage	Nonagricultural Damages: Δ Double Damage	Urban Damages: Δ Frequency	Urban Damages: Damage	Urban Damages: Double Damage	Urban Damages: Δ Double Damage
0			$4,800,000				$680,000				$1,050,000		
	0.7			$7,475,000	$5,232,500	0.7		$1,003,100	$702,170	0.7		$1,269,100	$888,370
0.7		80,000	2,675,000				323,100				219,100		
	0.3			4,795,000	1,438,500	0.3		463,100	138,930	0.3		281,300	84,390
1.0		68,000	2,120,000				140,000				62,200		
	0.2			4,060,000	812,000	0.2		217,500	43,500	0.2		98,200	19,640
1.2		64,000	1,940,000				77,500				36,000		
	0.2			3,668,000	733,600	0.2		94,500	18,900	0.2		48,000	9,600
1.4		59,000	1,728,000				17,000				12,000		
	0.2			3,368,000	673,600	0.2		32,000	6,400	0.2		17,800	3,560
1.6		56,000	1,640,000				15,000				5,800		
	0.2			3,220,000	644,000	0.2		28,500	5,700	0.2		8,100	1,620
1.8		53,000	1,580,000				13,500				2,300		
	0.2			3,114,000	622,800	0.2		25,000	5,000	(1.9) 52,000 0.1		2,300	230
2.0		50,000	1,534,000				11,500				0		
	0.5			2,994,000	1,497,000	0.5		21,000	10,500				1,007,410
2.5		46,000	1,460,000				9,500						
	0.5			2,630,000	1,315,000	0.5		16,000	8,000				
3.0		41,500	1,170,000				6,500						
	0.5			2,100,000	1,050,000	0.5		11,500	5,750				
3.5		38,500	930,000				5,000						
	0.5			1,670,000	835,000	0.5		9,000	4,500				
4.0		36,000	740,000				4,000						
	1.0			1,220,000	1,220,000	1.0		6,500	6,500				
5.0		32,000	480,000				2,500						
	1.0			805,000	805,000	1.0		4,000	4,000				
6.0		29,000	325,000				1,500						
	1.0			535,000	535,000	1.0		2,500	2,500				
7.0		26,500	210,000				1,000						
	1.0			348,000	348,000	1.0		1,500	1,500				
8.0		24,500	138,000				500						
	1.0			223,000	223,000	1.0		700	700				
9.0		23,000	35,000				200						
	1.0			135,000	135,000	1.0		300	300				
10.0		21,500	50,000				100						
	2.0			70,000	140,000	(11.2) 20,000 1.2		100	120				
12.0		19,000	20,000				0						
	2.0			25,000	50,000				964,970				
14.0		17,200	5,000										
	2.0			7,000	14,000								
16.0		16,000	2,000										
	1.2			2,000	2,400								
17.2		15,000	0										
					18,326,400								

$\frac{18,326,400}{200}$ = $91,632.00

$\frac{964,970}{200}$ = $4,824.8

$\frac{1,007,410}{200}$ = $5,037.05

Modified by Montell Reservoir

Total Damages: Δ Frequency	Total Damages: Discharge (cfs)	Total Damages: Damage	Total Damages: Double Damage	Total Damages: Δ Double Damage	Nonagricultural Damages: Δ Frequency	Nonagricultural Damages: Damage	Nonagricultural Damages: Double Damage	Nonagricultural Damages: Δ Double Damage	Urban Damages: Δ Frequency	Urban Damages: Damage	Urban Damages: Double Damage	Urban Damages: Δ Double Damage
		$3,480,400				$165,000				$174,800		
0.7			$5,420,400	$3,794,280	0.7		$243,000	$170,100	0.70		$211,300	$147,910
	64,000	1,940,000				78,000				36,500		
0.3			3,455,000	1,036,500	0.3		89,000	26,700	(0.75) 52,000 0.05		36,500	1,825
	48,900	1,515,000				11,000				0		
0.2			2,870,000	574,000	0.2		19,000	3,800				149,735
	44,000	1,355,000				8,000						
0.2			2,455,000	491,000	0.2		14,000	2,800				
	40,600	1,100,000				6,000						
0.2			1,990,000	398,000	0.2		11,000	2,200				
	38,000	890,000				5,000						
0.2			1,600,000	320,000	0.2		9,500	1,900				
	35,600	710,000				4,500						
0.2			1,285,000	257,000	0.2		7,500	1,500				
	33,500	575,000				3,000						
0.5			975,000	487,500	0.5		5,000	2,500				
	30,500	400,000				2,000						
0.5			680,000	340,000	0.5		3,500	1,750				
	28,000	280,000				1,500						
0.5			472,000	236,000	0.5		2,500	1,250				
	26,000	192,000				1,000						
0.5			330,000	165,000	0.5		1,800	900				
	24,500	138,000				800						
1.0			198,000	198,000	1.0		1,200	1,200				
	22,000	60,000				400						
1.0			84,000	84,000	(5.9) 20,000 0.9		400	360				
	19,800	24,000				0						
1.0			36,000	36,000				216,960				
	18,200	12,000										
1.0			15,000	15,000								
	16,800	3,000										
1.0			4,000	4,000								
	15,900	1,000										
1.0			1,000	1,000								
	15,000	0										
				8,437,280								

$\frac{8,437,280}{200}$ = $42,186.40

$\frac{216,960}{200}$ = $1,084.80

$\frac{149,735}{200}$ = $748.68

Existing Conditions

Total Average Annual Damages	=	$91,600
Agricultural Average Annual Damages	=	81,800
Nonagricultural Average Annual Damages	=	4,800
Urban Average Annual Damages	=	5,000

Modified by Montell Reservoir

Total Average Annual Damages	=	$42,200
Agricultural Average Annual Damages	=	40,400
Nonagricultural Average Annual Damages	=	1,100
Urban Average Annual Damages	=	700

using an annual rate of 3-1/8 percent interest.

14. A typical computation of annual equivalent factors is shown in table 7. The factors of increase of the individual indicators and of the proxy indicators for Reach 6 of the Nueces River are also given in table 7. The annual equivalent factors used for converting the average annual flood damages which are based on development existing in 1964 into average annual damages during the 100-year period of analysis are also shown. The annual equivalent factors for the stream reaches studied in this report are factors weighted according to property classifications and are shown in the following tabulation:

WEIGHTED DEVELOPMENT FACTORS - FLOOD CONTROL

Stream	Reach	Average Annual Factor 1975 - 2075
Guadalupe River	1	2.37
	L-2	2.37
	U-2	2.37
	3A-1	1.91
	3A-2	--(1)
	3B	--(1)
	4A	--(1)
	4B	1.91
	5	2.21
	6	--(2)
	L-7A	2.99
	L-7B	2.99
	L-7C	2.99
San Marcos River	1	1.91
	2	1.91
	3	1.91
	4	2.56
Blanco River	1	2.56
	2	2.56
Sandies Creek	1	1.91
Nueces River	1B	2.49
	1A	3.20
	1-1	3.22
	1-2	2.70
	1-3	2.55
	1-4	2.51
	2	2.17
	3	2.18
	4	2.08
	5 & 5A	2.20
	6	2.13

WEIGHTED DEVELOPMENT FACTORS - FLOOD CONTROL (Continued)

Stream	Reach	Average Annual Factor 1975 - 2075
Frio River	1A	2.71
	1B	2.46
	2	2.36
	3	2.21
	4	2.17
	5	2.06
Sabinal River	1	2.53
Hondo Creek	1	2.20
	2	2.89
Seco Creek	1	2.24
	2	3.09
	3	2.44

(1) Inundated by proposed Cuero Stage II Reservoir
(2) Inundated by Canyon Reservoir.

15. BENEFITS DUE TO PREVENTION OF DAMAGES.- The average annual damages due to flooding were computed using the procedures outlined in paragraph 10 of this appendix. The computations for the Guadalupe River were based on conditions which would exist with the effect of the existing Canyon Reservoir and the proposed Cuero Stage II Reservoir in operation. The computations for the Nueces River do not consider any existing flood-control projects. In each case, these are referred to as existing conditions. Similar computations were then made based on conditions which would exist after construction of each of the proposed improvements. By deduction, the average annual benefits based on 1964 conditions of flood plain development were found. The benefits thus computed were converted to the average annual benefits for the period from 1975 to 2075 by applying the development factors tabulated in paragraph 14. For the purposes of project formulation, benefits were computed for each project considered alone, and for various project sizes. The benefits are presented in appendix I, Project Formulation. The benefits attributable to the recommended projects are presented in this appendix. Tables 8 and 9 give the average annual damages under existing conditions and under conditions of modification by the proposed plan of improvement, and the resulting benefits due to prevention of damages, based on 1964 conditions of flood plain development, for the Guadalupe and Nueces Rivers, respectively. Tables 10 and 11 give similar data, based on 1975-2075 flood plain development and the benefits attributable to each of the projects in the plan of improvement.

TABLE 7

FLOOD CONTROL DEVELOPMENT FACTORS
NUECES RIVER - REACH 6

	1975	2000	2025	2050	2075
Agricultural = 94.4%					
1960 = 1.000					
Population	1.350	2.150	3.360		
Value of farm products sold	1.370	1.720	2.154		
Geometric mean	1.360	1.923	2.690	3.457	4.020
1964 = 1.000	1.225	1.732	2.423	3.114	3.622
Annual equivalent - using 3-1/8 percent interest rate = 1.80					
Nonagricultural = 5.6%					
1960 = 1.000					
Population	2.128	3.670	6.237		
Value of mineral production	2.723	6.100	13.748		
Retail sales	2.768	6.950	17.853		
Bank deposits	2.768	6.950	17.853		
Disposable personal income	2.768	6.950	17.853		
Geometric mean	2.617	5.959	13.730	21.501	24.843
1964 = 1.000	2.561	5.831	13.435	21.038	24.309
Annual equivalent - using 3-1/8 percent interest rate = 7.76					
Weighted factor = (1.80 x .944) + (7.76 x .056) = 2.13					

TABLE 8

FLOOD CONTROL BENEFITS
1964 CONDITIONS OF DEVELOPMENT
GUADALUPE RIVER BASIN

Stream	Reach	Average annual damages: Existing	Average annual damages: Modified by Cloptin Crossing Reservoir	Benefits due to prevention of damages by Cloptin Crossing Reservoir
Guadalupe River	1	$ 14,900	$ 5,400	$ 9,500
	2	79,300	20,600	58,700
	3A1	900	--	900
	3A2	(Inundated by Cuero Reservoir)		
	3B	(" " " ")		
	4A	(" " " ")		
	4B	140,700	130,700	10,000
San Marcos River	1	30,900	20,200	10,700
	2	193,600	151,200	42,400
	3	134,700	70,000	64,700
	4	109,500	31,300	78,200
Sandies Creek	1	--	--	--
Blanco River	1	13,300	100	13,200
	2	7,100	300	6,800
Total		$724,900	$429,800	$295,100

TABLE 9

FLOOD CONTROL BENEFITS
1964 CONDITIONS OF DEVELOPMENT
NUECES RIVER BASIN

Stream	Reach	Average Annual Damages				Benefits due to prevention of damages (1)		
		Existing	Modified by Montell Reservoir	Modified by Concan Reservoir	Modified by Sabinal Reservoir	Montell Reservoir	Concan Reservoir	Sabinal Reservoir
Nueces River	1B	$ 10,000	$ 300	$ 10,000	$ 10,000	$ 9,700	$ 0	$ 0
	1A	64,800	23,200	64,800	64,800	41,600	0	0
	1-1	15,300	7,100	15,300	15,300	8,200	0	0
	1-2	8,300	3,900	8,300	8,300	4,400	0	0
	1-3	91,600	42,200	91,600	91,600	49,400	0	0
	1-4	182,400	111,300	182,400	182,400	71,100	0	0
	2	13,800	10,200	13,800	13,800	3,600	0	0
	3	43,800	31,300	43,800	43,800	12,500	0	0
	4	42,900	36,600	42,900	42,900	6,300	0	0
	5 & 5A	165,100	145,200	155,900	161,500	19,900	9,200	3,600
	6	78,600	73,300	76,000	77,200	5,300	2,600	1,400
Frio River	1A	3,400	3,400	400	3,400	0	3,000	0
	1B	9,400	9,400	4,700	6,300	0	4,700	3,100
	2	8,500	8,500	6,600	7,300	0	1,900	1,200
	3	2,600	2,600	2,100	2,300	0	500	300
	4	11,900	11,900	9,600	10,400	0	2,300	1,500
	5	23,100	23,100	21,700	22,500	0	1,400	600
Sabinal River	1	8,900	8,900	8,900	900	0	0	8,000
TOTAL		$784,400	$552,400	$758,800	$764,700	$232,000	$25,600	$19,700

(1) Sum of benefits for individual reservoirs virtually equal to total benefits for the three-reservoir system.

TABLE 10

FLOOD CONTROL BENEFITS
1975-2075 CONDITIONS OF DEVELOPMENT
GUADALUPE RIVER BASIN

Stream	Reach	Average annual damages: Existing	Average annual damages: Modified by Cloptin Crossing Reservoir	Benefits due to prevention of damages by Cloptin Crossing Reservoir
Guadalupe River	1	$ 35,300	$ 12,800	$ 22,500
	2	188,000	48,800	139,200
	3A1	1,800	--	1,800
	3A2	(Inundated by Cuero Reservoir)		
	3B	(" " " ")		
	4A	(" " " ")		
	4B	268,700	249,600	19,100
San Marcos River	1	59,000	38,600	20,400
	2	369,800	288,800	81,000
	3	257,300	133,700	123,600
	4	280,300	80,100	200,200
Sandies Creek	1	--	--	--
Blanco River	1	34,100	300	33,800
	2	18,200	800	17,400
Total		$1,512,500	$853,500	$659,000

TABLE 11

FLOOD CONTROL BENEFITS
1975 - 2075 CONDITIONS OF DEVELOPMENT
NUECES RIVER BASIN

Stream	Reach	Average Annual Damages				Benefits due to prevention of damages (1)		
		Existing	Modified by Montell Reservoir	Modified by Concan Reservoir	Modified by Sabinal Reservoir	Montell Reservoir	Concan Reservoir	Sabinal Reservoir
Nueces River	1B	$ 24,900	$ 700	$ 24,900	$ 24,900	$ 24,200	$ 0	$ 0
	1A	207,400	74,200	207,400	207,400	133,200	0	0
	1-1	49,300	22,900	49,300	49,300	26,400	0	0
	1-2	22,400	10,500	22,400	22,400	11,900	0	0
	1-3	233,600	107,700	233,600	233,600	125,900	0	0
	I-4	457,800	279,000	457,800	457,800	178,800	0	0
	2	29,900	22,100	29,900	29,900	7,800	0	0
	3	95,500	68,300	95,500	95,500	27,200	0	0
	4	89,200	76,100	89,200	89,200	13,100	0	0
	5 & 5A	363,200	319,500	343,000	355,400	43,700	20,200	7,800
	6	168,900	156,100	163,000	165,800	11,300	5,900	3,100
Frio River	1A	8,600	8,600	1,200	8,600	0	7,400	0
	1B	23,100	23,100	11,900	15,800	0	11,200	7,300
	2	22,500	22,500	17,700	19,400	0	4,800	3,100
	3	5,700	5,700	4,600	5,000	0	1,100	700
	4	25,600	25,600	20,700	22,400	0	4,900	3,200
	5	48,000	48,000	45,100	46,700	0	2,900	1,300
Sabinal River	1	21,200	21,200	21,200	2,200	0	0	19,000
TOTAL		$1,896,800	$1,291,800	$1,838,400	$1,851,300	$603,500	$58,400	$45,500

(1) Sum of benefits for individual reservoirs virtually equal to total benefits for the three-reservoir system.

APPENDIX VII

COMMENTS OF OTHER AGENCIES

SURVEY REPORT
ON
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE, SAN ANTONIO AND NUECES RIVERS
AND TRIBUTARIES, TEXAS

APPENDIX VII

COMMENTS OF OTHER AGENCIES

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

SURVEY REPORT
ON
EDWARDS UNDERGROUND RESERVOIR
GUADALUPE, SAN ANTONIO AND NUECES RIVERS
AND TRIBUTARIES, TEXAS

APPENDIX VII

COMMENTS OF OTHER AGENCIES

INTRODUCTION

Draft copies of this report were sent to other Federal agencies at field level for review, in accordance with the Interagency Agreement on Coordination of Water and Related Land Resources Activities approved by the President on May 26, 1954. Draft copies of the report were also sent for review to the Texas Water Commission and to river authorities, city water boards, improvement districts, and military commands within the Edwards Underground Reservoir area. Letters received from these agencies containing their comments, and replies where appropriate, are presented in this appendix.

OTHER FEDERAL AGENCIES

PAGES 3 THROUGH 36

STATE AGENCIES

PAGES 38 THROUGH 61

REGION SIX
ARKANSAS
LOUISIANA
OKLAHOMA
TEXAS
06-41

U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
Austin, Texas 78701

January 8, 1965

IN REPLY REFER TO:

Colonel F. P. Koisch
District Engineer
Corps of Engineers
100 West Vickery Boulevard
Fort Worth, Texas

Dear Colonel Koisch:

We are returning the draft copy (Serial No. 80) of your "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas," dated December 1964.

We appreciate the opportunity to review this report and would be pleased to receive a final copy of Volume 1, Main Report.

Sincerely yours,

L. S. Coy
Division Engineer

REGION SIX
ARKANSAS
LOUISIANA
OKLAHOMA
TEXAS

U.S. DEPARTMENT OF COMMERCE
BUREAU OF PUBLIC ROADS
P. O. BOX 12037
FORT WORTH 16, TEXAS

January 14, 1965

IN REPLY REFER TO:
06-00.1

Colonel F. P. Koisch
District Engineer
Corps of Engineers
100 West Vickery Boulevard
Fort Worth, Texas

Dear Colonel Koisch:

We are returning the draft copy (Serial No. 81) of your "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas," furnished with our copy of your 24 December 1964 letter to Mr. Coy.

We appreciate the opportunity to review this report. We have no comments to offer for inclusion in the final report.

Sincerely,

J. A. Heasser (signature)

For Bill L. Andrews
Assistant Regional Engineer

Attachment

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF OUTDOOR RECREATION
7860 WEST 16TH AVENUE
DENVER, COLORADO 80215

L7423

January 8, 1965

Your Ref: SWFGP

Colonel F. P. Koisch, District Engineer
U. S. Army Engineer District, Fort Worth
Corps of Engineers
P. O. Box 1600
Fort Worth, Texas 76101

Dear Colonel Koisch:

This is in reply to your letter of December 24, 1964, wherein we were requested to review a draft copy of your Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers, Texas, dated December 1964.

We commend you for your thorough analysis of the recreation problems associated with the subject area. At this time we have no specific comments on the proposed projects or their relation to providing opportunities for the public to engage in outdoor recreation activities. By this statement, we do not wish to imply that we approve or disapprove of the report as written or that we are not interested. Our Bureau is now engaged in collecting and analyzing data for the preparation of a Nationwide Outdoor Recreation Plan. This endeavor will provide information relating to recreation supply and demand associated with water resource development projects such as contemplated in the subject report. The State of Texas is also actively engaged in the preparation of a comprehensive Statewide Outdoor Recreation Plan under P.L. 88-578. When these data have been developed, it might be desirable to reevaluate the recreation program as proposed in your December 1964 report.

We appreciate the opportunity to review the draft report. As requested, we are returning the copy, serial number 89. When the report has been finalized, we would appreciate a copy of the recreation appendix and other related pertinent data for our files.

Sincerely yours,

W. W. Dresskell
Regional Director

Enclosures:
Vols. I, II,
and III

IN REPLY REFER TO:

SPA-RH

UNITED STATES
DEPARTMENT OF THE INTERIOR
SOUTHWESTERN POWER ADMINISTRATION

POST OFFICE DRAWER 1619
TULSA X OKLAHOMA 74101

January 18, 1965

Your reference:
SWFGP

District Engineer
U. S. Army Engineer District,
Fort Worth
Corps of Engineers
P. O. Box 1600
Fort Worth, Texas 76101

Dear Sir:

The draft copy (serial number 94) of your Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas, dated December 1964, has been reviewed.

The proposed improvements will not affect the interests of this Administration. However, in further studies of the region in which reservoir projects are included, it is suggested that the hydroelectric power potential be considered in both conventional and pumped storage projects.

As requested, the draft copy is being returned.

Sincerely yours,

Earl E. Roberts
Chief, Division of
Planning and Resources

Enclosures 3

FEDERAL POWER COMMISSION
REGIONAL OFFICE
100 North University Drive
Fort Worth, Texas 76107
January 20, 1965

The District Engineer
U. S. Army Engineer District, Fort Worth
P. O. Box 1600
Fort Worth, Texas 76101

Attention: SWFGP

Dear Sir:

Attached hereto is the draft copy of your "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas" which has been reviewed and is being returned as requested by your letter of December 24, 1964.

Our review of this report was directed toward the feasibility of inclusion of hydroelectric power facilities as a part of the plan of development. The proposed Montell, Concan, and Sabinal projects in the Nueces River Basin would not be adaptable to power generation, since, in order to meet requirements for flood control and recharge purposes, these reservoirs will be operated on the "dry-pool" principle, with the exception of a minor amount of storage at Montell.

The proposed multiple-purpose project at Cloptin Crossing on the Blanco River in the Guadalupe River Basin was studied in some detail. It was found that any appreciable quantity of storage at the site would result in a critical hydro period of almost ten years. The comparatively low rate of precipitation and high rate of evaporation in the area are not conducive to economic storage of water for so long a drawdown period. Several assumptions were made in order to increase dead storage in the interest of more head for power at the Cloptin Crossing development. It was found that prime power in the amount of 500-600 kilowatts could be developed under the several alternatives which were studied. This would support low load factor installations of 10,000-12,000 kilowatts. However, with ratios of benefits to costs of less than 0.7 none of the alternatives studied would be economically feasible by present criteria.

On the basis of these findings we concur in your conclusion (Appendix I, Page 53) that the inclusion of hydroelectric power facilities at Federal expense is not justified at these reservoir projects and we do not find any justification for provisions which would allow installation of power facilities at some future date. We note that there is a possibility that the recharge system may increase the flow of Comal and associated springs thus increasing power production at the series of small existing hydroelectric stations on the Guadalupe River.

We appreciate the opportunity to review the report at this stage. It should be noted that our comments are made at field level and are not necessarily those of the Federal Power Commission.

Sincerely yours,

Lenard B. Young
Regional Engineer

Enclosure No. 4207:
As stated herein (u.s.c.)

PUBLIC HEALTH SERVICE

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
REGIONAL OFFICE
1114 Commerce Street
Dallas, Texas 75202

January 21, 1965

Your reference:
SWFGP

District Engineer
U. S. Army Engineer District, Fort Worth
P. O. Box 1600
Fort Worth, Texas 76101

Dear Sir:

The draft copy (Serial Number 83) of your "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio, and Nueces Rivers, and Tributaries, Texas," dated December 1964, has been reviewed.

Our "Water Supply and Water Quality Control Study, Edwards Underground Reservoir, Texas," which evaluates municipal and industrial water supply and water quality control by flow regulation requirements, will be included in the report as Attachment 2, Appendix I.

Several minor discrepancies have been noted in colored pencil on the copy of the report which we are returning under separate cover. Your report compares future water requirements determined by this office with 1962 reported water use. Our report employed 1958 as the base water use year.

Paragraph 91 of your report relating to future water requirements should be headed "Municipal, Rural, Industrial, and Power Demands" to be consistent with the data presented in the report from this office. Domestic use is a segment of both municipal and rural water demands.

We expect that the various minor inconsistencies can be worked out in meetings with your staff.

Concerning water quality control, your report should indicate that consideration was given to use of storage in the proposed projects for regulation of streamflow for the purpose of water quality control in accordance with Section 2b of the Federal Water Pollution Control Act, as amended.

With respect to vector problems, it is unlikely that construction of the reservoir projects will create a significant encephalitis hazard or other vector-borne disease problems in the area.

A few cases of encephalitis among horses have been reported from the area. The encephalitis mosquito -- Culex tarsalis -- occurs in the region, but the ecology of the area is not too suitable for this species.

As public health safeguards against vector problems, it would seem a wise course of action for the Corps of Engineers and other agencies to carry out a few preventative measures, as outlined below:

1. Eliminate seepage areas (favorite breeding places for Culex tarsalis mosquitoes) by constructing drains to natural channels.

2. In connection with recreational developments,

   a. Provide for proper storage, collection, and disposal of refuse for the prevention of flies, wasps, rats, and wild rodents.

   b. Provide for rodent-proofed buildings.

   c. Provide for periodic removal of debris, rubbish, and other materials which may serve as harborage for rodents and other small mammals.

   d. Provide for supplemental use of insecticides and rodenticides in situations where adequate vector control is not obtained through source reduction methods outlined above.

It is recommended that a postimpoundage vector control survey be conducted to determine what additional measures are needed to provide for adequate public health safeguards.

The opportunity to review the report is appreciated.

Sincerely yours,

Jerome H. Svore

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

Enclosure
Draft Copy (Serial No. 83)

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
100 WEST VICKERY BOULEVARD
FORT WORTH 4, TEXAS

ADDRESS REPLY TO:
DISTRICT ENGINEER
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
P. O. BOX 1600
FORT WORTH, TEXAS
IN REPLY REFER TO

SWFGP

17 March 1965

Mr. Jerome H. Svore
Regional Program Director
Water Supply and Pollution Control
Public Health Service
U. S. Department of Health, Education and Welfare
1114 Commerce Street
Dallas, Texas 75202

Dear Mr. Svore:

This is in reply to your letter of 21 January 1965 containing your comments on our "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas." Inclosed with your letter was the draft copy, serial No. 83, of the report with a few discrepancies noted in colored pencil.

The discrepancies noted in the report and included in your letter have been corrected. You also noted that the report compared 1962 water use from the aquifer, determined by the Geological Survey, with the future requirements determined by the Public Health Service. The references to the contributing agencies are shown on Figure 8, Table 10, and other locations throughout the report. Since a significant portion of the data presented in the report is based on hydrologic records through the year 1962, it is considered essential to present the 1962 water use in this form. However, this should have no effect on your determination of future water requirements.

A discussion of consideration given to use of storage in the proposed reservoirs for streamflow regulation for water quality control purposes has been added to the report.

Your letter containing the suggestions pertaining to the public health safeguards against vector problems and recommendations for a postimpoundage vector control survey will be appended to the report. Consideration will be given your suggestions and recommendations during the advance planning and construction phases of the projects.

Your review of the report and comments are appreciated.

Sincerely yours,

F. P. Koisch

F. P. KOISCH
Colonel, CE
District Engineer

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
5401 Federal Office Bldg.
Little Rock, Arkansas 72201

January 28, 1965

Colonel F. P. Koisch, District Engineer
U. S. Army Engineer District, Ft. Worth
Post Office Box 1600
Ft. Worth, Texas 76101

Dear Colonel Koisch:

We are enclosing a letter dated January 20, 1965 from Mr. J. K. Vessey, Regional Forester, covering the field level comment of his agency on your draft survey report on Edwards Underground Reservoir, Guadalupe, San Antonio, and Nueces Rivers and Tributaries, Texas. Also, according to our information, you were furnished a letter of comments dated January 21, 1965 from Mr. H. N. Smith, Texas State Conservationist, Soil Conservation Service, covering the field level comments of his agency. These comments are submitted in accordance with interagency agreement on coordination of proposed water resource projects.

In accordance with your request, draft reports numbers 86 and 87 are being returned under separate cover. We would like to receive one copy of your final report when prepared.

This is to advise that the above noted comments from the U. S. Forest Service and the Soil Conservation Service constitute the field level comments of the U. S. Department of Agriculture.

Sincerely yours,

William B. Davey
State Conservationist
(USDA AWRBIAC Representative)

Enclosure

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Atlanta, Georgia 30323

IN REPLY REFER TO

3520

January 20, 1965

Colonel F. P. Koisch, District Engineer
U. S. Army Engineer District, Fort Worth
Corps of Engineers
P. O. Box 1600
Fort Worth, Texas 76101

Dear Colonel Koisch:

We have reviewed the draft copy of your "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas."

Paragraphs 47, 48, and 49 of Volume 2, Pages II-74 and II-97 discuss watershed development as a factor in reducing runoff. Our interest from a forestry standpoint is limited because the study area is out of the commercial forest zone. However, we believe the role of land treatment combined with floodwater-retarding structures is dismissed too easily in this report.

Sincerely yours,

J. K. VESSEY
Regional Forester

By [signature]

Enclosures

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
P. O. Box 648
Temple, Texas 76502

January 21, 1965

Colonel F. P. Koisch
District Engineer
Corps of Engineers, U.S.Army
100 West Vickery Blvd.
Box 1600
Fort Worth, Texas 76101

Dear Colonel Koisch:

A review has been completed for your "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas" as requested by letter dated December 16, 1964, in accordance with Inter-Agency agreement on coordination of proposed water resource projects.

The purpose of the investigations and study, as stated, is to devise effective means of accomplishing the recharge and replenishment of the Edwards Underground Reservoir as a part of plans for flood control and water conservation.

The Edwards Underground Water District is the State Agency designated to cooperate with the Corps of Engineers in this study.

The plan of improvement would provide for construction of Montell Reservoir on the Nueces River, Concan Reservoir on the Frio River, and Sabinal Reservoir on the Sabinal River with joint storage for flood control and recharge purposes. A small conservation pool would be provided in the Montell Reservoir for downstream water supply. Two reservoir projects are also proposed in the Guadalupe River basin to provide a supplemental water supply for the Edwards Reservoir area. Clopton Crossing Reservoir, a multiple-purpose project on the Blanco River, is proposed for Federal construction. Dam No. 7 Reservoir, on the Guadalupe River, is proposed for construction by local interest for water conservation purposes.

"The proposed plan of improvement would meet the municipal, domestic, industrial, military, thermal power, and irrigation demands in the Edwards Reservoir area to approximate the year 2000. To meet the anticipated water demands beyond this date will acquire more adequate use of return flows and development of additional water supply outside the Edwards Reservoir area."

The following comments are presented for your consideration:

1. Data presented in the report indicate that the proposed project will increase average annual recharge by approximately 63,900 acre-feet. It is estimated that of this amount, the safe yield will be 29,000 acre-feet through increase in well withdrawal and the remaining 34,900 acre-feet would be discharged from the aquifer through the major springs.

   The report does not state that the total annual recharge is expected to be recovered. However, calculations for determining the monetary value of recharge indicate that 100 percent recovery was considered and that the same value was used for each acre-foot of recharge whether recaptured through wells or discharged through major springs.

2. Volume I, Page 85, Table 5 - Sediment storage in York Creek should be 4,950 instead of 4,599 acre-feet. The 4,599 acre-feet does not include 351 acre-feet capacity provided in the detention pool.

3. Volume II, Page II-19, Table 5 - The sediment storage capacity for York Creek is in error as above.

   Drainage area of Salado Creek watershed is shown to be 211 square miles. The work plan shows this to be 218 square miles and Texas Water Commission Circular No. 63-07 shows the drainage area to be 223 square miles. The use of 211 has no effect on SCS program.

   The Service spillway release rate for Martinez Creek shows 430 cfs. This includes 71 cfs from Sites 4 and 5 which are in series with Site 6A. The release from the watershed should be 369 cfs.

4. It is noted that Montell, Concan and Sabinal Reservoirs are proposed with storage for groundwater recharge. These will contribute 26,600, 21,500, and 15,800 acre-feet annually to groundwater recharge. The recharge water is valued at $38 per acre-foot. This value is higher than we generally estimate, but is not unreasonable when the total resources of an area are needed as in the San Antonio area.

We find the subject report to be well presented and contains interesting analyses and good basic data.

In accordance with instructions, we are returning draft copies of Serial Nos. 84 and 85, under separate cover. We would like to keep draft copy No. 88, if there is no objection. We appreciate this opportunity to review the report.

Sincerely yours,

Clyde W. Graham

for H. N. Smith
State Conservationist

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
100 WEST VICKERY BOULEVARD
FORT WORTH 4. TEXAS

ADDRESS REPLY TO:
DISTRICT ENGINEER
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
P. O. BOX 1600
FORT WORTH, TEXAS
IN REPLY REFER TO
SWFGP

17 March 1965

Mr. H. N. Smith
State Conservationist
Soil Conservation Service
U. S. Department of Agriculture
P. O. Box 648
Temple, Texas 76502

Dear Mr. Smith:

This is in reply to your letter of 21 January 1965 regarding our "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas."

Corrections to data presented in the report on the Soil Conservation Service reservoirs have been made in accordance with comments 2 and 3 shown on page 2 of your letter.

With regard to comment No. 1 on page 2 of your letter concerning recovery of the total annual recharge, it is assumed that in future years the springflow from the Edwards Underground Reservoir will be in such great demand that facilities will be installed by local interests to fully utilize the increased flow. For this reason we have considered 100 percent recovery of the increased quantity of recharge water. However, the same value has not been placed on the quantity of water available for pumping and the quantity expected to be discharged from the various major springs in the region. As described in paragraphs 48 through 52, appendix I, a separate value or unit benefit was determined for the increased water available for pumping and the increased flow at each of the major springs. The unit values and benefits were computed on the basis of being equal to the same cost of delivered water from the most likely or most economical alternative source, taking into account the differential costs of pumping and treatment. Because of the high quality of the artesian water from the aquifer and the high water demands indicated for the future in this region, the value placed on the quantity of increased water resources that could be developed is considered conservative.

SWFGP
Mr. H. N. Smith

17 March 1965

The comments contained in your letter with regard to the subject report are appreciated.

Sincerely yours,

F. P. KOISCH
Colonel, CE
District Engineer

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

January 22, 1965

AIRMAIL

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

Dear Sir:

By letter dated December 24, 1964, reference SWFGP, you requested our comments on the draft of your "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas," dated December 1964.

We have reviewed the draft of the survey report including Volumes 1 through 3. We are pleased to note that the Bureau of Sport Fisheries and Wildlife report will be attached to Appendix VI, Recreation and Fish and Wildlife. We expect that our report will be released in final form in a week or two.

Viewed with interest were the statements in paragraph 102, page 114, of the report that ". . . fish and wildlife resources must be considered in the overall plan of improvement for the Edwards Underground Reservoir area." and that "The recommendations of the Bureau of Sport Fisheries and Wildlife will be given every consideration in development of the projects in this area." We trust that the recommendations made by this Bureau will be listed and discussed in conjunction with the "WATER RESOURCE DEVELOPMENT" section of your report, rather than in the appendix.

It is noted, with concern, that the annual benefits for fishing and hunting are given at $735,000. Our report, which will be released shortly, indicates fishing benefits of $238,000 annually and no hunting benefits.

The fishing and hunting benefits shown in your report evidently are based on the premise that fishing and hunting will increase on a reservoir in direct proportion to the increase in human population over the

100-year period of analysis. The report, however, does not appear to take into consideration the change in quality of fish and wildlife habitat over the period of analysis. As you know, most reservoirs in Texas are productive during the early years of impoundment. During this period sport fishing is good. Thereafter, nongame fish predominate, and the amount of sport fishing declines.

The sport fishing benefits shown in our Bureau's report were derived through the cooperative efforts of this Bureau and the Texas Parks and Wildlife Department. We believe such estimates are the best available. Therefore, we feel that these estimates, which were compiled by experts in the field of fish and wildlife, should be used in your report rather than those shown in the draft of the survey report.

We appreciate the opportunity extended to us to comment on the survey report. Under separate cover, we are returning copy No. 92 of the draft including appendixes. By copy of this letter, we are requesting Mr. John G. Degani, Field Supervisor of our Field Office in Fort Worth, Texas, to return copy No. 93 of the draft direct to your office.

Sincerely yours,

John C. Gatlin

John C. Gatlin
Regional Director

Separate cover:
Copy No. 92 draft report

cc:
Executive Director, Texas Parks and Wildlife Department, Austin, Texas
Regional Director, Bureau of Commercial Fisheries, St. Petersburg Beach, Florida
Laboratory Director, Biological Laboratory, Bureau of Commercial Fisheries, Galveston, Texas
Field Supervisor, Branch of River Basin Studies, Bureau of Sport Fisheries and Wildlife, Fort Worth, Texas

U. S. ARMY ENGINEER DISTRICT, FORT WORTH

CORPS OF ENGINEERS

100 WEST VICKERY BOULEVARD
FORT WORTH 4, TEXAS

ADDRESS REPLY TO:
DISTRICT ENGINEER
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
P. O. BOX 1600
FORT WORTH, TEXAS
IN REPLY REFER TO

SWFGP

17 March 1965

Mr. John C. Gatlin
Regional Director
Bureau of Sport Fisheries and Wildlife
Fish and Wildlife Service
U. S. Department of the Interior
P. O. Box 1306
Albuquerque, New Mexico 87103

Dear Mr. Gatlin:

This is in reply to your letter of 22 January 1965 containing your comments on our "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas."

The "Water Resource Development" section of the report, in which you requested the recommendations of the Bureau be listed and discussed, consists of a discussion of projects in the study area for water resource development that are existing, under construction or authorized. It is not considered appropriate to insert recommendations on operation of proposed reservoirs in this part of the report.

You noted, with concern, that the benefits for fishing and hunting computed by the Corps were in excess of those determined by the Bureau. Your report containing the benefits determined by your agency was received subsequent to the transmittal of the Corps report to other Federal and State agencies for review. The benefits in our report were determined in consonance with visitation standards established by the Outdoor Recreation Resources Review Commission and with Supplement No. 1 to Senate Document 97, 87th Congress, 2nd Session, subject: Evaluation Standards for Primary Outdoor Recreation Benefits. In comparison with the standards established, our estimates of visitations are considered very conservative. Predictions made by the Corps and others indicate that maximum recreation development at existing, authorized and proposed reservoirs within the Edwards Underground Reservoir area will not even approach the satisfaction of future water-related recreation needs. It is recognized that quality of fishing and hunting opportunities will decline as visitations increase; however, based on attendance figures at existing Corps of Engineers reservoir projects, the man-days of fishing and hunting do not necessarily decrease.

The visitation figures at Corps projects are based on the use of mechanical traffic counters, personal interview surveys, and at-site observations by project personnel. During the last three years, surveys have indicated that visitations to projects within the Fort Worth District have averaged 43 percent fishermen and 9 percent hunters. Therefore, the use in the report of 34.65 percent of the visitation for fishing and 0.35 percent for hunting is considered conservative.

Our report will be revised to include appropriate provisions for reservoir zoning as a part of the plan of development. It is recognized that an adequate zoning plan will be necessary for the safe, orderly use of any reservoir for fishing, hunting and general recreation activities.

A copy of your letter of comments and this reply will be included in the report. Your review of the report and comments are appreciated.

Sincerely yours,

F. P. KOISCH
Colonel, CE
District Engineer

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SOUTHWEST FIELD COMMITTEE, REGION SIX
807 Brazos Street
Austin, Texas 78701

January 25, 1965

Colonel F. P. Koisch, District Engineer
U. S. Army Engineer District, Fort Worth
Corps of Engineers
P. O. Box 1600
Fort Worth, Tex.

Dear Colonel Koisch:

The report "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas" transmitted by your letter of Dec. 24, 1964 (SWFGP) has been reviewed in accordance with the Interagency Agreement approved by the President on May 26, 1954.

We found this an interesting report, particularly the comprehensive analysis of the hydrology and the methods for supplementing ground-water recharge with impounded flood waters. It is gratifying to know that the surface and ground-water investigations of the Geological Survey produced enough information for planning optimum development of the water resources of the report area. These investigations have been underway in varying degrees for more than 65 years.

From the Geological Survey's viewpoint, the most significant conclusions are:

(1) That proposed development will meet water demands to the year 2000.

(2) Major reservoirs for impounding flood flows, developing water for recharge, and for conservation use in some of the reservoirs, are planned at the Montel site on the Nueces River, Concan site on the Frio River, Sabinal site on the Sabinal River, Dam No. 7 on the Guadalupe River, and Cloptin Crossing site on the Blanco River.

(3) A dependable annual yield of 4,300 acre feet (average daily 6cfs) will be provided for beneficial use from the Montel project.

Vol. II, page 180 makes recommendations for studies to determine a specific program for expanding the climatic and the surface-water network. This expansion will be necessary when the project plan is placed in operation. The Geological Survey concurs fully in these recommendations and suggests also that the statement on page 180 be expanded to include appropriate hydrologic instrumentation for the study of ground-water aquifers downstream from each of the major reservoirs and for the study of the quality of water of the surface and ground-water system.

The channel conditions and movement of water in the channels and in the gravels under the flood plain downstream from the major flood control structures undoubtedly will be much different after the system is in operation. Consideration should be given to the establishment of stable weirs at the outflow stations to accurately measure the released flows from the reservoir. Ground-water observation wells will be required for studying ground-water movement in the river valleys upstream from and across the Balcones fault zone. The report states that recharge from the new dams should take place at the maximum infiltration rate of the streambed in the fault zone. These rates, known only approximately, could be defined more accurately with the control that may be afforded by the new structures. Proper gaging stations at suitable locations for measuring not only releases from the dam but also for measuring all flow into the recharge zone of the streambed should be provided. Also, detailed field investigations (including test drilling in the alluvium and installation of shallow observation wells) to define the relationship between bank storage and streamflow should be made. The thought here is that controlled releases may create constant and definite channel conditions that may later result in large evapotranspiration losses of streamflow. Reservoir releases then may have to be increased to keep the maximum infiltration rate going over the streambed in the fault zone.

Reference is made to page 55, Vol, I, main report.--The concentration of calcium bicarbonate in the water of the Edwards limestone in the zone of good quality of water generally is above 200 parts per million. The dissolved-solids concentration in this zone generally ranges from 250 to 450 parts per million.

The Topographic Division of the Geological Survey is now mapping the river divide between the Nueces and Guadalupe rivers. These maps will be available in February 1965 and the Survey will make new determinations of drainage areas for the Frio, Sabinal, Medina, and Guadalupe river basins. The new drainage areas probably will be required for your use in the final studies of flood-control design and will be supplied to you when available.

Vol. II, page II-41 contains a statement on the history of the collection of basic data in the Nueces River basin. This statement is in error and should be corrected to show that the Geological Survey, and not the Texas Water Commission, started and has continued all the systematic stream and ground-water investigations in the report area. The publication "A History of the Water Resources Branch of the U. S. Geological Survey to June 30, 1919" states the following:

> "Texas.-In the fall of 1898, Babb, while on a western trip, stopped at Austin to inspect the Austin dam and met Prof. Thomas U. Taylor of The University of Texas. Taylor was interested in Texas rivers and had made some miscellaneous measurements. The result of this meeting was Taylor's appointment as resident hydrographer for Texas. So strong was public interest in stream gaging that the establishment of one station Taylor was escorted to the site by a large contingent of citizens (although perhaps lacking the proverbial brass band) who watched with awe the process of measurement. When told that the meter used was an electric one, their faith in its accuracy was unbounded, as to them the term "electric" signified marvelous qualities.
>
> Because of the flashy character of Texas streams, it was difficult to obtain high-water measurements. When the hydrographer succeeded in reaching a station in flood, he would remain for several days making measurements as the river fell. By this practice, only, was it possible to complete the rating curve for the station."

Water-Supply Paper 50, pages 332-346 contain basic data on streamflow investigations conducted by the Geological Survey from 1896 to 1899.

The U. S. Geological Survey entered into a cooperative agreement with the Texas Board of Water Engineers (now Texas Water Commission) soon after it was created. This program has continued to date with the Geological Survey operating all of the regular surface-water investigations and most of the ground-water and quality of water investigations.

The basic data investigation programs conducted in the past have been primarily for the planning of water-development and water-use projects. The Corps of Engineers' recommended program on the Edwards Underground Reservoir contemplates the optimum development of the water resources of that region. Under optimum development, it is essential that basic hydrologic data be collected to evaluate the degree to which the proposed development fulfills the anticipated benefits, and also to obtain additional data for modifying or improving the projects after they have been operated under the new conditions. A high degree of accuracy in the collection of such data is required.

The Geological Survey Water Resources Division, Texas District offices, wish to be kept informed as to advancements of the Corps of Engineers' developments. Such information will assist these offices in modifying or expanding their water resources study programs as funds are made available to meet planning and operational needs of the Corps and others operating in the basin. The Geological Survey will cooperate with the Corps and others in planning and developing essential hydraulic programs to perfect and operate the comprehensive water plans of the Edwards basin of Texas.

The draft copy (Serial No. 97) of the Report is being returned under separate cover. Please furnish me a copy of the final report when available.

Very truly yours,

Trigg Twichell
Contact Official of
the Geological Survey

cc: Douglas R. Woodward, USGS, Washington, D.C.
S. K. Jackson, Area Hydrologist, Denver, Colo.
A. G. Winslow, GW, Austin, Tex.
C. H. Hembree, QW, Austin, Tex.

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
100 WEST VICKERY BOULEVARD
FORT WORTH 4, TEXAS

ADDRESS REPLY TO:
DISTRICT ENGINEER
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
P. O. BOX 1600
FORT WORTH, TEXAS
IN REPLY REFER TO
SWFGP

17 March 1965

Mr. Trigg Twichell
Contact Official of the Geological Survey
Southwest Field Committee, Region Six
Geological Survey
U. S. Department of the Interior
807 Brazos Street
Austin, Texas 78701

Dear Mr. Twichell:

This is in reply to your letter of 25 January 1965 containing comments on our "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas."

We will revise our report to include a statement that appropriate instrumentation for the study of ground-water aquifers and surface water quality will also be considered for inclusion in the hydrologic network in connection with preconstruction planning as suggested in your letter. It is noted that in the past, we have coordinated expansion and installation of hydrologic network gages in cooperation with the Geological Survey. We will continue this policy in the future in line with the Bureau of the Budget Circular No. A-67 dated 28 August 1964.

We will revise the statement on page II-41 to show that the Geological Survey started and has continued all systematic stream and ground-water investigations in the report as you suggested. The information with reference to the installation of the Cinonia and Derby stream gages by the Texas Water Commission was taken from station description published in Water Supply Paper No. 408.

The reference to dissolved-solids concentration in the zone of good quality of water in the Edwards Reservoir was in error and will be corrected.

SWFGP
Mr. Trigg Twichell

17 March 1965

The comments contained in your letter with regard to the subject report are appreciated.

Sincerely yours,

F. P. KOISCH
Colonel, CE
District Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE

Southwest Region
Santa Fe, New Mexico 87501

IN REPLY REFER TO:

L7423

JAN 1965

AIRMAIL

F. P. Koisch, Colonel, CE
District Engineer
U. S. Army Engineer District
Corps of Engineers
100 West Vickery Boulevard
Fort Worth, Texas

Dear Sir:

Thank you for the opportunity of reviewing the draft copy of your "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas" dated December 1964, enclosed in your letter of 24 December 1964 (SWFGP).

Of especial interest to us is your planning for recreation, as developed in the Main Report and in more detail in Appendix VI. It appears that you have given the many facets of that subject careful study. In particular, it is noted that you have recognized the recreational value of the unique scenic feature to be created in the Concan and Sabinal Reservoirs when floodwaters are released to recharge the Edwards Underground Reservoir.

You mention that the operation of Concan Reservoir for its flood control function will, in its upper reaches, affect to a small degree some of the development at Garner State Park, and that some relocation and protective works to existing facilities may be necessary. It would appear that this potential project function could substantially damage the popular state park unless the remedial measures are carefully and cooperatively worked out. No doubt you already have, or will in the detail planning for the Concan unit work out solutions jointly with the Texas Parks and Wildlife Commission.

It will be appreciated if, after authorization of the project, you will notify this office well in advance of construction, so that we may program the site surveys and excavations required in the Archeological Salvage program.

The three volumes of the Survey Report draft are being returned under separate cover.

George W. Miller
Acting Regional Director

Enclosure
Under separate cover:
Survey Report draft - 3 volumes

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
REGIONAL OFFICE, REGION 5
P. O. BOX 1609
AMARILLO, TEXAS

IN REPLY
REFER TO: 5-730

JAN 29 1965

Colonel F. P. Koisch
District Engineer
U. S. Army Engineer District, Fort Worth
P. O. Box 1600
Fort Worth, Texas 76101

Dear Colonel Koisch:

This is in reply to your letter of December 24, 1964, file SWFGP, transmitting a draft copy of "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio, and Nueces Rivers and Tributaries, Texas," for review and comment.

Our comments on the report are as follows:

Control of withdrawals from the aquifer is necessary before the recharge plan can assure any increase in dependable aquifer yield. Without controls, excessive pumpage may reduce the content of the aquifer to the minimum safe level prior to or early in a drought period. The safe yield during the remainder of the drought would then be limited to the small drought period recharge, which would not be increased by the proposed project. This is pointed out in the report. Control of withdrawals does not exist at present and may not be obtainable. Nothing in Texas legislative history lends any hope for ground water laws. Even if control of withdrawals is obtained, the increase in the safe yield of the aquifer for pumping that would be provided by the recharge reservoirs would be modest and the unit cost relatively high.

The analysis presented in paragraph 162 assumes that surplus Guadalupe water is not available to the San Antonio Basin, while the analysis in paragraph 163 assumes that surplus Guadalupe water (including Canyon yield) is available to the San Antonio Basin. However, the latter analysis indicates that the increase in water supply shown therein over that indicated in paragraph 162 is entirely due to Dam No. 7 and Cloptin Crossing Reservoirs. The analysis also makes no allowance for bypasses of Canyon and Cloptin Crossing inflow to water rights downstream from the area of study.

Paragraph 167 does not present a complete picture of the effect of the project upon downstream water supply. The plan of operation and recharge analysis for Montell Reservoir appears to make no provision for bypasses to channel dams and irrigators below Uvalde. During years of adequate streamflow the Zavala-Dimmit County Water Control and Improvement District No. 1, and other irrigation systems have diverted a large volume of water from the Nueces River. A considerable portion of their historic water use is believed to have been derived from runoff occurring at the Montell site. The report of the U. S. Study Commission, Part III, pages 197-204, contains some information on this irrigation. Volume 1 of the Nueces River Master Plan Study (Freese and Nichols, 1958) lists some of the irrigation water rights in this area and data on historic water use on pages 16-18. Page 29 of Volume 1 of the Texas Board of Water Engineers Bulletin No.5608 describes a possible mechanism whereby a portion of the floodflow of the Nueces has been transformed into base flow of use to irrigators below Uvalde.

It is true that the larger size for Dam 7 and Cloptin Crossing proposed in this report as compared to the master plan would not result in further reductions in the yield of Cuero Reservoir. However, the report fails to state that Cloptin Crossing at either the report size or the master plan size will reduce the yield of Cuero Reservoir. A considerable portion of the yield claimed for Cloptin Crossing would be at the expense of yield at Cuero. Also, no mention was made of the effect that storing all inflow at Cloptin Crossing would have on existing water rights downstream from the area of study.

Paragraph 200 states that "...the additional streamflow would enhance the yield of the Cuero Project...." Figure 25 indicates that for a repetition of historic weather conditions, the additional springflow would increase Cuero spills during wet years, but would not increase Cuero yield during the 1947-1956 critical period.

Table 12 lists the allocated cost of recharged water at 7.6 cents per 1,000 gallons for Montell Reservoir, 6.9 cents for Concan Reservoir, and 8.4 cents for Sabinal Reservoir. As pointed out in paragraph 156, only 45 percent of the increased recharge would result in an increase in the safe yield of the aquifer for pumping (assuming control of withdrawals). Therefore, the cost of the potential increase in safe yield for pumping would be 15 cents to 19 cents per 1000 gallons. At Montell Reservoir, the analysis does not make provision for bypasses to existing irrigation in the Winter Garden area. Allowance for such bypasses would cause a substantial reduction in the recharge and a substantial increase in the unit cost of recharge.

The opportunity to review your report is appreciated. The draft copy of the report, Serial No. 95, is being returned as requested. Please furnish this office, and our Austin Development Office, one copy each of the final report.

Sincerely yours,

Leon W. Hill

Regional Director

Enclosure

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
100 WEST VICKERY BOULEVARD
FORT WORTH 4, TEXAS

ADDRESS REPLY TO:
DISTRICT ENGINEER
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
P. O. BOX 1600
FORT WORTH, TEXAS
IN REPLY REFER TO
SWFGP

22 March 1965

Mr. Leon W. Hill
Regional Director
Bureau of Reclamation, Region 5
U. S. Department of the Interior
P. O. Box 1609
Amarillo, Texas

Dear Mr. Hill:

This is in reply to your letter of 29 January 1965, containing comments on our "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers, and Tributaries, Texas."

A net average annual increase in resources of approximately 68,200 acre-feet could be developed by the construction and operation of the three recharge reservoirs as proposed in the report. The control of withdrawals is an essential part of the plan for the preservation of the underground reservoir, whether through law or cooperation between the major water interests. When considering the available resources of the area, the losses that would occur if the water were stored in surface reservoirs and the cost of conducting the water by pipeline to the areas of need, the net yield developed by the proposed plan is relatively high and its cost is reasonable.

The analysis presented in paragraph 162 is intended to show the anticipated future water situation in the Edwards Underground Reservoir area within the Nueces and San Antonio River Basins. The analysis presented in paragraph 163 represents the anticipated future water situation in the entire Edwards area with the full plan of development considered to be economically feasible at this time. This will be clarified in the final report.

Regarding downstream water rights and needs, full consideration was given to the master plans of other agencies for development of water resources within the area of influence of the Edwards

Underground Reservoir. Since projected water demands far exceed the available water resources of the area, first consideration was given to the replenishment and preservation of the area's primary water resource. Additional comprehensive basin studies, not provided for by Public Law 86-645, will be required to determine what additional measures can be taken to supply the remaining water needs of the three basins.

The Cloptin Crossing Reservoir is an essential part of any plan for the development of the water resources of the Guadalupe River Basin. Its flood control potential is extremely good. It would be cheaper to develop the water resources as part of the multiple-purpose project to meet a portion of the large water demand in the Edwards Reservoir area rather than convey the water upstream from some downstream project. The construction of any reservoir upstream from the Cuero Reservoir will affect its storage-yield relationship. However, development of the multiple-purpose Cloptin Crossing Reservoir would reduce flood-control storage requirements in Cuero Reservoir with a consequent reduction in the cost of that project, or by reallocating storage in Cuero Reservoir, the basin yield could be further increased.

Paragraph 200 will be revised concerning the effect of the increased springflow on the water resources of the Cuero project.

As previously stated, the quantity of the increased resources developed by the recharge reservoirs which could be made available for pumping depends entirely on the operating level in the underground reservoir. However, if the plan were adopted to limit the pumping to avert drawing the level of water in the aquifer below the historic low reached in 1956, there would be a substantial increase in springflow. It is assumed that in future years the springflow from the Edwards Underground Reservoir will be in such great demand that facilities will be installed by local interests to fully utilize the increased flow. For this reason we have considered 100 percent recovery of the increased quantity of recharge water. However, the same value has not been placed on the quantity of water available for pumping and the quantity expected to be discharged from the various major springs in the region.

Your review of the report and comments are appreciated.

Sincerely yours,

F. P. Koisch

F. P. KOISCH
Colonel, CE
District Engineer

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
AREA IV
Mineral Resource Office

Office of
AREA DIRECTOR

ROOM 204 FEDERAL BUILDING
BARTLESVILLE, OKLAHOMA 74004

April 2, 1965

Colonel F. P. Koisch
District Engineer
U.S. Army Engineer District, Fort Worth
P.O. Box 1600
Fort Worth, Tex. 76101

Refer to: SWFGP

Dear Colonel Koisch:

This office of the Bureau of Mines has now completed our review of the Corps of Engineers draft copy (Serial No. 90) of "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas", dated December 1964. This review was made with respect to mineral involvement.

The report shows that the Edwards Underground Reservoir is a segment of a limestone aquifer that stretches about 250 miles from Austin westward to Comstock. It lies in the Balcones Fault Zone, a zone of major faulting that separates two physiographic provinces known as the Edwards Plateau to the northwest and the Gulf Coastal Plain to the southeast. The Edwards Plateau, covering 6,400 square miles north of the Balcones escarpment, is the water drainage area for supplying the Edwards limestone aquifer.

Water supply from the Edwards Plateau for charging the Edwards Underground Reservoir normally is provided by streams that cross the storage area. However, the plan to provide more adequate water supplies to recharge this underground reservoir calls for construction of five surface reservoirs. These are as follows:

1. Montell Reservoir.--This reservoir is on the Nueces River, Uvalde County, and will cover 10,180 acres at a maximum water surface elevation of 1,366 feet.

2. Sabinal Reservoir.--This reservoir is on the Sabinal River, Uvalde County, and will cover 3,860 acres at a maximum water surface elevation of 1,238.8 feet.

3. Concan Reservoir.--This reservoir is on the Frio River, Uvalde County, and will cover 5,690 acres at a maximum water surface elevation of 1,394.2 feet.

4. Cloptin Crossing Reservoir.--This reservoir is on the Blanco River, Hays County, and will cover 9,600 acres at a maximum water surface elevation of 1,017.5 feet.

5. Dam No. 7 Reservoir.--This reservoir is on the Guadalupe River, Kendall County, and will have a maximum water surface at elevation 1,247 feet.

The purpose of the proposed overall plan is to meet municipal, industrial, military (bases), thermal power, and irrigation water demands of the Edwards Underground Reservoir to the year 2000.

Mineral Resources.--In 1963, the output of minerals from 12 counties in the three river basins (Vol. I, plate 5) included in the project plan consisted of petroleum, natural gas, sand and gravel, stone, lime, cement, asphalt rock, and clays, valued at $27.6 million. Of this total, mineral output in Uvalde, Hays, and Kendall Counties (locations of the five surface reservoir sites) consisted of sand and gravel, asphalt rock, and basalt, valued at $2.8 million.

In the Corps of Engineers economic study, the projection of total value of mineral production on page V-89 appears to be optimistic for the study area indicated in the report. This projection shows that the value, in 1960 prices, will rise from $405 million in 1960 to $2.4 billion in the year 2025, an increase of sixfold. Crude oil, natural gas, and natural gas liquids supplied over 77 percent of the total value of mineral production in the study area in 1960. It is very doubtful that enough new oil and gas reserves will be found to support the projected increase in total value of mineral production.

Concerning employment, the report shows on page V-35 that estimated employment in the mining industry will increase from 12,000 in 1960 to 16,000 in the year 2025. This gain appears a little conservative in view of the rapid increase in the mineral production value that has been projected.

No field examination was made.

The review of available information in this office indicates that the proposed Edwards Underground Reservoir will have no adverse effect on mineral resource development in the area. Therefore, the Area IV Mineral Resource Office, Bureau of Mines, has no objection to the work plan, but recommends that a field investigation and report by petroleum and mining engineers be made prior to construction planning.

Sincerely yours,

Robert S. Sanford

Robert S. Sanford
Area Director

TEXAS WATER COMMISSION

COMMISSIONERS

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SAM HOUSTON
STATE OFFICE BUILDING

AREA CODE 512
GREENWOOD 5-4514

P. O. BOX 12311
CAPITOL STATION
AUSTIN, TEXAS, 78711

JOHN J. VANDERTULIP
CHIEF ENGINEER

C. R. BASKIN
ASS'T. CHIEF ENGINEER

BURREL ROWE
CHIEF EXAMINER

AUDREY STRANDTMAN
SECRETARY

February 3, 1965

Colonel F. P. Koisch
District Engineer
Corps of Engineers, U.S. Army
100 West Vickery Boulevard
Fort Worth, Texas

Dear Colonel Koisch:

Your letter of December 24, 1964, transmitted copies of your three-volume report titled "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas." Subsequently, I transmitted a full copy of the report to the Texas Highway Department and the Texas Parks and Wildlife Department. Copies of the comments of those agencies are attached hereto.

The Corps of Engineers are to be commended for the excellent treatment of a very complex hydrologic problem. The use of available material, together with programs carried out during your investigation to obtain additional information, reflects a very thorough analysis.

Stream discharge information for the Frio and Sabinal Rivers reflects, in part, the intake capacity of the formation under unregulated conditions. However, it is possible that the formation may not be capable of sustained high intake rates over an extended period. Adjustments for any such differences in intake rates which occur should the projects be constructed, could be made by reducing reservoir discharges to the intake capacity of the formation.

It is suggested that Recommendation C, page 193, have the words "designated by the State of Texas" inserted after the phase "responsible local interests," and that Recommendation C.(2), page 194 have the word "obtain" substituted for the word "provide."

Should the projects recommended in this report be authorized, local interests and/or the State may desire during pre-construction planning to consider modifications of the projects as described in the report. It is our understanding that any modifications which appear appropriate at that time can be accomplished as a part of the preconstruction planning.

The opportunity to review the report is appreciated.

Sincerely yours,

John J. Vandertulip
John J. Vandertulip
Chief Engineer

Attachments (2)

COMMISSION
HERBERT C. PETRY, JR., CHAIRMAN
HAL WOODWARD
J. H. KULTGEN

TEXAS HIGHWAY DEPARTMENT

AUSTIN, TEXAS 78701

STATE HIGHWAY ENGINEER
D. C. GREER

February 2, 1965

IN REPLY REFER TO
FILE NO. D-5

Mr. Joe D. Carter, Chairman
Texas Water Commission
P. O. Box 12311
Capitol Station
Austin, Texas 78711

Dear Mr. Carter:

In accordance with your request by letter dated December 30, 1964, we have reviewed the report by the U. S. Corps of Engineers titled "Survey Report on Edwards Underground Reservoir". We have examined the proposed project in the light of its effect upon our highway system for both existing highways and planning for the immediate future.

Based upon the maps included in the report, it is our belief that the report, in general, contains both appropriate language and adequate provisions in the estimated costs to promote orderly development of the proposed project and the related highway relocations. It is contemplated that adjustments in costs of relocations may be necessitated when final planning has developed.

Your courtesy in making the report available for our review and comments is appreciated.

Yours truly,

D. C. Greer
State Highway Engineer

By: Clyde F. Silvus

Clyde F. Silvus
Bridge Engineer

PARKS AND WILDLIFE DEPARTMENT

COMMISSIONERS
WILL E. ODOM
CHAIRMAN, AUSTIN
A. W. MOURSUND
MEMBER, JOHNSON CITY
JAMES M. DELLINGER
MEMBER, CORPUS CHRISTI

J. WELDON WATSON
EXECUTIVE DIRECTOR

JOHN H. REAGAN BUILDING
AUSTIN, TEXAS 78701

January 14, 1965

Mr. John J. Vandertulip
Chief Engineer
Texas Water Commission
Box 12311, Capitol Station
Austin, Texas 78711

Dear Mr. Vandertulip:

Pursuant to your request submitted by letter of December 30, 1964 this Department has reviewed the 3-volume report of the Corps of Engineers' titled "Survey Report on Edwards Underground Reservoir."

The section to be supplied by the Bureau of Sport Fisheries and Wildlife, Fish and Wildlife Service, as part of Volume 3, Appendix VI, has been developed with the cooperation of this Department. I have just recently concurred with the Bureau's report and it will contain specific recommendations in regard to the conservation, improvement and development of fish and wildlife resources.

Due to the lack of specific data on the effects of this project on both fish and wildlife in this report, our review has been one of a general nature. We have no specific comments to add and concur with the report as submitted.

Your cooperation in making the report available for our review is appreciated.

Sincerely yours,

J. Weldon Watson

JWW:AJS:lf

U. S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
100 WEST VICKERY BOULEVARD
FORT WORTH 4, TEXAS

ADDRESS REPLY TO:
DISTRICT ENGINEER
U. S. ARMY ENGINEER DISTRICT, FORT WORTH
P. O. BOX 1600
FORT WORTH, TEXAS
IN REPLY REFER TO
SWFGP

17 March 1965

Mr. John J. Vandertulip
Chief Engineer
Texas Water Commission
P. O. Box 12311
Capitol Station
Austin, Texas 78711

Dear Mr. Vandertulip:

This is in reply to your letter dated 3 February 1965 containing your comments on our "Survey Report on Edwards Underground Reservoir, Guadalupe, San Antonio and Nueces Rivers and Tributaries, Texas." Copies of letters from the Texas Highway Department and the Texas Parks and Wildlife Department containing their comments on the report were inclosed with your letter.

In the event the State or local interests should desire modification to the development or operation of the reservoir projects as proposed in the report, further studies will be made during preconstruction planning.

The section of the report containing the recommendations will be revised in accordance with your comments.

Your review of the report and comments are appreciated.

Sincerely yours,

F. P. Koisch

F. P. KOISCH
Colonel, CE
District Engineer

EDWARDS UNDERGROUND WATER DISTRICT

1619 TOWER LIFE BLDG. PHONE: CAPITOL 2-2871

SAN ANTONIO, TEXAS 78205

March 23, 1965

The District Engineer
U. S. Army Engineer District, Ft. Worth
P. O. Box 1600
Ft. Worth, Texas

Dear Colonel Koisch:

This is in response to your request regarding the items of local cooperation to be furnished the United States in connection with the four reservoir projects included in the proposed plan of improvement for the Edwards Underground Reservoir area.

In signing the cooperative report, the Edwards Underground Water District expresses its full approval of the proposed plan of improvement for comprehensive development of the water resources of the Edwards area.

However, due to the fact that the State is now developing a statewide water plan, it is believed that proposals made should be integrated into the State plan. The Edwards Underground Water District will endeavor to provide the necessary local cooperation to assure the comprehensive development of the Edwards Reservoir.

Sincerely yours,

Paul W. Jahn

Paul W. Jahn, Chairman
Board of Directors

PWJ:jc
encs.

SAN ANTONIO RIVER AUTHORITY

CApitol 7-1373
430 Three A Life Building
San Antonio 5, Texas

February 10, 1965

Honorable Paul W. Jahn, Chairman, and
Members of the Board of Directors
Edwards Underground Water District
Tower Life Building
San Antonio, Texas 78205

Re: Survey Report of Edwards Underground Reservoir

Gentlemen:

At the outset permit us to congratulate you on the completion of subject Survey Report. The data contained in this report is a significant contribution to the area's knowledge of this invaluable natural resource.

This Authority's comments concerning the Survey Report are as follows:

1. The report assumes that the level of the Edwards aquifer should not be reduced below the historical low of 1956, elevation 612.5. This Authority does not believe that anyone can, with certainty, guarantee what would occur if the level of the Edwards is drawn below elevation 612.5. On the one hand, water in the Edwards might not be affected at all. On the other hand, sulfurous waters adjacent to the so-called "good-bad" water line might encroach into and pollute all or a part of the aquifer. Certainly this invaluable supply cannot be risked. Water users dependent upon it cannot be placed in jeopardy. We do know, however, that water in the Edwards is the cheapest that will ever be available in the area. Therefore, feasibility of drawing the level of the Edwards below elevation 612.5 should be further investigated but the aquifer should not be mined below this elevation until supplemental surface water supplies are available to the area or until such investigations would clearly demonstrate that drawing the Edwards to a lower elevation is entirely safe.

2. The report points up the urgent necessity for developing all of the area's sources of surface water so that water users in the area will be adequately protected.

3. The report proposes that water stored in Montell, Concan and Sabinal Reservoirs be released so as to flow into the Edwards aquifer during drought years. This artificial recharge could occur under two conditions:

a. No draw-down below elevation 612.5. If the level of the Edwards is kept at or above elevation 612.5, a recharge of 57 MGD (63,900 AF/Yr) would occur. Of this amount, 31 MGD would flow out of the aquifer at the springs at San Marcos and New Braunfels. Only 26 MGD would be available for well pumping. The cost of this 26 MGD is estimated to be 16.75¢ per 1000 gallons.

   From the standpoint of over-all benefits, the full 57 MGD would be available somewhere in the acquifer or as springflow at an estimated cost of 7.64¢ per 1000 gallons, under which circumstances there will be a problem of relating this cost to those who benefit from this additional water.

b. Unlimited draw-down. If no limitations are placed on the level to which water in the aquifer can be drawn down, the recharge of 57 MGD would be available for well pumping. The cost of this 57 MGD is estimated to be 7.64¢ per 1000 gallons. If only 47.5 MGD (or 53,224 AF/Yr) of the 57 MGD total recharge could be intercepted by wells, the cost of this 47.5 MGD is estimated to be 9¢ per 1000 gallons.

In order to balance the equities of those in the area dependent either upon spring-flow or upon water pumped directly from the aquifer, it seems that an equitable regulation of the level of the aquifer could be achieved through regulation of both artificial recharge and of pumping withdrawals. Such a system of regulation during drought periods would protect municipal water users, who should have first priority on water in the Edwards.

The Edwards Underground Water District is the proper agency to carry out such a program of regulation.

4. We wish to call your attention to the agreement of May 15, 1963 between this Authority and the Guadalupe-Blanco River Authority, which recognizes that the total annual yield of reservoirs upstream from the proposed Cuero Project would be 135,550 acre-feet. More specifically, the agreement contemplates that the proposed Cloptin Crossing Project would have an annual yield of 33,360 acre-feet. The development of a site above Canyon Dam and Reservoir would be governed by the amount of leakage, if any, from Canyon. It will take several years to determine the amount of this leakage. This determination would be made under the provisions of Article 4 of the Contract, Conservation

Storage, Canyon Dam and Reservoir, of September 20, 1957 between the United States of America and the Guadalupe-Blanco River Authority.

We appreciate your courtesy in requesting the comments of this Authority.

Yours very truly,

SAN ANTONIO RIVER AUTHORITY

By: Martin C. Giesecke
MARTIN C. GIESECKE
Chairman of the Board

MCG:bw

COPY

GUADALUPE-BLANCO RIVER AUTHORITY
P. O. Box 832
Seguin, Texas

January 22, 1965

Colonel McDonald D. Weinert, General Manager
Edwards Underground Water Dist.
1619 Tower Life Building
San Antonio, Texas 78205

Dear Colonel Weinert:

This will acknowledge receipt on January 14, 1965, of the preliminary copy of the Corps of Engineers' survey report on the Edwards Underground Reservoir which was accompanied by copy of the Corps' letter of transmittal dated 24 December 1964. You requested in your note on the letter of transmittal from the Corps that I furnish you, by January 23, 1965, the views of the Guadalupe-Blanco River Authority on this report.

It is noted that the report was prepared in accordance with Section 209 of Public Law 86-645, 86th Congress, approved on July 14, 1960. It is also noted that the authorizing legislation specifies that the report be made "in cooperation with appropriate agencies of the State of Texas," and that it be signed jointly by the Corps of Engineers and the appropriate representative of the Governor of Texas. It is further noted that the report is signed by Mr. Paul W. Jahn in behalf of the Edwards Underground Water District, and it is assumed from this that the Edwards Underground Water District is the sponsoring agency for the State of Texas.

In connection with the authorized purpose of the study and report, it is believed that the pertinent language can be quoted from Public Law 86-645 as follows: "with a view to devising effective means of accomplishing the recharge and replenishment of the Edwards Underground Reservoir." (* -see note on page 3.)

It is noted in the report that five dams and reservoirs were studied as follows:

1. Montell Reservoir, on the Nueces River
2. Concan Reservoir, on the Frio River
3. Sabinal Reservoir, on the Sabinal River
4. Cloptin Crossing Reservoir, on the Blanco River
5. Dam No. 7 Reservoir, on the Guadalupe River

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Of the surface reservoirs studied, four are recommended for immediate authorization as Federal projects, namely: Montell, Concan, Sabinal and Cloptin Crossing. Dam No. 7 Reservoir is recommended for construction by local interests.

The Guadalupe-Blanco River Authority has only a casual interest in the three reservoirs recommended on the Nueces, Frio and Sabinal Rivers, since these reservoirs are outside the boundaries of the Guadalupe-Blanco River Authority and have little or no effect upon the development of the water resources of the Guadalupe River and its tributaries. However, the Authority would like to point out that these reservoirs seem to be of doubtful economic justification in the interests of water conservation. We would interpret the present draft of the report to require local contribution to these projects in excess of $42,000,000 in the interests of water supply. In addition to these local contributions to the first cost of the projects, the local interests would be required to pay a very substantial part of the annual operating and maintenance charges on the three Federal projects. For this outlay of funds, the local interests, from the water supply standpoint, would be assured of 4,300 acre feet per year of surface water plus an estimated increase of 29,000 acre feet per year of safe withdrawal from the underground reservoir. This latter quantity of 29,000 acre feet, if realized, would be of general benefit to the area of the Edwards Underground Reservoir for withdrawal from wells and for which no charges could be made by the sponsoring local agency under existing State law. It appears to the Guadalupe-Blanco River Authority that the cost of the insignificant amount of firm water supply to be created by the projects is unrealistic and certainly cannot be justified in the forseeable future. Alternate means are available for obtaining water in the area at substantially lower cost, and should be investigated before binding commitments are made by local interests in the proposed three Federal reservoir projects.

The Guadalupe-Blanco River Authority does have a real and continuing interest in the two reservoir projects known as Dam No. 7 on the Guadalupe River and Cloptin Crossing Dam on the Blanco River. It is apparent from the treatment of these projects in the report that they are not proposed for the primary purpose authorized for study by Public Law 86-645, i.e., "recharge and replenishment of the Edwards Underground Reservoir." It is also apparent that the report gives no consideration to existing water rights in its treatment of these two projects.

Further, the Cloptin Crossing project as proposed in the preliminary report is inconsistent with the Master Plan of the Guadalupe-Blanco River Authority. One great difference is in the amount of conservation storage. The Master Plan of the Guadalupe-Blanco River

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Authority provides for conservation storage in the Cloptin Crossing Project to the extent of approximately 147,000 acre feet which would produce an annual yield, without reference to downstream water rights, of about 33,000 acre feet. Thus it can be seen that the additional conservation storage proposed in the Edwards Underground Reservoir report appears to be of questionable economic justification, producing only about 10,000 acre feet per year of additional yield from the additional 128,000 acre feet of storage; a ratio of about 13 acre feet of storage to 1 acre foot of yield. (This compares with a ratio of approximately 4-1/2 acre feet of storage to 1 acre foot of yield in the GBRA project.)

The Guadalupe-Blanco River Authority believes that the Cloptin Crossing Project, when constructed to the optimum size and operated for the benefit of the Guadalupe Valley in conjunction with downstream rights, is a desirable and justified project.

No further differences between the Edwards Underground Reservoir survey report and the GBRA Master Plan will be discussed since the basic position of the Guadalupe-Blanco River Authority is that the inclusion of Dam No. 7 and Cloptin Crossing Dam in the report exceeds the authorization of Congress under which it was prepared. Accordingly, the Guadalupe Blanco River Authority protests their inclusion in the report and requests that the report be revised to eliminate them in their entirety.

Proper presentation of the Cloptin Crossing Project by the Corps of Engineers should be made in a report dealing with the water supply and flood control problems of the Guadalupe River watershed and, if so presented, would have the full support of the Guadalupe-Blanco River Authority.

I appreciate the opportunity given to the Guadalupe-Blanco River Authority to have its comments considered at this time and at field level.

Very truly yours,

RHV/cf

s/s Robert H. Vahrenkamp

General Manager

CC: Col. Frank P. Koisch
Mr. John Vandertulip

The following statement was added to the letter by Edwards Underground Water District:
* - The Act authorizing the study states further after the word

"RESERVOIR," "as a part of plans for flood control and water conservation in the Nueces, San Antonio, and Guadalupe River Basins of Texas."

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EDWARDS UNDERGROUND WATER DISTRICT

1619 Tower Life Bldg. San Antonio, Texas

February 1, 1965

Mr. R. H. Vahrenkamp, General Manager
Guadalupe-Blanco River Authority
P. O. Box 832
Seguin, Texas

Dear Mr. Vahrenkamp:

The authority under which the Edwards Underground Water District was created by an overwhelming vote of the taxpayers within the District, gives a mandate to the Board of Directors to conserve, protect and recharge the underground waters in the formations known as the Edwards limestone and associated formations. In order to get an intelligent answer as to what could be done to conserve, protect and recharge this natural reservoir which is recognized as being one of the finest of its kind in the United States, our District entered into a cooperative agreement with the U. S. Army Corps of Engineers for a complete and comprehensive study of the entire area.

When a person is sick and ailing, his doctor usually sends him or her to a clinic for a comprehensive and complete diagnosis, for the entire body is given numerous tests, and not just one part of the body.

So in order to find an intelligent answer to our request for a complete diagnosis, the Corps advised that all of the adjacent, and especially all contributing areas, would have to be included for study and appraisal.

It is interesting to note that the Edwards underground reservoir has been, for over a hundred years in the history of our state, the most important contributing factor in the up-building of this part of Texas.

The Comal and San Marcos Springs, which discharge from the Edwards Reservoir, are the big contributors to the firm flow of the Guadalupe River from here to the coast. Goliad, Victoria, Cuero, Gonzales and Seguin all owe much to the firm flow of the Guadalupe River which was steadily maintained over the years by

COPY

these world famous springs. The vast irrigation farms in the lower reaches of the Guadalupe owe much to the flow of the Comal and San Marcos Springs. Many times in my lifetime have I seen the Guadalupe River dry above the junction of the Comal and Guadalupe Rivers.

The Edwards Underground Reservoir was the contributing factor to the establishment of the vast military installations in and around San Antonio, contributing to the economy of hundreds of thousands of people living within several hundred miles radius of the city of San Antonio.

The Comal and San Marcos Springs have gained world-wide publicity for their respective communities, New Braunfels and San Marcos, and have attracted and still do attract, hundreds of thousands of visitors each year to Landa Park in New Braunfels and the Aquarena Park in San Marcos. Ripley called the Comal River "The largest and smallest river in the world," largest by flow of fresh water, and smallest by reason of the fact that the springs and the mouth of the river are within the same city limits, and the river is only about two miles long. It is further interesting to note that the Comal Springs furnish the needed cooling waters for the Comal Electric Generator Plant of 60,000 KW capacity. The revenue from this plant was the nucleus of financing for the GBRA, and thereby took care of the local interest's financing for the construction of the Canyon Dam on the Guadalupe River. Without this aid the Canyon Dam would probably not be a reality as yet.

The report of the U. S. Army Corps of Engineers is strictly in line with the policy of the Texas Water Commission, --- to explore fully and find ways and means for the optimum development of water resources in the area.

The report, therefore, must include Dam No. 7 on the Guadalupe River and Cloptin Crossing Dam on the Blanco River which structures would assure a large amount of additional conservation storage which could be used for the protection of the precious Edwards underground reservoir. The Edwards Underground Water District recognizes that both Dam No. 7 on the Guadalupe River, and Cloptin Crossing Dam on the Blanco are a part of your Master Plan, and the District has no intention of taking any action in regard to these structures, but we feel that it is our duty to supply the information contained in the report.

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I would be unworthy of the trust placed in me by the voters of this District and the oath of office which I took, if I would recommend to the Corps of Engineers to delete the information on Dam No. 7 and Cloptin Crossing from the report as you suggested in your letter to our Engineer-Manager, Col. McD. D. Weinert, under date of January 22, 1965.

"To protect and preserve and find ways and means to recharge this greatest of God's blessings, the Edwards Underground Reservoir," this is the goal of our Edwards Underground Water District. We have pledged our full cooperation to all governmental agencies within the area willing to work toward this end.

We hope we can count on your cooperation.

Very truly yours,

Paul W. Jahn, Chairman
Board of Directors
Edwards Underground Water Dist.

ZAVALA-DIMMIT COUNTIES WATER IMPROVEMENT DISTRICT NO. 1

CRYSTAL CITY, TEXAS

March 25, 1965

Colonel McDonald D. Weinert
General Manager
Edwards Underground Water District
1619 Tower Life Building
San Antonio, Texas

Dear Colonel:

Your letter of the eighteenth of February was received on due time, however same was mislaid and comes to light today.

My District wants to reserve the right to be free to either support or oppose the Montell project.

No. 1 - Our plans for the development of the Nueces River and its tributaries sets up a series of Dams two of which were for the replentishment of ground waters.

No. 2 - All of the water on the Nueces proper is sorely needed for Corpus Christi and the multiple uses upstream.

No. 3 - If the Engineers are correct, on that a substantial quantity of water originates above Montell and which would do no harm to down streams users if it was fed to the Edwards then it follows that this water should be available to the Reservoirs approved in the Master plan.

We do not see fit, at this time, to lend our sanction to this project.

I hope that you health is good again.

Regards,

F. W. Pulliam, Manager
Zavala-Dimmit Counties Water
Improvement District No. 1

ALVIN MORRIS, PRESIDENT
CRYSTAL CITY, TEXAS

CLARENCE MARTENS, 1ST. VICE PRESIDENT
ALICE, TEXAS

O. M. SHANNON, 2ND. VICE PRESIDENT
PORTLAND, TEXAS

Nueces River Conservation and Reclamation District

CRYSTAL CITY, TEXAS 78839

April 7, 1965

JOE CARPER, SECRETARY-TREASURER
UVALDE, TEXAS

U. S. Army Engineer District, Fort Worth,
Corps of Engineers, Fort Worth, Texas.

Edwards Underground Water District,
San Antonio, Texas.

Gentlemen:

Herewith find comments of the Nueces River Conservation and Reclamation District on your Survey Report on Edwards Underground Reservoir, dated December 22, 1964. These comments are confined to the proposed projects in the Nueces River Watershed and to the relationship of these projects to the District's Master Plan which has been approved by the Texas Water Commission under the Act creating the District, Article 8280-115 of Vernon's Civil Statutes. This Act provides that, after approval of the plan, the Texas Water Commission, "in Authorizing improvements to control the waters of, and/or in allocating the right to use waters from said Nueces River and its tributaries shall substantially conform to, and effectually preserve the benefits of, the plan formulated by this district, and said district shall have the right to enforce the observance of same by judicial decree."

The Survey Report proposes three projects in the upper Nueces River Watershed above the Balcones Fault Zone, viz., the Montell Reservoir on the Nueces River, the Concan Reservoir on the Frio River, and the Sabinal Reservoir on the Sabinal River. Pertinent data with reference to these projects are given by the table on the following page.

	Montell Reservoir Project	Concan Reservoir Project	Sabinal Reservoir Project
Stream on Which Located:	Nueces River	Frio River	Sabinal River
Drainage Area: Square Miles	707	391	210
Reservoir Capacity: Acre Feet			
Conservation	1,000		
Recharge-Flood Control	239,300	141,200	89,100
Siltation Allowance	12,000	7,800	4,200
Total: Controlled Storage	252,300	149,000	93,300
Annual Yield: Acre Feet			
Avg Recharge to Edwards Res	26,600	21,500	15,800
Safe Yield for Irrigation	4,300		
Total Average Yield	30,900	21,500	15,800
Rate of Recharge: CFS	1,000	750	500
Estimated First Cost:			
Federal			
Flood Control	$10,733,000	$ 1,175,000	$ 915,000
Recharge	1,005,000	711,000	645,000
Recreation	1,650,000	223,000	230,000
Non-Federal			
Recharge	17,260,000	12,218,000	11,081,000
Downstream	1,443,000		
Total First Cost	$32,091,000	$14,327,000	$12,871,000
Interest During Construction	2,437,000	895,000	603,000
Total Investment	$34,528,000	$15,222,000	$13,474,000
Allocated Annual Charges:			
Flood Control	$ 398,300	$ 54,800	$ 43,100
Recharge	669,700	485,800	434,500
Downstream Supply	78,000		
Recreation	75,500	12,900	13,000
Total Annual Charges	$ 1,221,500	$ 553,500	$ 490,600
Allocated Water Cost: Per Ac Ft			
Recharge Water	$25.18	$22.60	$27.50
Downstream Supply	$18.14		

Under the Plan of Improvement, the Montell Reservoir would contain a small permanent pool of 2,200 acre-feet, consisting of 1,000 acre-feet of conservation storage and 1,200 acre-feet of sediment reserve. For this reason, part of the first cost and of the annual charges for the Montell Reservoir have been allocated to "fish and wildlife" and are included in the foregoing table under "recreation". The planned Concan and Sabinal Reservoirs do not contain any permanent pool storage and no first costs nor annual charges have been allocated to "fish and wildlife" in the case of these latter reservoirs.

The Survey Report apportions 5.5% of the costs and charges, allocated to recharge purposes, to the Federal Government on account of the use of water from the Edwards Underground Reservoir by military installations. The annual charges to local interests for recharge water are therefore 5.5% less than the amounts shown by the foregoing table, i.e., approximately as follows: Montell Reservoir - $632,900 per annum; Concan Reservoir - $459,100 per annum; Sabinal Reservoir - $410,600 per annum. Such charges to local interests extend over a period of 100 years. Of the total recharge of 63,900 acre-feet per year, the Survey Report estimates that 29,000 acre-feet per year, or 45.4%, would be available for pumping from the Edwards Underground Reservoir, and 34,900 acre-feet per year, or 54.6%, would be discharged from the aquifer as spring flow, principally through the major springs. As compared with the allocated water cost per acre-foot shown for the total recharge by the foregoing table, the allocated costs per acre-foot for the recharge available for pumping from the aquifer are: Montell Reservoir - $55.46; Concan Reservoir - $49.78; Sabinal Reservoir - $60.57.

The Survey Report allocates costs by the Separable Cost-Remaining Benefits Method. The Public Health Service determined a value or benefit of 13.6 cents per 1000 gallons, or $44.30 per acre-foot, for the average annual recharge from the three reservoirs. This is the equivalent of a value or benefit of 30.0 (13.6/45.4%) cents per 1000 gallons, or $97.75 per acre-foot, for the recharge which would be made available for pumping from the aquifer.

Based on our understanding of the Survey Report as set forth in the above analysis of the Montell, Concan and Sabinal Reservoir Projects, the Nueces Conservation and Reclamation District would like to comment as follows with reference to each of the three projects:

Montell Reservoir

Although the Montell Reservoir is intended to serve the purpose of the Tom Nunn Nill Reservoir in the District's Master Plan, in addition to recharging the Edwards Underground Reservoir, the Montell Reservoir does not conform, substantially, to the District's Master Plan. A fundamental difference is in the assumptions as to the run-off in the Nueces River which would be available for retention in the respective reservoirs. During a recurrence of the historical 1924-1962 run-off of the river, the proposed 240,300 acre-feet of conservation-recharge capacity in the Montell Reservoir would develop 100% of the run-off of the river and there would be no spillage from the reservoir for downstream impoundment and use. Under the District's Master Plan, the 50,000 acre-feet of conservation storage in the Tom Nunn Hill Reservoir would retain approximately 30% of the run-off of the river and approximately 70% would be spilled for downstream impoundment and use. The Survey Report states that, if the September 1955 flood were disregarded, construction of Montell Reservoir in lieu of Tom Nunn Hill Reservoir would not have an adverse effect on the yield of the downstream Wesley Seale and Cotulla Reservoirs as presented in the Master Plan, and states, further, that the probability of the recurrence of a flood of the magnitude of the September 1955 flood during some future critical drouth period is so remote that it should be disregarded in establishing the reservoir size or yield for the downstream projects.

Under the Plan of Improvement, 4,300 acre-feet per year would be delivered for downstream use from the Montell Reservoir, across the fault zone, to a point about 8.5 miles above Tom Nunn Hill. The Montell Reservoir would also recharge the Edwards Underground Reservoir to the extent of an average of 26,600 acre-feet per year of which some 45.4%, or 12,100 acre-feet per year, would be available for pumpage from the aquifer. The Montell Reservoir would therefore make available a maximum of an average of 16,400 (4,300 plus 12,100) acre-feet per year for use in the upper Nueces River watershed. As shown by Figure 5, following page 70, of the Nueces River Master Plan Study, a 200,000 acre-foot reservoir at the Tom Nunn Hill site would make approximately 37,000 acre-feet per year available for irrigation use in the Winter Garden Area on a 10% average deficit basis and still would have spilled an average of approximately 37-1/2% of the run-off of the river for downstream impoundment and use.

It is apparent from the District's studies that a 200,000 acre-foot reservoir at the Tom Nunn Hill site would yield more water for beneficial use in the District, i.e., 37,000 acre-feet per year for irrigation in the Winter Garden Area, than would be the case with the proposed 240,300 acre-foot reservoir, at the Montell site, which would yield 4,300 acre-feet per year for use in the Winter Garden Area and would make available an average of approximately 12,100 acre-feet of recharge water for pumping from the Edwards Underground Reservoir within and without the District. It appears, also, that such a reservoir at the Tom Nunn Hill site would not have much more effect on the downstream Cotulla and Wesley Seale Reservoirs than would be the case with the proposed Montell Reservoir. For these reasons, the Nueces River Conservation and Reclamation District is not willing to seek a modification of its Master Plan in order to accommodate the Montell Reservoir as proposed in the Survey Report.

Concan Reservoir

The Concan Reservoir with a capacity of 149,000 acre-feet, as proposed in the Survey Report, substantially conforms to the District's Master Plan which includes 147,000 acre-feet of capacity at the Concan site. Neither plan includes any permanent pool storage. By reason of the recreation and other benefits, Uvalde County is desirous of maintaining a permanent pool in the Concan Reservoir of 10,000 acre-feet capacity which would include a portion of the required silt storage in the reservoir. Uvalde County has secured a permit from the Texas Water Commission for such 10,000 acre-feet of conservation storage in the Concan Reservoir.

As stated in the above analysis of the Survey Report, the estimated cost to local interests of the water which would be recharged into the Edwards Underground Reservoir from the Concan Reservoir and which would also be available for pumpage from the aquifer is approximately $50 per acre-foot. This is greatly in excess of the value of the water in the ground for irrigation purposes, this being the principal use of such water within the District. Such estimated cost of the water to the local interests is based on two factors, viz., the estimated cost of the project and the derivation of the relative benefits attributable to the various purposes of the reservoir. Based on an assumed distribution of overhead costs, a breakdown of the total investment cost of the Concan Reservoir, as reflected by the Survey Report, is approximately as follows:

Lands, damages, relocations and clearing	$ 2,892,000
Embankment	1,964,000
Spillway	7,939,000
Outlet Works	2,055,000
Miscellaneous facilities	372,000
Total investment	$15,222,000

The proposed spillway, 1030 feet in width, is through the rock hill at the west end of the dam and requires 3,870,000 cubic yards of rock excavation, all of which can be used in the proposed dam. The outlet works, the principal purpose of which is to release the 750 cubic feet per second of recharge water, includes a 13 feet diameter conduit, through the dam, controlled by two 6 foot by 13 foot tractor type gates. It appears that the cost of the project might be reduced: (1) by taking advantage of the spillway capacity which could be obtained by the economical enlargement of the existing natural spillway which, under the present plans, would be closed by a dike approximately 650 feet in length, and (2) by smaller and simpler outlet works, perhaps at some sacrifice in the time of emptying the reservoir.

Also, the cost to local interests of the recharge water would be reduced somewhat by a more realistic evaluation of the benefits from the recharge operation. However, in the case of the Concan Reservoir, such reduction could not be material (approximately $5,100 per year) and still show a 1:1 ratio of annual benefits to allocated annual charges for each of the purposes.

The Nueces River Conservation and Reclamation District finds that the Concan Reservoir, as proposed in the Survey Report, is not justified at this time by reason of the fact that the cost to local interests of water from the reservoir is greatly in excess of the value of the water at this time.

Sabinal Reservoir

The Sabinal Reservoir with a capacity of 93,300 acre-feet, as recommended in the Survey Report, substantially conforms to the District's Master Plan which includes 90,000 acre-feet at the Sabinal Site. The allocated water supply cost per thousand gallons, or per acre-foot, for water from the Sabinal Reservoir is some 22% greater than the allocated cost from the Concan Reservoir. The District finds that the Sabinal Reservoir, as proposed in the Survey Report, is not justified at this time, the District's reasoning being much the same in respect to the Sabinal Reservoir as in the case of the Concan Reservoir.

Respectfully submitted,

NUECES RIVER CONSERVATION
AND RECLAMATION DISTRICT

By ______________________
Alvin Morris - President

COPY

April 13, 1965

Mr. Paul W. Jahn, Chairman
Edwards Underground Water District
1619 Tower Life Building
San Antonio, Texas 78205

Dear Sir:

Our review of the Survey Report on Edwards Underground Reservoir dated December 1964 and prepared by the Corps of Engineers, in cooperation with the Edwards Underground Water District, discloses that the report contains recommendations for the adoption and construction of a plan of improvement which fails to reserve any of the surface water supplies on the upper Guadalupe River within the boundaries of the Upper Guadalupe River Authority for development and use therein, as will be required to meet the future municipal and industrial needs of that area.

As you know, the Upper Guadalupe River Authority was granted the authority and the duty by the State Legislature to control, store, and preserve the waters of the upper Guadalupe River and its tributaries for all useful purposes within Kerr County. Current engineering studies confirm the findings of prior engineering investigations that the development of surface water resources of the upper Guadalupe River will be needed to supply the future water requirements of this area. The projects included in the plan of improvement recommended for adoption by the Corps of Engineers fail to take such required upstream water needs into account. For this reason, the Board of Directors for the Upper Guadalupe River Authority hereby objects to the adoption of that portion of the plan proposed for construction on the Guadalupe River.

Copies of our protest which is addressed to you as the sponsoring agency, are also being filed with the District Engineer, Fort Worth District, Corps of Engineers, and with the Texas Water Commission.

Very truly yours,

UPPER GUADALUPE RIVER AUTHORITY

/s/ J. L. Bullard
Dr. J. L. Bullard
Chairman

cc Fort Worth District Engineer
Texas Water Commission

FREESE, NICHOLS AND ENDRESS - March 12, 1965
COMMENTS ON SURVEY REPORT ON EDWARDS UNDERGROUND RESERVOIR
(Letter of transmittal to Chief of Engineers dated December 22, 1964)

Estimate of Water Requirements in Edwards Area.

The Survey Report estimates the water requirements in the Edwards Area to be 867.6 MGD as of 2025 for municipal and domestic, thermal power and industrial, and irrigation purposes, i.e., all uses except water for maintaining the quality of the flow in the San Antonio River (see p 101, Vol. 1). Such 867.6 MGD compares with San Antonio's latest estimate in the amount of 900 MGD as of 2025 (extrapolation from 2020 to 2025 of total use curve on Figure 1 of San Antonio's Progress Report of September 22, 1964).

Pumpage from Edwards Reservoir.

The Survey Report finds the safe pumpage from the Edwards Reservoir, under existing recharge conditions, to be 234,000 acre-feet per year (209 MGD) without depleting storage in the reservoir below elevation 612 at San Antonio (see pp 147-148, Vol. 1). "It is considered that, in view of the possible consequences of contamination, the water level should not be lowered appreciably beyond its historic low point, or elevation 612 ~~msl~~ MSL at San Antonio" (see p 148). The Report states that there was no change in the quality of water from wells in the "good-water" area as between water taken at the low level in 1956 and water taken when the reservoir had recovered, i.e. over a range of approximately 70 feet in the observation well (see p 99).

As compared with a pumpage of 234,000 acre-feet per year, the Report shows that a pumpage of 400,000 acre-feet per year would have resulted in an additional lowering of the water level of approximately 46 feet during the peak month (see p 97). The quality of water data which have become available during the past ten years does not indicate that there would be any appreciable change in the quality of the water used in the San Antonio System due to a further lowering of the reservoir level by as much as 40 to 50 feet as compared to the low level in 1956. In any case, the nature of the faulted interface between the good water and the bad water and, also, the relative amount of diluting good water flowing through the Edwards Reservoir as compared with the amount of bad water which could be fed through the interface, are such thct it is improbable that there would be any abrupt change in the slope of the curve of salinity vs. depth of water, there having been no change experienced in the slope of the curve over the first 70 feet of depth. The City of San Antonio has found that, based on studies of recharge, discharge, water levels, storage capacity, and quality, it is considered safe to set the limit of average annual pumping from wells in the Edwards Underground Reservoir at about 400,000 acre-feet per year (see p 13, City of San Antonio Progress Report dated September 22, 1964).

Figure 19, Page 97 of Volume 1 of the Survey Report, indicates that the pumpage of 400,000 acre-feet per year from the Edwards Reservoir, rather than the proposed 234,000 acre-feet per year, would lower the reservoir level approximately 24 feet during a recurrence from 1961 to 1985 of the 25 year recharge cycle which occurred from 1936 through 1960. Assuming a cost of power of 9 mills per KWH and an 80% overall efficiency of pump and motor installation, the cost of pumping the additional 24 feet is 0.85 mills per thousand gallons (less than 1/10 cent per thousand gallons).

Cloptin Crossing Reservoir

The proposed plan of improvement to meet the municipal, domestic, industrial, military, thermal power, and irrigation demands of the Edwards Reservoir area to approximately the year 2000, includes the Cloptin Crossing and the Dam No. 7 Reservoirs on the Upper Guadalupe River watershed (see Syllabus in front of Vol. 1). The yield of the Cloptin Crossing Reservoir is estimated at 38 MGD and that of the Canyon-Dam No. 7 Reservoir System is estimated at 127 MGD, a total yield from the upper Guadalupe River watershed of 165 MGD (see p 155, Vol. 1).

Under the plan of improvement, all of the 165 MGD would need to be transferred into the San Antonio and Nueces River Basins to meet the estimated water requirements in those basins as of year 2000. The Survey Report estimates the water requirements of the entire Edwards area to be approximately 621 MGD as of 2000, the requirements in the Guadalupe River Basin being estimated at approximately 66 MGD and those in the San Antonio-Nueces River Basins being estimated at approximately 555 MGD (interpolated from Table 10, p 155). The 621 MGD total requirements for the three basins would be met with 355 MGD originating in the Nueces and San Antonio River Basins and 266 MGD originating in the Guadulupe River Basin, which latter amount includes the 165 MGD from the Cloptin Crossing Reservoir and the Canyon-Dam No. 7 Reservoir System (see p 155). Based on the estimates of water requirements as of 2000 and based on the estimated water supply under the plan of improvement, approximately 200 MGD (266 MGD available in Guadalupe River Basin less 66 MGD use in the basin) would be transferred in year 2000 to the San Antonio and Nueces River Basins under the Plan of Improvement.

In allocating the cost of water conservation in the Cloptin Crossing Reservoir, annual benefits on account of water conservation were estimated at $653,000 or 4.71¢ per thousand gallons for the gross yield of 38.0 MGD (see p 177, Vol. 1).

The water supply benefits were based on the cheapest alternate source of water in the vicinity of the project (see p I-40, Vol. 2). The annual charges for water conservation are estimated at $332,700 which amounts to 2.40¢ per thousand gallons for the 38.0 MGD gross yield of the reservoir (see p 177, Vol. 1).

Recharge Reservoirs.

The allocation of annual charges for recharge from the three reservoirs is: Montell - $669,700; Concan - $485,800; Sabinal - $434,500; a total for the three reservoirs of $1,590,000 per annum (see p 177, Vol. 1). Of this amount 5.5% would be borne by the Federal Government on account of the use by military installations and the remaining 94.5% would be borne by the local interests. The estimated annual recharges from the three reservoirs are: Montell - 26,600 acre-feet; Concan - 21,500 acre-feet; Sabinal - 15,800 acre-feet; a total of 63,900 acre-feet per year or 57.0 MGD (see pp 138-142). The average charge for the gross recharge of 57.4 MGD is 7.64¢ per thousand gallons ($1,590,000 per annum or $4,356 per day for 57.0 MGD) which is the weighted average of the cost per thousand gallons shown on page 177, Vol. 1, viz: Montell - 7.6¢; Concan - 6.9¢; Sabinal - 8.4¢.

Of the gross recharge of 63,900 acre-feet per year or 57.0 MGD, the Survey Report estimates that 29,000 acre-feet per year (26 MGD) would be available for pumping from the Edwards Underground Reservoir and 34,900 acre-feet per year (31 MGD) would be discharged from the aquifer principally through the major springs (see pp 147-148). The increase in spring flow would increase the resources of the proposed Cuero Reservoir in the lower Guadalupe River (see p 162).

Assuming that the use of the 29,000 acre-feet per year (26 MGD) of recharge, available for pumping, will follow the 1962 use pattern, then 67.3% (17.5 MGD) of the available recharge will be used for municipal, industrial, domestic, stock watering and miscellaneous purposes, 27.1% (7.0 MGD) will be used for irrigation, and 5.6% (1.5 MGD) will be used by the military installations (see Figure 8, p 23). Of the allocated annual charges for recharge in the amount of $1,590,000, 5.5% or $87,500 per year have been apportioned to the Federal Government on account of the future military water requirements (see p 175). This leaves 94.5% or $1,502,500 ($1,590,000 less $87,500) per year to be paid by the local interests, presumably by the Edwards Underground Water District through the collection of ad valorem taxes in the annual amount of $1,502,500.

The irrigators cannot afford to pay their pro-rate share of the cost of the water ($34.74 per acre-foot). Nor is there any way, under the present Texas Statutes to keep the irrigators from using the recharge water. The ad-valorem taxes paid to the District by the irrigators on account of the use of the 7.0 MGD of irrigation water would be negligible. The net result is that, under the Survey Report on Edwards Underground Reservoir, the taxpayers of the Edwards Underground Water District would pay $1,502,500 per year or 23.52¢ per thousand gallons for the 17.5 MGD of recharge water which would be made available to them for municipal, industrial, domestic, stock watering, and miscellaneous purposes. This is several times the known cost of water from other sources.

One reason for the relatively high cost of recharge water is the method used in computing water supply benefits. "Benefits for water supply were computed on the basis of the cost of providing the same quantity and quality of water by the cheapest alternative means. The estimated cost of the alternate project was based on non-Federal financing and interest rates for the proposed publicly-owned project" (see pp 169-170, Vol. 1).

Annual benefits of the recharge from the three reservoirs are estimated as follows: Montell - $1,010,500; Concan - $816,800; Sabinal - $600,100; a total of $2,427,400 per year (see p 177). For the 63,900 acre-feet per year (57 MGD) of recharge water, the above estimated benefits equal 11.7¢ per thousand gallons. (On page I-40, Vol. 2, it is stated that a value, determined by the Public Health Service, of 13.6 cents per 1000 gallons of net increase in average annual recharge was used to evaluate the water conservation benefits.)

Under the method used in the Survey Report, a charge of 25¢ to 50¢ or more per thousand gallons could have been justified. Whatever the cost of the water conservation function of the recharge reservoirs, such cost would be justified by the method used for estimating benefits. In this particular case, a fairly accurate estimate can be made of the actual benefits from the recharge of 63,900 acre-feet per year (57 MGD) as follows:

Spring Flow (31 MGD): The actual benefits from this water supply are largely the value of the water to users in the lower Guadalupe River Valley.

Municipal, Military, Industrial and Miscellaneous (19 MGD): The benefits from this water supply should not exceed the cost of delivering a like amount of water to users in the Edwards Reservoir area as part of the larger proposed supply from the upper Guadalupe River watershed. Such delivered cost should be adjusted by adding the cost of treating the surface water and by deducting the cost of producing well water. For any part of the 19 MGD to be used by thermal power plants, the benefits should be computed on the basis of San Antonio's experienced cost of utilizing return flows from the San Antonio River, adjusted by deducting the cost of producing well water.

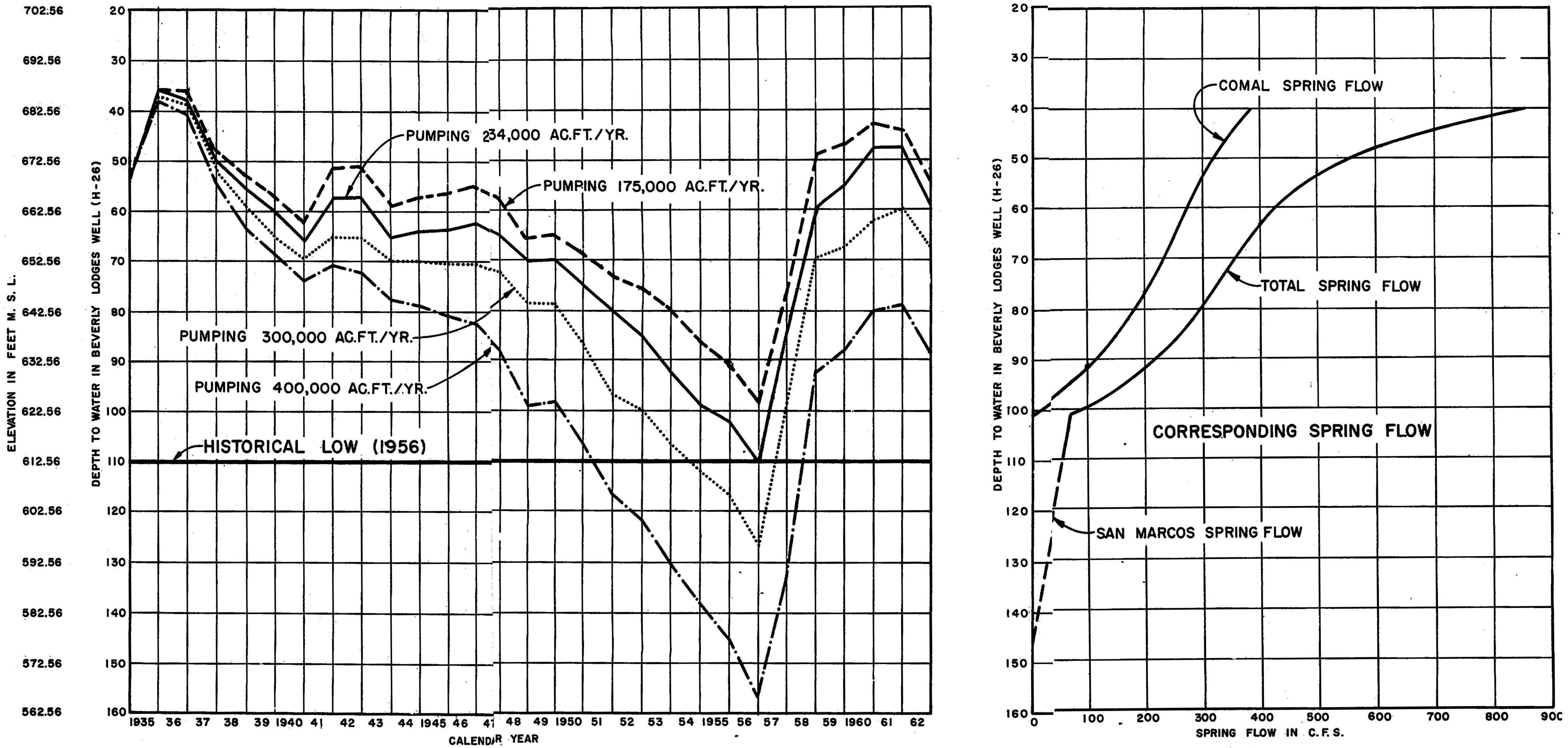
Irrigation (7 MGD): The benefits from this water supply equal the value to the irrigators of the water in the ground. The benefits should not exceed the profits which the irrigators can make from the use of this water.

All of these costs or values can be computed with a degree of accuracy permitting a realistic estimate of the actual benefits from the 57 MGD of water recharged into the Edwards Underground Reservoir by the proposed Montell, Concan and Sabinal Reservoirs.

Conclusions.

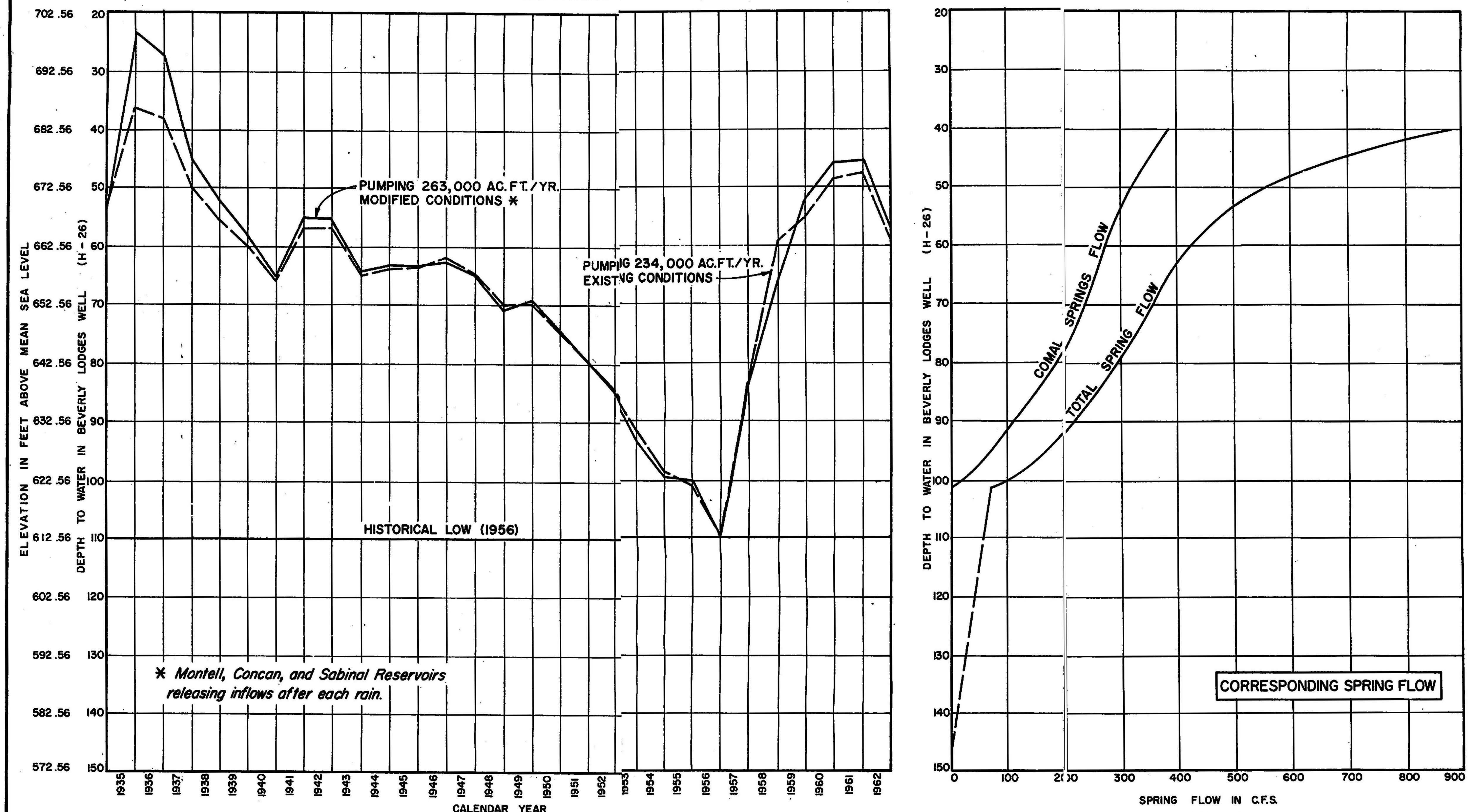
The use of the yield of the Cloptin Crossing Reservoir to meet the requirements of the Edwards Underground Reservoir Area in the San Antonio River Basin, as recommended by the Survey Report, is in full accord with the plans of the City of San Antonio for meeting its future water requirements. The estimated cost of 2.4¢ per thousand gallons for water at the Cloptin Reservoir is a reasonable cost. By reason of the elevation of the reservoir and its proximity to San Antonio, the cost of delivering the water to San Antonio would be relatively inexpensive. The utilization of the project, as proposed in the Survey Report, should be entirely satisfactory to San Antonio. However, the project is meaningless as a water conservation project until such time as an allocation of the yield of the reservoir is made by the State of Texas. As to the timing of construction of the project, consideration should be given to the optimum sequence of the construction of the Cuero, Cloptin Crossing and Dam 7 Reservoirs in order to meet the needs of the Edwards Underground Reservoir Area and of the Guadalupe River Valley in an orderly and timely manner.

The Survey Report shows a cost to local interests of water which could be utilized from the Montell, Concan and Sabinal Reservoirs of several times the value of such water at the present time. These projects should be deferred until such time as the projects can be worked out as economically feasible projects.



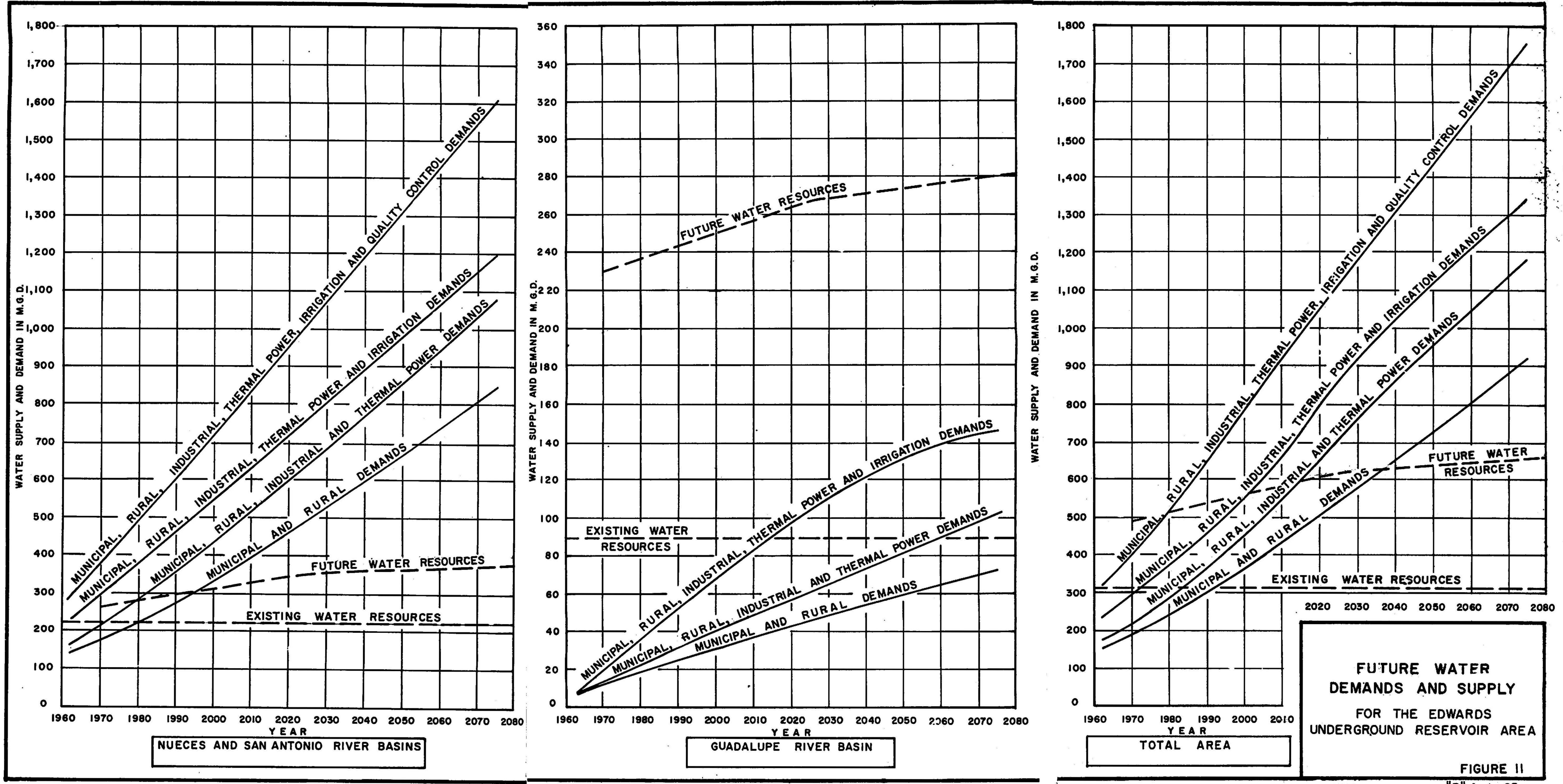
NOTE:
For hydrologic routings above El. 682.0 spring flow curves were extended.

FIGURE 3
EFFECTS OF CONSTANT PUMPAGE ON WATER LEVELS IN THE EDWARDS UNDERGROUND RESERVOIR – EXISTING CONDITIONS



NOTE:
For Hydrologic Routing above EL. 682, Springflow Curves were extended.

FIGURE 6
EFFECTS OF CONSTANT PUMPAGE ON WATER LEVELS IN THE EDWARDS UNDERGROUND RESERVOIR
MONTELL, CONCAN, & SABINAL RESERVOIRS IN OPERATION



FUTURE WATER DEMANDS AND SUPPLY

FOR THE EDWARDS UNDERGROUND RESERVOIR AREA

FIGURE 11

TABLE A1-1

DETAILED ESTIMATE OF FIRST COST
MONTELL DAM AND RESERVOIR
NUECES RIVER
(July 1964 price level)

Item	Unit quantity	Unit cost	Single-purpose 50-year flood control Quantity	Single-purpose 50-year flood control Cost	Multiple-purpose Recharge, W.C., F.C., F.& W. and Recreation Quantity	Multiple-purpose Recharge, W.C., F.C., F.& W. and Recreation Cost
PERTINENT DATA						
Top of dam, elevation			1369.5		1371.0	
Spillway crest, elevation			1328.5		1331.0	
Storage capacity (spillway crest less sediment), acre-feet			225,100		240,300	
A. DETAILED ESTIMATE OF FIRST COST - DAM AND RESERVOIR						
(01.0) Lands and damages						
a. Land costs						
(1) Fee simple lands (including mineral value)	Acre		400	$ 64,000	700	$ 105,000
(2) Flood easement lands	Acre		6,240	545,000	6,440	562,000
(3) Fee severance damage	L.S.			-		-
(4) Easement severance damage	L.S.			90,000		90,000
(5) Fee land improvements	L.S.			2,000		2,000
(6) Easement land improvements	L.S.			402,000		408,000
(7) Resettlement reimbursement	L.S.			17,000		17,000
Subtotal - land costs				1,120,000		1,184,000
b. Land acquisition expense	L.S.			102,000		103,000
Subtotal - lands and land acquisition				1,222,000		1,287,000
Contingencies, 15% ±				183,000		194,000
TOTAL - LANDS AND DAMAGES				1,405,000		1,481,000
(02.0) Relocations						
a. Roads and bridges						
(1) State Highway 55						
(a) Embankment, borrow	C.Y.	$ 0.60	20,000	12,000	30,000	18,000
(b) Base and surfacing (reservoir crossing)	Mi.	30,000.00	0.2	6,000	0.2	6,000
(c) Riprap	C.Y.	8.00	600	4,800	2,000	16,000
(d) Bedding	C.Y.	6.50	200	1,300	700	4,550
(e) Guard rail	L.F.	2.50	1,800	4,500	2,000	5,000
(f) New road outside reservoir	Mi.	82,000.00	10.3	844,600	10.3	844,600
(g) Connection to existing highway	L.S.			6,900		6,900
(h) Bridge (3 locations)	L.F.	250.00	300	75,000	300	75,000
Subtotal - State Highway 55				955,100		976,050
(2) County roads						
(a) Embankment, borrow	C.Y.	0.60	45,000	27,000	66,000	39,600
(b) Riprap	C.Y.	8.00	2,200	17,600	3,000	24,000
(c) Bedding	C.Y.	6.50	700	4,550	1,000	6,500
(d) Guard rail	L.F.	2.50	1,500	3,750	1,900	4,750
(e) Bridge	L.F.	175.00	150	26,250	150	26,250
(f) Base and surfacing (reservoir crossing)	Mi.	22,000.00	0.2	4,400	0.5	11,000
(g) New road outside reservoir	Mi.	70,000.00	1.417	99,200	1.330	93,100
Subtotal - county roads				182,750		205,200
Subtotal - roads and bridges				1,137,850		1,181,250
b. Cemeteries and utilities						
(1) Electric power lines	L.S.			145,000		145,000
(2) Telephone lines	L.S.			24,000		24,000
(3) Cemeteries	L.S.			51,000		51,000
Subtotal - cemeteries and utilities				220,000		220,000
Subtotal - relocations				1,357,850		1,401,250
Contingencies, 25% ±				339,150		350,750
TOTAL - RELOCATIONS				1,697,000		1,752,000
(03.0) Reservoirs						
a. Clearing	Acre	150.00			260	39,000
Contingencies, 15% ±						6,000
TOTAL - CLEARING						45,000
(04.0) Dams						
a. Embankment						
(1) Care of water	Pump. days	150.00	200	30,000	200	30,000
(2) Clearing and grubbing	Acre	300.00	142	42,600	145	43,500
(3) Excavation, stripping	C.Y.	0.25	101,900	25,475	103,200	25,800
(4) Excavation, common	C.Y.	0.30	76,400	22,920	77,400	23,220
(5) Excavation, cutoff trench	C.Y.	0.80	830,700	664,560	830,700	664,560
(6) Excavation, borrow, impervious	C.Y.	0.50	2,335,000	1,167,500	2,358,000	1,179,000
(7) Excavation, borrow, rock	C.Y.	1.50	-	-	90,000	135,000
(8) Compacted impervious fill	C.Y.	0.10	2,123,000	212,300	2,144,000	214,400
(9) Random rockfill	C.Y.	0.10	10,650,000	1,065,000	10,923,000	1,092,300
(10) Filter material	C.Y.	1.50	1,127,000	1,690,500	1,143,000	1,714,500
(11) Flexible base	C.Y.	7.50	3,630	27,225	3,630	27,225
(12) Aggregate	C.Y.	12.00	290	3,480	290	3,480
(13) Asphalt treatment	Gal.	0.25	15,030	3,758	15,050	3,763
(14) Cofferdam	C.Y.	0.25	223,000	55,750	223,000	55,750
(15) Foundation drilling and grouting	L.S.		-	100,000	-	100,000
(16) Foundation preparation	Sq.	1.00	2,100	2,100	2,100	2,100
Subtotal - embankment				5,113,200		5,314,600
b. Spillway						
(1) Clearing	Acre	150.00	60	9,000	59	8,850
(2) Excavation, rock	C.Y.	1.50	8,938,000	13,407,000	8,979,000	13,468,500
(3) Excavation, structural (rock)	C.Y.	12.00	208	2,496	213	2,556
(4) Concrete (including cement)	C.Y.	35.00	208	7,280	213	7,455
(5) Line drilling	S.F.	1.75	5,610	9,818	5,760	10,080
(6) Reinforcing steel	Lb.	0.15	15,700	2,355	16,100	2,415
(7) Drill and grout anchor holes	L.F.	2.25	935	2,104	960	2,160
(8) Tile gages	L.F.	20.00	82	1,640	80	1,600
Subtotal - spillway				13,441,700		13,503,600
c. Outlet works						
(1) Care of water	Pump. days	150.00	260	39,000	260	39,000
(2) Clearing	Acre	150.00	12	1,800	12	1,800
(3) Excavation, unclassified	C.Y.	1.35	94,000	126,900	94,000	126,900
(4) Backfill, structural	C.Y.	1.00	17,000	17,000	17,000	17,000
(5) Drill and grout anchor holes	L.F.	2.25	3,700	8,325	3,700	8,325
(6) Drill drain holes	L.F.	2.00	2,800	5,600	2,800	5,600
(7) Line drilling	S.F.	1.75	30,900	54,075	31,100	54,425
(8) Operating house	L.S.			20,000		20,000
(9) Concrete, control tower	C.Y.	30.00	655	52,400	665	53,200
(10) Concrete, tower base and transition	C.Y.	35.00	6,740	235,900	6,740	235,900
(11) Concrete, slab	C.Y.	30.00	1,235	37,050	1,235	37,050
(12) Concrete, wall	C.Y.	40.00	1,950	78,000	1,950	78,000
(13) Concrete, conduit	C.Y.	35.00	7,880	275,800	7,980	279,300
(14) Concrete, bridge deck	C.Y.	80.00	112	8,960	114	9,120
(15) Concrete, bridge piers	C.Y.	70.00	430	30,100	440	30,800
(16) Cement	Bbl	5.00	23,750	118,750	23,900	119,500
(17) Steel, reinforcing	Lb.	0.13	2,261,000	293,930	2,274,000	295,620
(18) Steel, structural	Lb.	0.22	137,500	30,250	141,500	31,130
(19) Pipe railing	Lb.	0.35	4,130	1,446	4,200	1,470
(20) Miscellaneous metals	Lb.	0.50	1,000	500	1,000	500
(21) Ladder, grates, grills	Lb.	0.50	3,700	1,850	3,700	1,850
(22) Air vents, steel, 36" ∅	L.F.	80.00	300	24,000	300	24,000
(23) Air supply vents, steel, 18" ∅	L.F.	60.00	130	7,800	130	7,800
(24) Gage well facilities	L.S.			9,100		9,100
(25) Spiral stairs	L.F.	60.00	130	7,800	130	7,800
(26) Conduit liner	Lb.	0.60	99,600	59,760	99,600	59,760
(27) Rubber water stop	L.F.	3.00	1,980	5,940	2,030	6,090
(28) Water gage, tile	L.F.	20.00	175	3,500	175	3,500
(29) Tractor gates and equipment	L.S.			321,750		321,750
(30) Bulkhead gates and guides	L.S.			35,000		35,000
(31) Ventilation system	L.S.			5,000		5,000
(32) Elevator and inclosure	L.S.			20,000		20,000
(33) Electrical facilities	L.S.			25,000		25,000
(34) Foundation preparation	Sq.	1.00	485	485	490	490
Subtotal - outlet works				1,962,800		1,971,800
Subtotal - dams				20,517,700		20,790,000
Contingencies, 15% ±				3,077,300		3,119,000
TOTAL - DAMS				23,595,000		23,909,000
(08.0) Access road	L.S.			69,500		69,500
Contingencies, 15% ±				10,500		10,500
TOTAL - ACCESS ROAD				80,000		80,000
(19.0) Buildings, grounds, and utilities						
a. Maintenance buildings	L.S.			54,000		54,000
b. Powerline and substation	L.S.			169,000		169,000
c. Water supply	L.S.			10,000		10,000
Subtotal - buildings, grounds, and utilities				233,000		233,000
Contingencies, 15% ±				35,000		35,000
TOTAL - BUILDINGS, GROUNDS AND UTILITIES				268,000		268,000
(20.0) Permanent operating equipment						
a. Stream gages	L.S.			15,000		15,000
b. Radio facilities	L.S.			5,000		5,000
c. Work boat	L.S.			-		10,000
d. Evaporation and rain gages	L.S.			1,000		1,000
e. Sediment and degradation ranges	L.S.			-		51,000
f. Office furniture and equipment	L.S.			5,000		5,000
g. Miscellaneous equipment	L.S.			-		-
Subtotal - permanent operating equipment				26,000		87,000
Contingencies, 15% ±				4,000		13,000
TOTAL - PERMANENT OPERATING EQUIPMENT				30,000		100,000
(30.0) Engineering and design				2,000,000		2,034,000
(31.0) Supervision and administration				1,680,000		1,701,000
TOTAL ESTIMATED FIRST COST - DAM AND RESERVOIR				30,755,000		31,370,000(1)
B. DETAILED ESTIMATE OF FIRST COST - FISH AND WILDLIFE AND RECREATION						
(01.0) Lands and damages (including contingencies)	L.S.					11,500
(03.0) Reservoirs						
a. Clearing (includes contingencies)	Acre	100.00			80	8,000
(14.0) Recreation facilities (includes contingencies)	L.S.					225,500
(30.0) Engineering and design						16,000
(31.0) Supervision and administration						14,000
TOTAL ESTIMATED FIRST COST - FISH, WILDLIFE, AND RECREATION LANDS AND FACILITIES						275,000
TOTAL ESTIMATED FIRST COST - DAM, RESERVOIR, AND RECREATION LANDS AND FACILITIES						31,645,000
C. DETAILED ESTIMATE OF FIRST COST - PIPELINE SYSTEM TO TOM NUNN HILL RESERVOIR SITE						
(04.0) Channel dam (including contingencies)	L.S.					313,000
(09.0) Pipeline (including contingencies)	L.S.					587,000
TOTAL ESTIMATED FIRST COST - PIPELINE SYSTEM TO TOM NUNN HILL RESERVOIR SITE						900,000
D. TOTAL ESTIMATED PROJECT FIRST COST				$30,755,000		$32,545,000

(1) Also single-purpose recharge project or triple-purpose water supply, recharge and flood control project.

TABLE A1-2

DETAILED ESTIMATE OF FIRST COST
CONCAN DAM AND RESERVOIR
FRIO RIVER
(July 1964 price level)

Item	Unit quantity	Unit cost	Single-purpose 50-yr flood control: Quantity	Single-purpose 50-yr flood control: Cost	Joint storage Recharge and 50-yr flood control(1): Quantity	Joint storage Recharge and 50-yr flood control(1): Cost
PERTINENT DATA						
Top of dam, elevation			1399.5		1399.5	
Spillway crest, elevation			1366.5		1366.5	
Storage capacity (spillway crest less sediment), acre-feet			141,200		141,200	
A. DETAILED ESTIMATE OF FIRST COST - DAM AND RESERVOIR						
(01.0) Lands and damages						
a. Land costs						
(1) Fee simple lands	Acre	-	400	$ 145,000	880	$ 319,000
(2) Flood easement lands	Acre	-	3,960	822,200	3,480	723,800
(3) Fee and easement severance damages	L.S.			130,000		130,000
(4) Fee and easement land improvements	L.S.			540,000		540,000
(5) Mineral estate	L.S.			32,700		32,700
(6) Resettlement reimbursement	L.S.			14,700		14,700
Subtotal - land costs				1,684,600		1,760,200
b. Land acquisition	L.S.			112,900		112,900
Subtotal - lands and land acquisition				1,797,500		1,873,100
Contingencies, 15% +				269,500		280,900
TOTAL - LANDS AND DAMAGES				2,067,000		2,154,000
(02.0) Relocations						
a. Roads and bridges						
(1) U. S. Highway 83 (raise in place)						
(a) Embankment complete (borrow)	C.Y.	$ 0.60	25,000	$ 15,000	25,000	$ 15,000
(b) Base and surfacing	Mi.	30,000.00	0.4	12,000	0.4	12,000
(c) Riprap	C.Y.	8.00	1,500	12,000	1,500	12,000
(d) Bedding	C.Y.	6.50	500	3,250	500	3,250
(e) Guardrail	L.F.	2.50	2,000	5,000	2,000	5,000
(f) Culvert	L.S.			4,000		4,000
(g) Detour	L.S.			3,000		3,000
(2) County roads						
(a) New road	Mi.	56,000.00	6.2875	352,100	6.2875	352,100
(b) Bridge	L.F.	175.00	100	17,500	100	17,500
(3) Park road - Garner State Park	Mi.	26,500.00	0.2	5,300	0.2	5,300
Subtotal - roads				429,150		429,150
b. Utilities						
(1) Rural electric distribution lines	Mi.	2,000.00	5.0	10,000	5.0	10,000
(2) Rural telephone lines	Mi.	1,200.00	5.0	6,000	5.0	6,000
(3) Relocate small structures in Garner State Park	Ea.	2,000.00	5	10,000	5	10,000
Subtotal - utilities				26,000		26,000
Subtotal - relocations				455,150		455,150
Contingencies, 25% +				113,850		113,850
TOTAL - RELOCATIONS				$ 569,000		$ 569,000
(04.0) Dams						
a. Embankment						
(1) Care of water	Pump days	150.00	150	22,500	150	22,500
(2) Clearing and grubbing	Acre	300.00	65	19,500	65	19,500
(3) Excavation, stripping	C.Y.	0.30	46,300	13,890	46,300	13,890
(4) Excavation, common	C.Y.	0.40	34,800	13,920	34,800	13,920
(5) Excavation, cutoff trench	C.Y.	1.00	80,600	80,600	80,600	80,600
(6) Excavation, impervious, borrow	C.Y.	0.50	781,800	390,900	781,800	390,900
(7) Compacted impervious fill	C.Y.	0.10	710,800	71,080	710,800	71,080
(8) Excavation, rock, borrow	C.Y.	1.25	2,713,000	3,391,250	2,713,000	3,391,250
(9) Random rockfill	C.Y.	0.10	4,984,000	498,400	4,984,000	498,400
(10) Filter material	C.Y.	1.50	507,200	760,800	507,200	760,800
(11) Flexible base	C.Y.	7.50	1,460	10,950	1,460	10,950
(12) Aggregate	C.Y.	12.00	120	1,440	120	1,440
(13) Asphalt treatment	Gal.	0.25	6,040	1,510	6,040	1,510
(14) Cofferdam	C.Y.	0.40	48,000	19,200	48,000	19,200
(15) Foundation preparation	Sq.	1.00	770	770	770	770
(16) Foundation drilling and grouting	L.S.			175,000		175,000
Subtotal - embankment				5,471,700		5,471,700
b. Spillway						
(1) Clearing	Acre	150.00	77	11,550	77	11,550
(2) Excavation, rock	C.Y.	1.50	1,352,000	2,028,000	1,352,000	2,028,000
(3) Excavation, structural (rock)	C.Y.	12.00	660	7,920	660	7,920
(4) Concrete (includes cement)	C.Y.	35.00	860	30,100	860	30,100
(5) Line drilling	S.F.	1.75	6,480	11,340	6,480	11,340
(6) Steel, reinforcing	Lb.	0.15	99,800	14,970	99,800	14,970
(7) Drill and grout anchor holes	L.F.	2.25	1,930	4,343	1,930	4,343
(8) Tile gages	L.F.	20.00	66	1,320	66	1,320
Subtotal - spillway				2,109,500		2,109,500
c. Outlet works						
(1) Care of water	Pump days	150.00	210	31,500	210	31,500
(2) Clearing	Acre	150.00	5	750	5	750
(3) Excavation, unclassified	C.Y.	0.90	265,000	238,500	265,000	238,500
(4) Backfill, structural	C.Y.	1.00	14,000	14,000	14,000	14,000
(5) Drill and grout anchor holes	L.F.	2.25	2,520	5,670	2,520	5,670
(6) Drill drain holes	L.F.	2.00	1,890	3,780	1,890	3,780
(7) Line drilling	S.F.	1.75	25,100	43,925	25,100	43,925
(8) Operating house	L.S.			20,000		20,000
(9) Concrete, control tower	C.Y.	80.00	660	52,800	660	52,800
(10) Concrete, tower base and transition	C.Y.	35.00	5,230	183,050	5,230	183,050
(11) Concrete, slab	C.Y.	30.00	710	21,300	710	21,300
(12) Concrete, wall	C.Y.	40.00	1,255	50,200	1,255	50,200
(13) Concrete, conduit	C.Y.	35.00	7,100	248,500	7,100	248,500
(14) Concrete, bridge deck	C.Y.	80.00	120	9,600	120	9,600
(15) Concrete, bridge piers	C.Y.	70.00	450	31,500	450	31,500
(16) Cement	Bbl.	5.00	19,400	97,000	19,400	97,000
(17) Steel, reinforcing	Lb.	0.13	1,820,000	236,600	1,820,000	236,600
(18) Steel, structural	Lb.	0.22	149,000	32,780	149,000	32,780
(19) Pipe railing	Lb.	0.35	4,400	1,540	4,400	1,540
(20) Miscellaneous metal	Lb.	0.50	1,000	500	1,000	500
(21) Ladder, gates, grille	Lb.	0.50	3,700	1,850	3,700	1,850
(22) Air vents, steel, 36"⌀	L.F.	80.00	305	24,400	305	24,400
(23) Air supply vent, steel 18"⌀	L.F.	60.00	134	8,040	134	8,040
(24) Gage well facilities	L.S.			7,000		7,000
(25) Spiral stairs	L.F.	60.00	134	8,040	134	8,040
(26) Conduit liner	Lb.	0.60	70,190	42,114	70,190	42,114
(27) Rubber water stop	L.F.	3.00	1,885	5,655	1,885	5,655
(28) Water gages, tile	L.F.	20.00	185	3,700	185	3,700
(29) Tractor gates and equipment	L.S.			214,500		214,500
(30) Bulkhead gate and guides	L.S.			25,000		25,000
(31) Ventilation system	L.S.			5,000		5,000
(32) Elevator and inclosure	L.S.			20,000		20,000
(33) Electrical facilities	L.S.			25,000		25,000
Subtotal - outlet works				1,714,800		1,714,800
Subtotal - dams				9,296,000		9,296,000
Contingencies, 15% +				1,394,000		1,394,000
TOTAL - DAMS				10,690,000		10,690,000
(08.0) Access road	L.S.			82,500		82,500
Contingencies, 15% +				12,500		12,500
TOTAL - ACCESS ROAD				95,000		95,000
(19.0) Buildings, grounds, and utilities						
a. Maintenance buildings	L.S.			54,000		54,000
b. Water supply	L.S.			10,000		10,000
c. Powerline and substation	L.S.			161,000		161,000
Subtotal - buildings, grounds, and utilities				225,000		225,000
Contingencies, 15% +				34,000		34,000
TOTAL - BUILDINGS, GROUNDS AND UTILITIES				259,000		259,000
(20.0) Permanent operating equipment						
a. Radio-telephone equipment	L.S.			5,000		5,000
b. Boat	L.S.			-		-
c. Miscellaneous furniture and equipment	L.S.			5,000		5,000
d. Stream gages	L.S.			15,000		15,000
e. Evaporation and rain gages	L.S.			1,000		1,000
f. Sediment and degradation ranges	L.S.			-		-
Subtotal - permanent operating equipment.				26,000		26,000
Contingencies, 15% +				4,000		4,000
TOTAL - PERMANENT OPERATING EQUIPMENT				30,000		30,000
(30.0) Engineering and design				1,009,000		1,009,000
(31.0) Supervision and administration				772,000		772,000
TOTAL - ESTIMATED FIRST COST - DAM AND RESERVOIR				15,491,000		15,578,000
B. DETAILED ESTIMATE OF FIRST COST - RECREATION						
(01.0) Lands and damages (including contingencies)	Acre	300.00			10	3,000
(03.0) Reservoirs						
a. Clearing (includes contingencies)	Acre	100.00			30	3,000
(14.0) Recreation facilities (includes contingencies)	L.S.					57,000
(30.0) Engineering and design						6,000
(31.0) Supervision and administration						3,000
TOTAL - ESTIMATED FIRST COST - RECREATION						72,000
C. TOTAL - ESTIMATED PROJECT COST				$15,491,000		$15,650,000

(1) Also single-purpose recharge reservoir project and multiple-purpose recharge, flood control, and recreation project.

TABLE A1-4

DETAILED ESTIMATE OF FIRST COST
CLOPTIN CROSSING DAM AND RESERVOIR
BLANCO RIVER
(July 1964 price level)

Item	Unit quantity	Unit cost	Single-purpose 75-Yr flood control: Quantity	Single-purpose 75-Yr flood control: Cost	Single-purpose maximum water conservation: Quantity	Single-purpose maximum water conservation: Cost	Multiple-purpose FC, WC, FW, & R: Quantity	Multiple-purpose FC, WC, FW, & R: Cost
PERTINENT DATA								
Top of dam, elevation			973.0		1005.0		1023.0	
Spillway crest, elevation			947.0		980.0		998.0	
Storage capacity (spillway crest less sediment), acre-feet			114,700		271,200		394,800	
A. DETAILED ESTIMATE OF FIRST COST - DAM AND RESERVOIR								
(01.0) Lands and damages								
a. Land costs								
(1) Fee simple lands (including minerals)	Acre		500	$ 70,000	6,580	$ 590,600	9,700	$ 1,043,000
(2) Flood easement lands and improvements	Acre		3,700	211,600		-		-
(3) Fee severance damage	L.S.			55,000		75,000		100,000
(4) Fee land improvements	L.S.			70,000		660,000		775,000
(5) Easement land improvements	L.S.			475,000		-		-
(6) Resettlement reimbursement	L.S.			20,000		24,000		26,000
Subtotal - land costs				901,600		1,349,600		1,944,000
b. Land acquisition expense	L.S.			56,000		70,400		70,400
Subtotal - lands and land acquisition				957,600		1,420,000		2,014,400
Contingencies, 15% ±				143,400		213,000		301,600
TOTAL - LANDS AND DAMAGES				1,101,000		1,633,000		2,316,000
(02.0) Relocations								
a. Roads and bridges								
(1) County road - Bendigo crossing								
(a) New road	Mi.	$60,000.00	1.3	78,000	1.3	78,000	1.3	78,000
(b) Bridge	L.F.	175.00	200	35,000	320	56,000	400	70,000
Subtotal - roads and bridges				113,000		134,000		148,000
b. Utilities								
(1) Electric power lines	Mi.	2,000.00	2	4,000	2	4,000	2	4,000
(2) Rural telephone lines	Mi.	1,200.00	2	2,400	2	2,400	2	2,400
Subtotal - utilities				6,400		6,400		6,400
Subtotal - relocations				119,400		140,400		154,400
Contingencies, 25% ±				29,600		34,600		38,600
TOTAL - RELOCATIONS				149,000		175,000		193,000
(03.0) Reservoirs								
a. Clearing	Acre	50.00		-	3,720	186,000	3,750	187,500
Contingencies, 15% ±				-		28,000		28,500
TOTAL - RESERVOIRS						214,000		216,000
(04.0) Dams								
a. Embankment								
(1) Care of water	Pump. days	150.00	75	11,250	120	18,000	160	24,000
(2) Clearing and grubbing	Acre	350.00	57	19,950	88	30,800	110	38,500
(3) Excavation, stripping	C.Y.	0.30	37,800	11,340	58,900	17,670	74,700	22,410
(4) Excavation, common	C.Y.	0.40	28,300	11,320	44,200	17,680	56,000	22.400
(5) Excavation, borrow, rock	C.Y.	1.25	-	-	4,530,000	5,662,500	6,610,000	8,262,500
(6) Excavation, borrow, impervious	C.Y.	0.50	524,200	262,100	846,600	423,300	1,098,000	549,000
(7) Excavation, cutoff trench	C.Y.	1.00	32,500	32,500	32,500	32,500	32,500	32,500
(8) Compacted impervious fill	C.Y.	0.10	476,600	47,660	769,600	76,960	998,200	99,820
(9) Filter material	C.Y.	1.50	524,200	786,300	822,700	1,234,050	1,057,100	1,585,650
(10) Random rockfill	C.Y.	0.10	2,458,000	245,800	4,939,000	493,900	6,905,000	690,500
(11) Flexible base	C.Y.	6.50	2,230	14,495	3,320	21,580	3,720	24,180
(12) Aggregate	C.Y.	12.00	180	2,160	270	3,240	300	3,600
(13) Asphalt treatment	Gal.	0.25	9,200	2,300	13,740	3,435	15,380	3,845
(14) Cofferdam	C.Y.	0.20	80,000	16,000	80,000	16,000	80,000	16,000
(15) Foundation preparation	Sq.	1.00	315	315	315	315	315	315
(16) Foundation drilling and grouting	L.S.			100,000		150,000		200,000
Subtotal - embankment				1,563,500		8,201,900		11,575,200
b. Spillway								
(1) Clearing	Acre	200.00	84	16,800	21	4,200	35	7,000
(2) Excavation, common	C.Y.	0.40	663,000	265,200	170,000	68,000	223,000	89,200
(3) Excavation, rock	C.Y.	1.25	3,285,000	4,106,250	200,000	250,000	110,000	137,500
(4) Concrete, slab	C.Y.	25.00	23,680	592,000	18,440	461,000	14,750	368,750
(5) Concrete, wall	C.Y.	35.00	980	34,300	980	34,300	980	34,300
(6) Cement	Bbl.	5.00	30,830	154,150	24,280	121,400	19,660	98,300
(7) Reinforcing steel	Lb.	0.13	1,870,000	243,100	1,470,000	191,100	1,200,000	156,000
(8) Riprap	C.Y.	6.00	16,540	99,240	13,040	78,240	10,580	63,480
(9) Bedding	C.Y.	5.00	7,100	35,500	5,600	28,000	4,540	22,700
(10) Drill and grout anchor holes	L.F.	2.25	32,000	72,000	25,250	56,813	20,500	46,125
(11) Line drilling	S.F.	1.75	26,800	46,900	23,500	41,125	21,200	37,100
Subtotal - spillway				5,665,400		1,334,200		1,060,500
c. Outlet works								
(1) Care of water	Pump. days	150.00	230	34,500	200	30,000	200	30,000
(2) Clearing	Acre	200.00	9	1,800	9	1,800	9	1,800
(3) Excavation, unclassified	C.Y.	1.50	214,000	321,000	181,000	271,500	184,000	276,000
(4) Backfilling, structural	C.Y.	1.00	4,000	4,000	6,700	6,700	7,700	7,700
(5) Drill and grout anchor holes	L.F.	2.25	5,120	11,520	5,300	11,925	5,300	11,925
(6) Drill drain holes	L.F.	2.00	3,120	6,240	3,250	6,500	3,250	6,500
(7) Line drilling	S.F.	1.75	22,200	38,850	24,900	43,575	26,400	46,200
(8) Operating house	L.S.			20,000		20,000		20,000
(9) Concrete, control tower	C.Y.	75.00	380	28,500	620	46,500	740	55,500
(10) Concrete, tower base and transition	C.Y.	30.00	6,740	202,200	5,230	156,900	5,230	156,900
(11) Concrete, conduit	C.Y.	30.00	4,170	125,100	5,240	157,200	6,550	196,500
(12) Concrete, slab	C.Y.	25.00	1,130	28,250	1,130	28,250	1,130	28,250
(13) Concrete, wall	C.Y.	35.00	1,070	37,450	1,150	40,250	1,150	40,250
(14) Concrete, bridge deck	C.Y.	75.00	70	5,250	100	7,500	120	9,000
(15) Cement	Bbl.	5.00	17,100	85,500	17,310	86,550	19,210	96,050
(16) Steel, reinforcing	Lb.	0.13	1,653,000	214,890	1,652,000	214,760	1,811,000	235,430
(17) Steel, structural	Lb.	0.20	76,000	15,200	121,000	24,200	158,000	31,600
(18) Pipe railing	Lb.	0.35	2,500	875	3,840	1,344	4,600	1,610
(19) Metals, miscellaneous	Lb.	0.50	1,000	500	1,000	500	1,000	500
(20) Ladders, grates, grills	Lb.	0.50	3,600	1,800	3,200	1,600	3,200	1,600
(21) Spiral stairs	L.F.	55.00	62	3,410	99	5,445	117	6,435
(22) Conduit liner	Lb.	0.55	99,600	54,780	70,200	38,610	70,200	38,610
(23) Rubber water stop	L.F.	3.00	1,250	3,750	1,830	5,490	1,970	5,910
(24) Water gages, tile	L.F.	20.00	143	2,860	175	3,500	193	3,860
(25) Tractor gates and equipment	L.S.			297,000		214,500		214,500
(26) Bulkhead gates, guides, etc.	L.S.			30,000		25,000		25,000
(27) Gage well facilities	L.S.			3,700		5,250		6,150
(28) Electrical facilities	L.S.			22,000		22,000		22,000
(29) Riprap	C.Y.	6.00	2,780	16,680	2,780	16,680	2,780	16,680
(30) Bedding	C.Y.	5.00	1,110	5,550	1,110	5,550	1,110	5,550
(31) Concrete, bridge piers	C.Y.	65.00	120	7,800	380	24,700	450	29,250
(32) Air vents, 18" ∅	L.F.	60.00	55	3,300	90	5,400	110	6,600
(33) Air vents, 36" ∅	L.F.	80.00	320	25,600	280	22,400	310	24,800
(34) Ventilation system	L.S.			5,000		5,000		5,000
(35) Elevator, inclosure, etc.	L.S.			20,000		20,000		20,000
(36) Foundation preparation	Sq.	1.00	595	595	600	600	650	650
Subtotal - outlet works				1,685,500		1,577,700		1,684,300
Subtotal - dams				8,914,400		11,113,800		14,320,000
Contingencies, 15% ±				1,337,600		1,667,200		2,148,000
TOTAL - DAMS				10,252,000		12,781,000		16,468,000
(08.0) Access road	L.S.			11,600		11,600		11,600
Contingencies, 15% ±				1,400		1,400		1,400
TOTAL - ACCESS ROAD				13,000		13,000		13,000
(19.0) Buildings, grounds and utilities								
a. Maintenance facilities	L.S.			54,000		54,000		54,000
b. Water supply	L.S.			12,000		12,000		12,000
c. Powerline and substation	L.S.			121,000		121,000		121,000
Subtotal - buildings, grounds and utilities				187,000		187,000		187,000
Contingencies, 15% ±				28,000		28,000		28,000
TOTAL - BUILDINGS, GROUNDS AND UTILITIES				215,000		215,000		215,000
(20.0) Permanent operating equipment								
(1) Radio-telephone equipment	L.S.			4,000		4,000		4,000
(2) Boat	L.S.			-		8,000		8,000
(3) Miscellaneous furniture and equipment	L.S.			5,000		10,800		10,800
(4) Stream gages	L.S.			15,000		15,000		15,000
(5) Evaporation and rain gages	L.S.			1,000		1,000		1,000
(6) Sedimentation and degradation ranges	L.S.			-		68,300		68,300
Subtotal - permanent operating equipment				25,000		107,100		107,100
Contingencies, 15% ±				4,000		15,900		15,900
TOTAL - PERMANENT OPERATING EQUIPMENT				29,000		123,000		123,000
(30.0) Engineering and design				970,000		1,160,000		1,252,000
(31.0) Supervision and administration				710,000		895,000		999,000
TOTAL - ESTIMATED PROJECT FIRST COST - DAM AND RESERVOIR (Single- and dual-purpose projects)				13,439,000		17,209,000		21,795,000
B. DETAILED ESTIMATE OF FIRST COST - FISH AND WILDLIFE AND RECREATION								
(01.0) Lands and damages								
a. Land costs								
(1) Fee simple lands	Acre						900	168,100
(2) Fee severance damage	L.S.							10,000
Subtotal - land costs								178,100
Contingencies, 15% ±								26,700
TOTAL - LAND COSTS								204,800
b. Land acquisition expense	L.S.							5,200
TOTAL - LANDS AND DAMAGES								210,000
(03.0) Reservoirs								
a. Clearing	Acre						2,420	96,800
Contingencies, 15% ±								14,200
TOTAL - RESERVOIRS								111,000
(14.0) Recreation facilities								
a. Access roads and park roads	L.S.							795,600
b. Parking areas	L.S.							185,000
c. Picnic facilities	L.S.							407,000
d. Water supply	L.S.							185,000
e. Sanitary facilities	L.S.							166,500
f. Boat launching ramps	L.S.							55,500
g. Vegetative improvements	L.S.							37,000
h. Signs	L.S.							37,000
Subtotal - recreation facilities								1,868,600
Contingencies, 10% ±								186,400
TOTAL - RECREATION FACILITIES								2,055,000
(30.0) Engineering and design								138,000
(31.0) Supervision and administration								131,000
TOTAL - ESTIMATED FIRST COSTS - FISH AND WILDLIFE AND RECREATION								2,645,000
C. TOTAL - ESTIMATED PROJECT FIRST COST				$13,439,000		$17,209,000		$24,440,000

TABLE 12

AVERAGE MONTHLY EVAPORATION DATA
AUSTIN, DEL RIO, DILLEY, SAN ANTONIO, SONORA, AND WINTER HAVEN, TEXAS

Month	Austin, Texas 1930-1960 U. S. Weather Bureau Pan Coefficient 0.69			Del Rio, Texas 1946-1957 U. S. Weather Bureau Pan Coefficient 0.69			Dilley, Texas 1931-1960(1) U. S. Weather Bureau Pan Coefficient 0.69			San Antonio, Texas 1907-1930 Bureau of Plant Industry Pan Coefficient 0.94			Sonora, Texas 1950-1960(2) Bureau of Plant Industry Pan Coefficient 0.94			Winter Haven, Texas 1936-1960 Bureau of Plant Industry Pan Coefficient 0.94		
	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)	Observed Pan Evaporation (inches)	Evaporation from Reservoir Surface (inches)	Observed Precipitation (inches)
January	2.73	1.88	2.32	3.43	2.37	.79	2.94	2.03	1.30	2.46	2.32	1.15	2.56	2.41	1.34	2.09	1.96	1.18
February	3.21	2.21	2.55	4.61	3.18	1.08	3.51	2.42	1.43	3.03	2.85	1.50	3.16	2.97	1.15	2.74	2.58	1.14
March	5.11	3.53	2.09	8.05	5.55	.67	6.08	4.20	0.93	4.46	4.19	1.87	4.97	4.67	1.14	4.66	4.38	1.00
April	6.19	4.27	3.47	9.45	6.52	1.91	7.21	4.96	2.03	5.53	5.20	3.19	5.96	5.60	1.25	5.52	5.19	1.81
May	7.44	5.13	3.88	10.75	7.42	2.51	8.51	5.87	2.90	6.51	6.12	3.15	6.20	5.83	1.86	6.54	6.15	3.46
June	8.95	6.18	3.18	12.58	8.68	1.89	9.89	6.82	2.81	7.95	7.47	2.43	7.71	7.25	2.75	7.93	7.45	2.09
July	9.90	6.83	2.11	14.38	9.92	.97	11.07	7.64	2.12	9.09	8.55	1.66	8.98	8.44	1.62	8.80	8.27	1.74
August	9.79	6.76	1.94	13.37	9.23	1.09	10.87	7.50	1.68	9.19	8.64	1.69	8.37	7.87	1.49	8.70	8.18	2.33
September	7.35	5.07	3.43	9.90	6.83	2.28	11.24	7.76	2.65	6.81	6.40	2.65	6.40	6.02	2.36	6.29	5.91	2.79
October	5.65	3.90	3.00	7.34	5.06	1.23	5.85	4.04	2.08	5.10	4.79	2.91	5.06	4.76	2.09	4.54	4.27	2.13
November	3.64	2.51	2.11	4.97	3.43	.45	3.73	2.57	1.22	3.16	2.97	2.13	3.49	3.28	.50	3.02	2.84	.82
December	2.66	1.84	2.56	3.61	2.49	.52	2.78	1.92	1.56	2.45	2.30	1.75	2.84	2.67	.58	2.14	2.01	1.09
ANNUAL	72.62	50.11	32.64	102.44	70.68	15.39	83.68	57.73	22.71	65.74	61.80	26.08	65.70	61.77	18.13	62.97	59.19	21.58
NET ANNUAL LOSS FROM RESERVOIR SURFACE		17.47"			55.29"			35.02			35.72"			43.64"			37.61"	

(1) No record May-August 1943; January, February 1950.

(2) No record January-May 1950; June 1953.

TABLE 15

FLOOD DATA

Date of flood	Peak discharge (cfs)	Date of peak	Flood volume passing gage (acre-feet)	Flood volume passing gage (inches)
West Nueces River near Brackettville - D.A. = 700 sq. mi.				
June 1935	550,000(1)	June 14	-	-
June 16-19, 1958	104,000	June 17	104,400	2.80

(1) Measurement made by U. S. Geological Survey 10 miles above mouth.

Date of flood	Peak discharge (cfs)	Date of peak	Flood volume passing gage (acre-feet)	Flood volume passing gage (inches)
Nueces River at Laguna - D.A. = 764 sq. mi.				
June 13-18, 1935	213,000	June 14	277,900	6.82
September 15-19, 1936	114,000	September 16	111,890	2.74
July 13-15, 1939	222,000	July 13	89,000	2.18
September 24-27, 1955	307,000	September 24	153,810	3.77
Nueces River below Uvalde - D.A. = 1,947 sq. mi.				
September 1-4, 1932	207,000	September 1	280,000	2.72(1)
June 13-18, 1935	616,000	June 14	461,700	4.48(1)
July 13-15, 1939	89,000	July 13	57,480	0.55
September 24-27, 1955	189,000	September 24	143,900	1.39
June 17-20, 1958	146,000	June 17	191,100	1.84

(1) Measurement was made at the gage near Uvalde-D.A. = 1,930 sq. mi.

Date of flood	Peak discharge (cfs)	Date of peak	Flood volume passing gage (acre-feet)	Flood volume passing gage (inches)
Frio River at Concan - D.A. = 405 sq. mi.				
July 1-6, 1932	162,000	July 1	150,620	6.97
June 13-18, 1935	106,000	June 14	115,140	5.33
September 15-19, 1936	119,000	September 16	44,230	2.05
Frio River near Derby - D.A. = 3,493 sq. mi.				
July 2-8, 1932	230,000	July 4	528,080	2.83
May 29-June 8, 1935	68,300	June 2	261,600	1.40
June 13-22, 1935	50,500	June 16	251,660	1.35
Sabinal River near Sabinal - D.A. = 206 sq. mi.				
May 24-25, 1954	15,800	May 24	5,460	0.50
June 17-19, 1958	55,200	June 17	29,850	2.72
June 25-28, 1959	11,900	June 25	10,950	1.00
Sabinal River at Sabinal-D.A. = 247 sq. mi. (1)				
May 24-26, 1954	15,900	May 24	8,050	0.61
June 17-20, 1958	73,300	June 17	42,230	3.19
June 26-29, 1959	15,900	June 26	11,250	0.85

(1) Gage is located below Balcones fault zone.

Date of flood	Peak discharge (cfs)	Date of peak	Flood volume passing gage (acre-feet)	Flood volume passing gage (inches)
Hondo Creek near Tarpley - D.A. = 101 sq. mi.				
May 24-26, 1954	18,600	May 24	2,080	0.39
September 22-24, 1957	25,300	September 22	6,900	1.28
June 17-20, 1958	69,800	June 17	26,400	4.90
Hondo Creek near Hondo - D.A. = 132 sq. mi. (1)				
May 24-26, 1954	13,700	May 24	2,600	0.37
September 22-24, 1957	20,500	September 22	6,810	0.97
June 17-20, 1958	71,700	June 17	22,980	3.26

(1) Gage is located below Balcones fault zone.

Date of flood	Peak discharge (cfs)	Date of peak	Flood volume passing gage (acre-feet)	Flood volume passing gage (inches)
Seco Creek near Utopia - D.A. = 53 sq. mi.				
September 22-25, 1957	12,100	September 22	3,340	1.18
June 17-20, 1958	52,600	June 17	13,770	4.87
Seco Creek near D'Hanis - D.A. = 87 sq. mi. (1)				
May, 1935	230,000(2)	May 31	-	-
September 22-24, 1957	12,400	September 22	3,750	0.81
June 17-19, 1958	72,000	June 17	20,020	4.32

(1) Gage located below Balcones fault zone.
(2) Measurement made by U. S. Geological Survey 11 miles above D'Hanis)

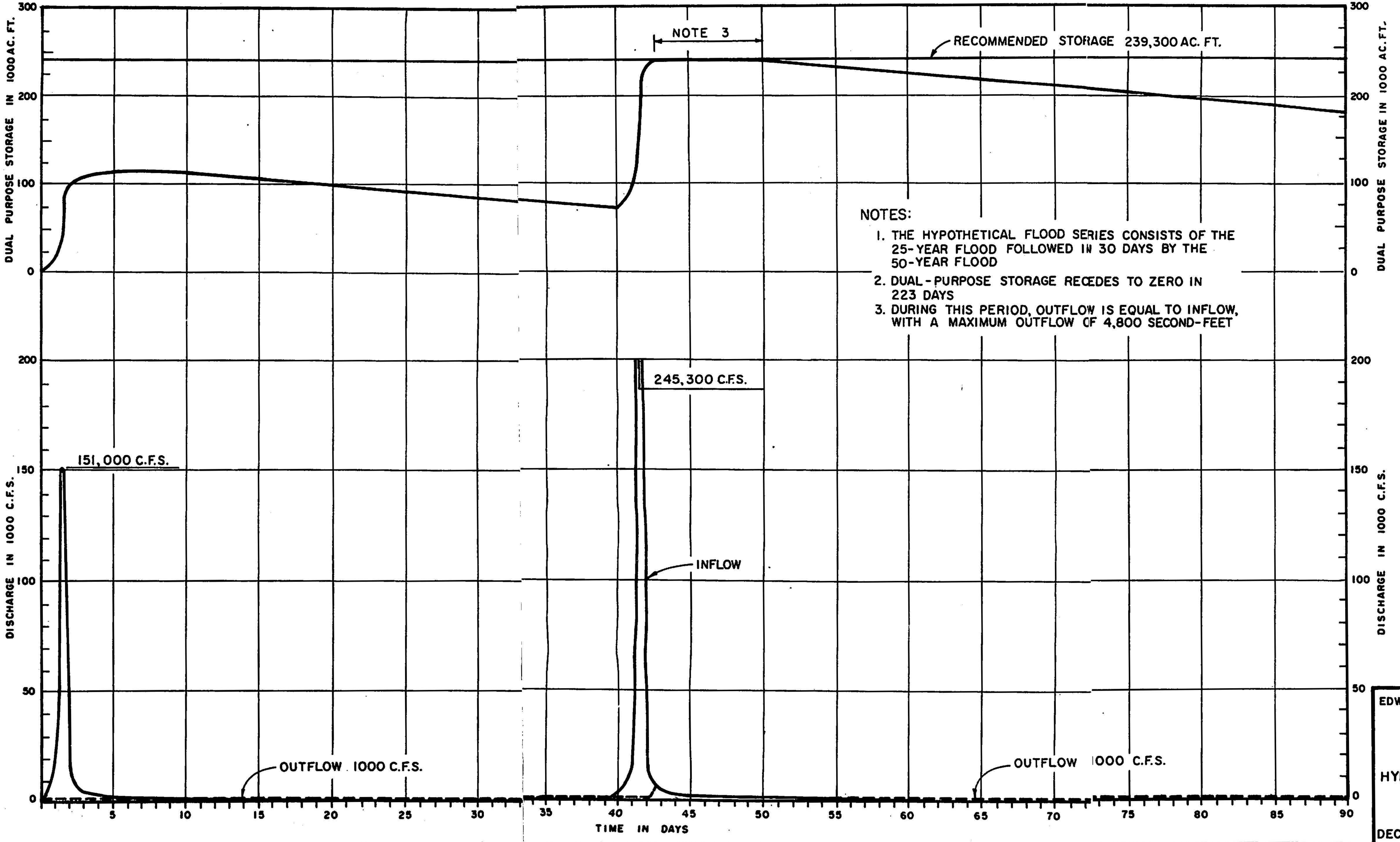
Date of flood	Peak discharge (cfs)	Date of peak	Flood volume passing gage (acre-feet)	Flood volume passing gage (inches)
Medina River near Pipe Creek - D.A. = 474 sq. mi.				
July 1-5, 1932	64,000	July 1	81,880	3.24
July 24, 1935	40,400(1)	July 24	-	-
June 17-19, 1958	37,100	June 17	30,660	1.21

(1) Station abandoned July 25.

Date of flood	Peak discharge (cfs)	Date of peak	Flood volume passing gage (acre-feet)	Flood volume passing gage (inches)
Guadalupe River at Comfort - D.A. = 836 sq. mi.				
July 1-3, 1932	182,000	July 1	136,070	3.35(1)
May 25-28, 1944	59,400	May 26	49,030	1.10
September 10-12, 1952	38,600	September 10	19,840	0.44
October 4-7, 1959	93,200	October 4	56,900	1.28

(1) Measurement was made at gage near Comfort - D.A. = 762 sq. mi.
Note: Gage was not operating during 1935 flood.

Date of flood	Peak discharge (cfs)	Date of peak	Flood volume passing gage (acre-feet)	Flood volume passing gage (inches)
Guadalupe River near Spring Branch - D.A. = 1,282 sq. mi.				
July 2-4, 1932	121,000	July 3	194,580	2.85
June 13-17, 1935	114,000	June 15	179,520	2.63
May 25-29, 1944	28,000	May 27	62,940	0.92
September 10-13, 1952	66,900	September 11	119,190	1.74
October 4-8, 1959	42,500	October 5	68,270	1.00
Blanco River at Wimberley - D.A. = 353 sq. mi.				
May 28-31, 1929	113,000	May 28	84,630	4.50
September 11-14, 1952	95,000	September 11	77,840	4.13
April 24-26, 1957	62,600	April 24	27,990	1.49
May 2-5, 1958	96,400	May 2	43,700	2.36



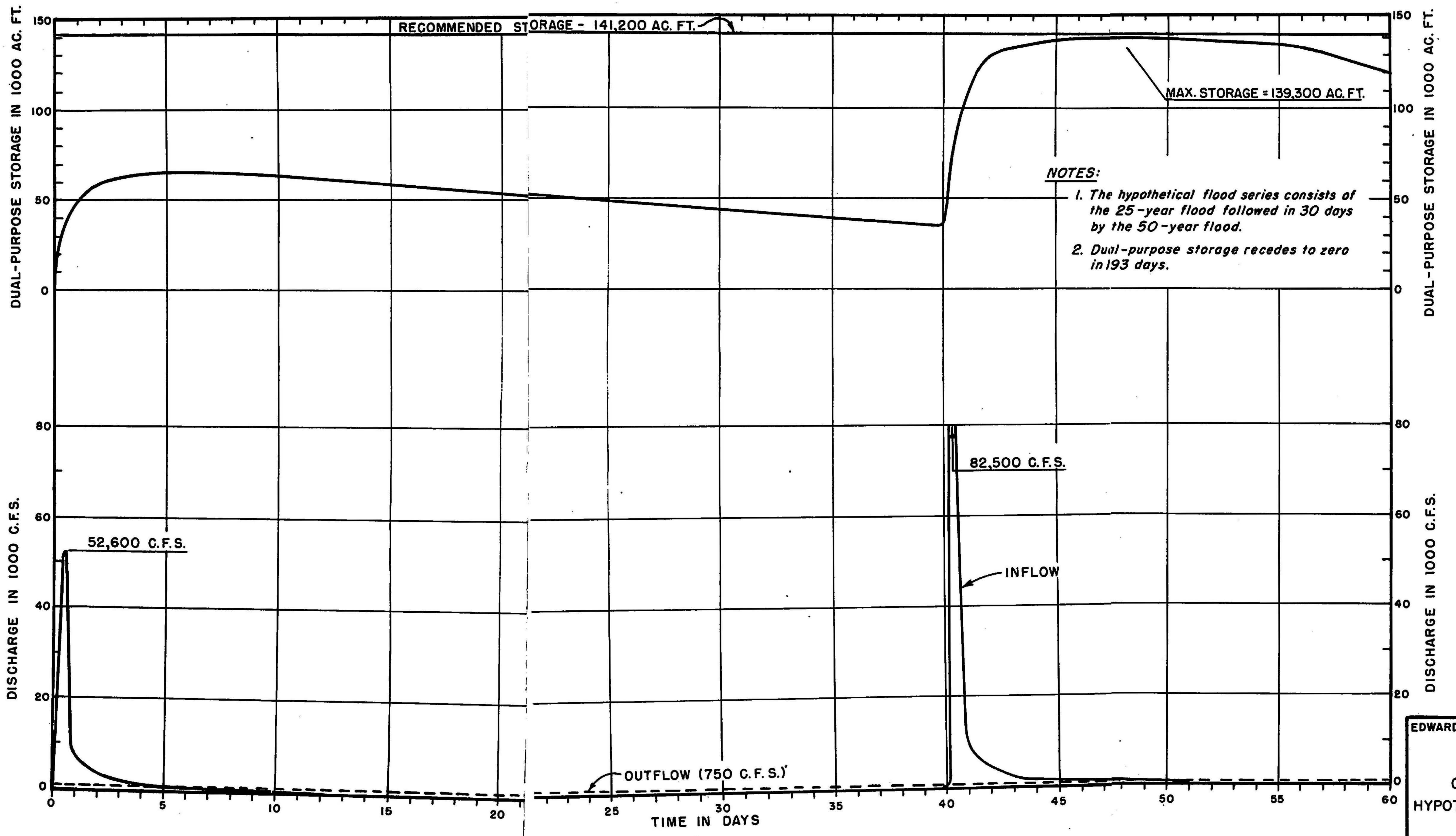
EDWARDS UNDERGROUND RESERVOIR

MONTELL RESERVOIR
HYPOTHETICAL FLOOD SERIES

DEC. 1964

PLATE 16

A.M.F.



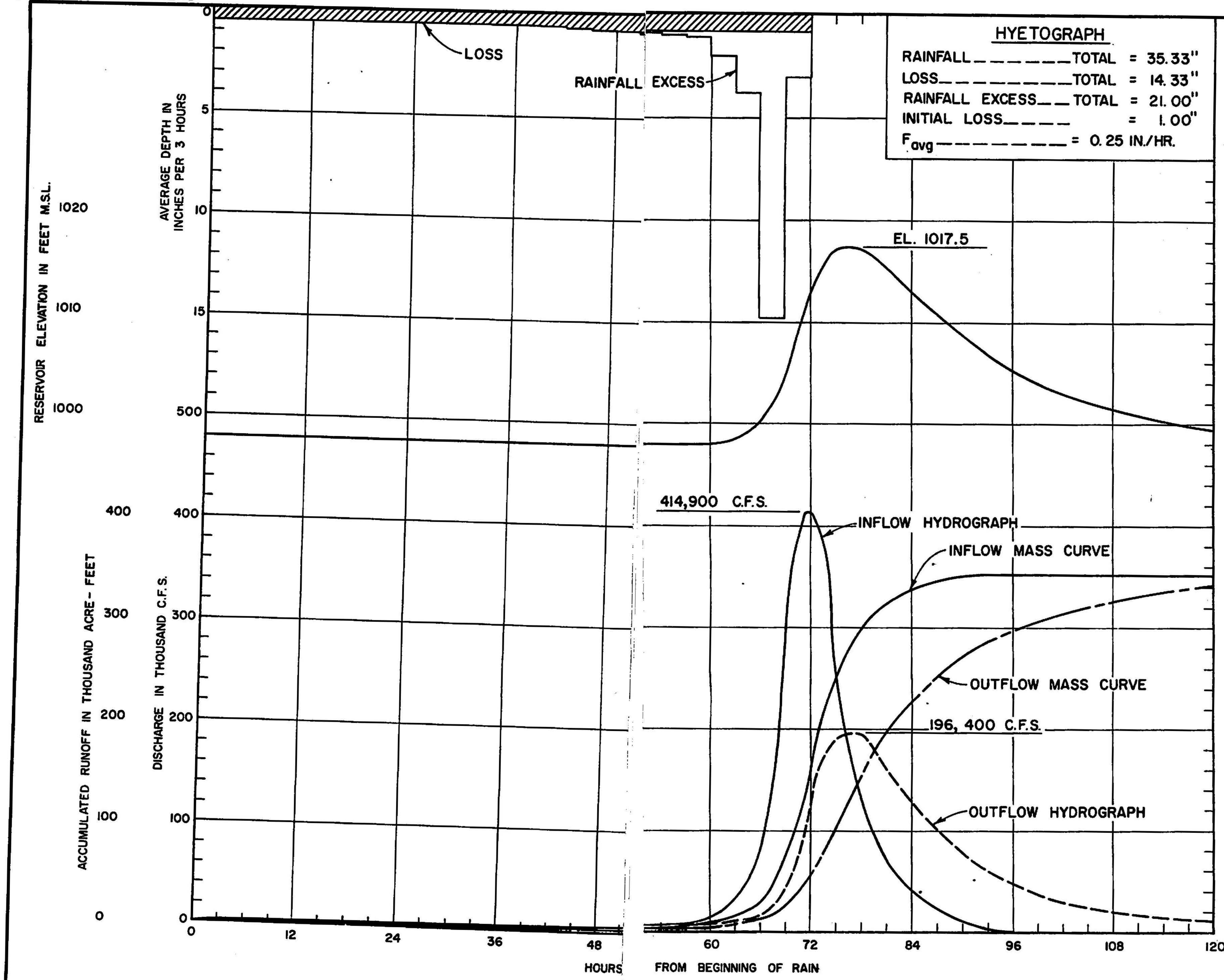
EDWARDS UNDERGROUND RESERVOIR

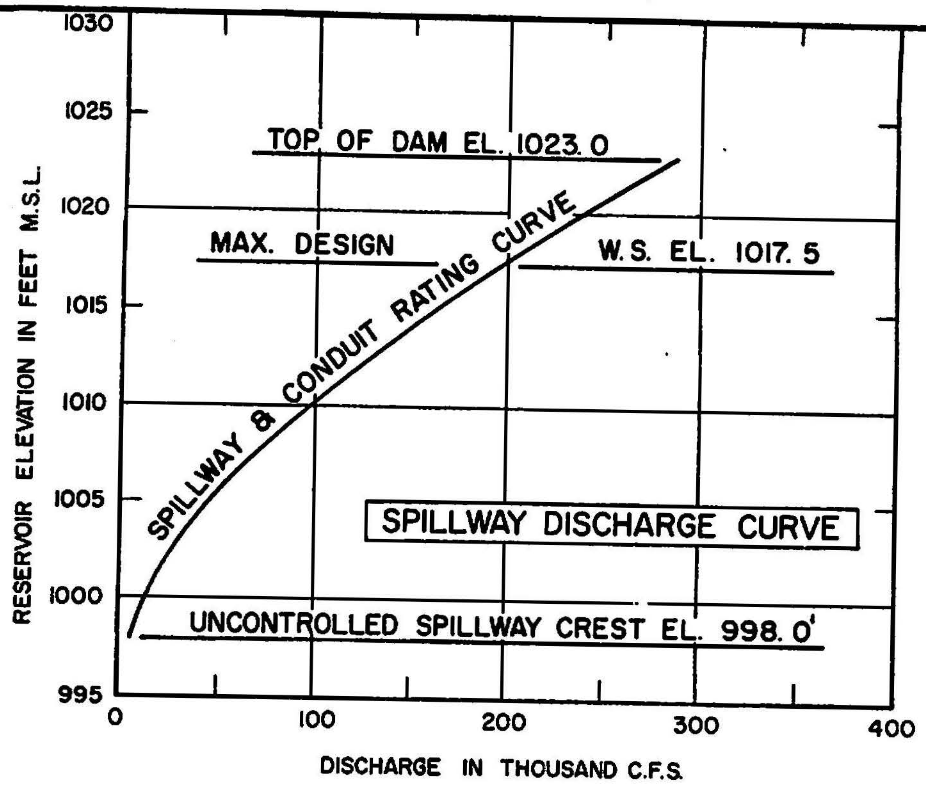
CONCAN RESERVOIR
HYPOTHETICAL FLOOD SERIES

DEC. 1964 PLATE 19

CORPS OF ENGINEERS

U.S. ARMY





NOTES:

Drainage area 307 square miles. Outflow partially controlled by one 13' diameter conduit, invert elevation 855.0', with two 6'x13' tractor type gates. Spillway is uncontrolled 760' Broadcrested Weir, crest elevation 998.0'

Flood - control conduit operative during spillway design flood.

Reservoir level, at spillway crest elevation 998.0' at beginning of rain, returns to spillway crest 144 hours after beginning of rain.

EDWARDS UNDERGROUND RESERVOIR

CLOPTIN CROSSING RESERVOIR
INFLOW-OUTFLOW HYDROGRAPHS
SPILLWAY DESIGN FLOOD

DEC 1964 PLATE 36

 W.H.W.-T.L.W.

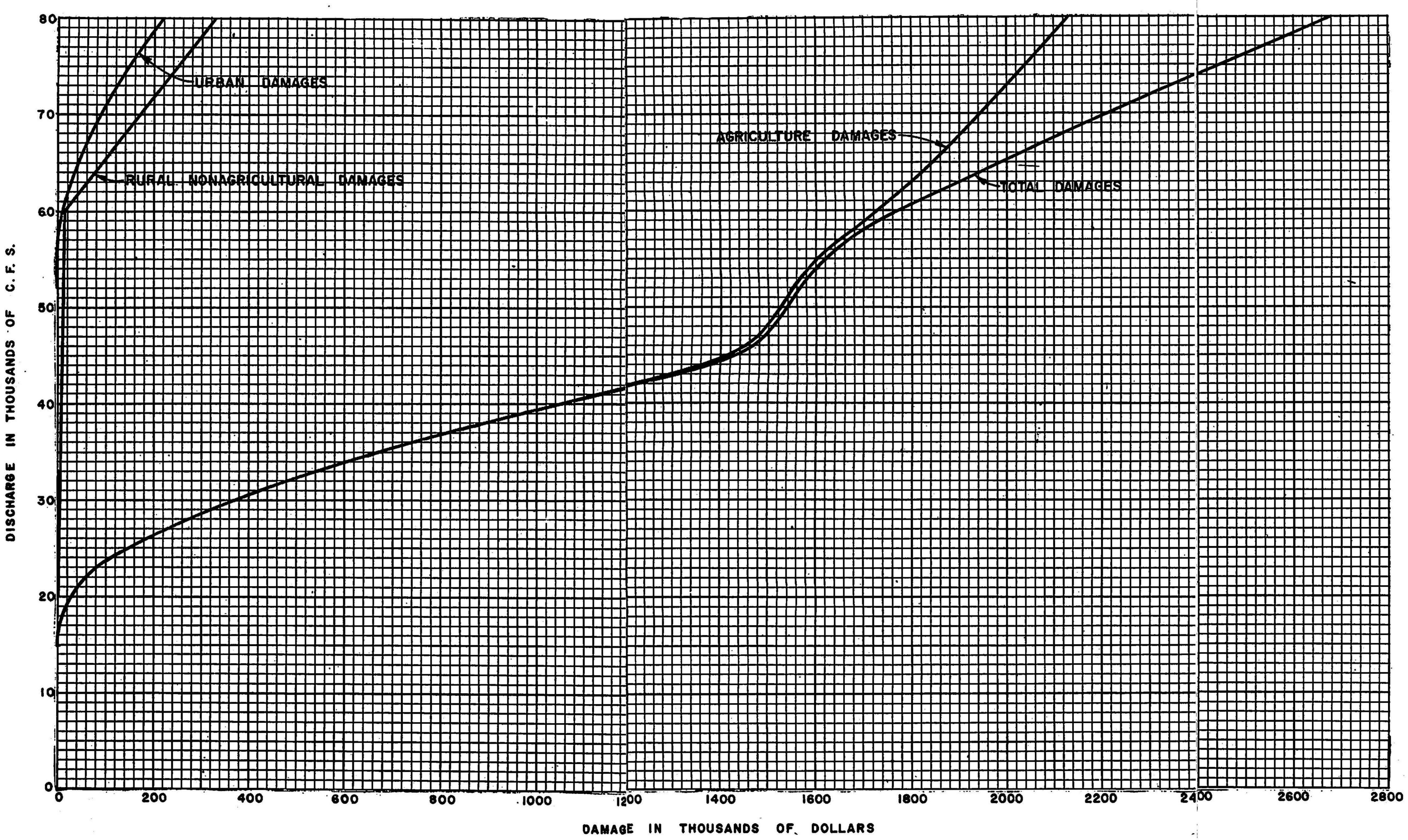


FIGURE 2

DISCHARGE - DAMAGE CURVES

NUECES RIVER - REACH I - 3

SCALES AS SHOWN

Figure 3

COMPUTATION OF AVERAGE ANNUAL DAMAGES
NUECES RIVER - REACH 1-3

Existing Conditions

	Total Damages					Nonagricultural Damages				Urban Damages			
Frequency	Δ Frequency	Discharge (cfs)	Damage	Double Damage	Δ Double Damage	Δ Frequency	Damage	Double Damage	Δ Double Damage	Δ Frequency	Damage	Double Damage	Δ Double Damage
0	0.7		$4,800,000	$7,475,000	$5,232,500	0.7	$680,000	$1,003,100	$702,170	0.7	$1,050,000	$1,269,100	$888,370
0.7	0.3	80,000	2,675,000	4,795,000	1,438,500	0.3	323,100	463,100	138,930	0.3	219,100	281,300	84,390
1.0	0.2	68,000	2,120,000	4,060,000	812,000	0.2	140,000	217,500	43,500	0.2	62,200	98,200	19,640
1.2	0.2	64,000	1,940,000	3,668,000	733,600	0.2	77,500	94,500	18,900	0.2	36,000	48,000	9,600
1.4	0.2	59,000	1,728,000	3,368,000	673,600	0.2	17,000	32,000	6,400	0.2	12,000	17,800	3,560
1.6	0.2	56,000	1,640,000	3,220,000	644,000	0.2	15,000	28,500	5,700	0.2	5,800	8,100	1,620
1.8	0.2	53,000	1,580,000	3,114,000	622,800	0.2	13,500	25,000	5,000	(1.9) 52,000 0.1	2,300	2,300	230
2.0	0.5	50,000	1,534,000	2,994,000	1,497,000	0.5	11,500	21,000	10,500		0		
2.5	0.5	46,000	1,460,000	2,630,000	1,315,000	0.5	9,500	16,000	8,000				
3.0	0.5	41,500	1,170,000	2,100,000	1,050,000	0.5	6,500	11,500	5,750				
3.5	0.5	38,500	930,000	1,670,000	835,000	0.5	5,000	9,000	4,500				
4.0	1.0	36,000	740,000	1,220,000	1,220,000	1.0	4,000	6,500	6,500				
5.0	1.0	32,000	480,000	805,000	805,000	1.0	2,500	4,000	4,000				
6.0	1.0	29,000	325,000	535,000	535,000	1.0	1,500	2,500	2,500				
7.0	1.0	26,500	210,000	348,000	348,000	1.0	1,000	1,500	1,500				
8.0	1.0	24,500	138,000	223,000	223,000	1.0	500	700	700				
9.0	1.0	23,000	35,000	135,000	135,000	1.0	200	300	300				
10.0	2.0	21,500	50,000	70,000	140,000	(11.2) 20,000 1.2	100	100	120				
12.0	2.0	19,000	20,000	25,000	50,000		0						
14.0	2.0	17,200	5,000	7,000	14,000								
16.0	1.2	16,000	2,000	2,000	2,400								
17.2		15,000	0										
					18,326,400				964,970				1,007,410

18,326,400 / 200 = $91,632.00

964,970 / 200 = $4,824.85

1,007,410 / 200 = $5,037.05

Modified by Montell Reservoir

	Total Damages					Nonagricultural Damages				Urban Damages			
Frequency	Δ Frequency	Discharge (cfs)	Damage	Double Damage	Δ Double Damage	Δ Frequency	Damage	Double Damage	Δ Double Damage	Δ Frequency	Damage	Double Damage	Δ Double Damage
0	0.7		$3,480,400	$5,420,400	$3,794,280	0.7	$165,000	$243,000	$170,100	0.70	$174,800	$211,300	$147,910
0.7	0.3	64,000	1,940,000	3,455,000	1,036,500	0.3	78,000	89,000	26,700	(0.75) 52,000 0.05	36,500	36,500	1,825
1.0	0.2	48,900	1,515,000	2,870,000	574,000	0.2	11,000	19,000	3,800		0		
1.2	0.2	44,000	1,355,000	2,455,000	491,000	0.2	8,000	14,000	2,800				
1.4	0.2	40,600	1,100,000	1,990,000	398,000	0.2	6,000	11,000	2,200				
1.6	0.2	38,000	890,000	1,600,000	320,000	0.2	5,000	9,500	1,900				
1.8	0.2	35,600	710,000	1,285,000	257,000	0.2	4,500	7,500	1,500				
2.0	0.5	33,500	575,000	975,000	487,500	0.5	3,000	5,000	2,500				
2.5	0.5	30,500	400,000	680,000	340,000	0.5	2,000	3,500	1,750				
3.0	0.5	28,000	280,000	472,000	236,000	0.5	1,500	2,500	1,250				
3.5	0.5	26,000	192,000	330,000	165,000	0.5	1,000	1,800	900				
4.0	1.0	24,500	138,000	198,000	198,000	1.0	800	1,200	1,200				
5.0	1.0	22,000	60,000	84,000	84,000	(5.9) 20,000 0.9	400	400	360				
6.0	1.0	19,800	24,000	36,000	36,000		0						
7.0	1.0	18,200	12,000	15,000	15,000								
8.0	1.0	16,800	3,000	4,000	4,000								
9.0	1.0	15,900	1,000	1,000	1,000								
10.0		15,000	0										
					8,437,280				216,960				149,735

8,437,280 / 200 = $42,186.40

216,960 / 200 = $1,084.80

149,735 / 200 = $748.68

Existing Conditions

Total Average Annual Damages = $91,600
Agricultural Average Annual Damages = 81,800
Nonagricultural Average Annual Damages = 4,800
Urban Average Annual Damages = 5,000

Modified by Montell Reservoir

Total Average Annual Damages = $42,200
Agricultural Average Annual Damages = 40,400
Nonagricultural Average Annual Damages = 1,100
Urban Average Annual Damages = 700