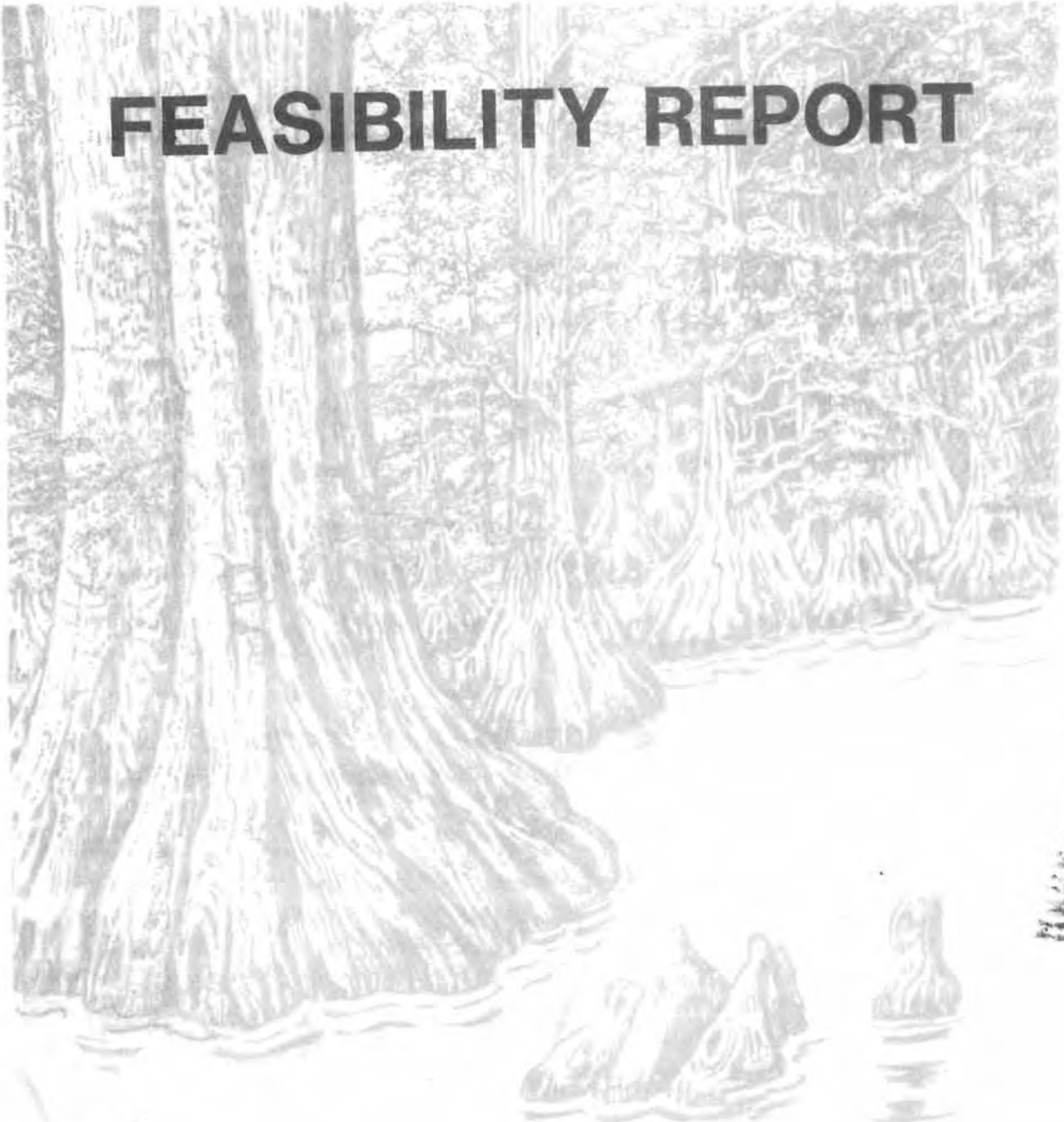
HYDROLOGY FILES

US Army Corps of Engineers
Fort Worth District

CYPRESS BAYOU BASIN, TEXAS

FEASIBILITY REPORT



HYDROLOGY FILES

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SYLLABUS

This report presents the results of a study concerning water resouces plan of improvements for the Cypress Bayou Basin, Texas. The study has been conducted under authority derived from the resolution adopted by the Committee on Public Works and Transportation of the House of Representatives on 9 May 1979.

The study has identified the potential for: significant annual economic losses due to flood damage, significant water supply deficits, and need for additional recreation resources. The study has found the water supply deficit to be the most serious water resource problem in the Cypress Bayou Basin.

A full range of nonstructural and structural alternatives were investigated in an effort to determine the most feasible alternative to best meet the needs of the study area.

The plan investigated by the Fort Worth District that best satisfied the water supply, flood control, and recreation objectives of this study in terms of economic viability was the development of Marshall Lake. However, it was determined there was no federal interest in development of Marshall Lake since its primary purpose would be municipal and industrial water supply, development of which is considered the primary responsibility of the local entities. Although not fully addressing the needs of the study area, the reallocation of storage at Lake O' The Pines alternative was the only other alternative considered implementable and within the purview of existing Corps of Engineers authority. However, the immediate need of the additional water supplies are in question, since the local Little Cypress Utility District is presently pursuing the development of a reservoir in the Little Cypress watershed. The reservoir under consideration would provide outputs similar to Marshall Lake investigated by the Fort Worth District.

The report recommends to take no Federal action at this time and to defer further study regarding storage reallocations at Lake O' The Pines until such time water supply needs develop within the study area.

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102-0300

REPLY TO
ATTENTION OF:

CYPRESS BAYOU BASIN , TEXAS

FEASIBILITY REPORT

CYPRESS BAYOU BASIN STUDY
FEASIBILITY REPORT

MAIN REPORT

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CYPRESS BAYOU BASIN STUDY

CHAPTER 1 - INTRODUCTION

This report presents the results of investigations undertaken to determine the feasibility of providing flood control, water supply, and other water resources purposes within the Cypress Bayou Basin.

STUDY AUTHORITY

The Cypress Bayou Basin Study was authorized by the following resolution adopted on 9 May 1979:

> "Resolved by the Committee on Public Works and Transportation of the House of Representatives, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the reports on Red River and tributaries, Texas, Oklahoma, Arkansas, and Louisiana, downstream from Denison Dam, submitted in House Document No. 602, 79th Congress, 2nd Session, and prior reports, with a view to determining if improvements within the Cypress Bayou Basin, Harrison, Gregg, Marion, Camp, Cass, Morris, Titus, Franklin, Wood, and Upshur Counties in Texas and Caddo Parrish, Louisiana, with respect to flood control, ground and surface water supply and conservation, drainage, and other water resources purposes are warranted."

SCOPE OF STUDY

This feasibility study addresses and evaluates the water resource problems and needs of the Cypress Bayou Basin. The report serves to document: the water resource problems in the basin and their relationship to the overall environmental and socioeconomic needs and desires of the basin's people; the development of alternative management measures; the determination of costs, benefits, and environmental effects associated with implementing these measures; selection of a plan which would effectively solve the basin's problems in a way that would be compatible with the socioeconomic and environmental needs and desires of the study area's peoples; and the study recommendation.

STUDY PARTICIPANTS AND COORDINATION

The Cypress Bayou Basin Study was conducted by the Fort Worth District of the U.S. Army Corps of Engineers in coordination with interested Federal, State, and local agencies and officials, and the public. Area economic and water supply studies were prepared by the Economic and Social Analysis Branch of the Southwestern Division of the Corps of Engineers. Coordination has been maintained with the U.S. Fish and Wildlife Service (USFWS) throughout the study. The USFWS has submitted a series of planning aid letters to help in the formulation and evaluation of alternatives. The Vicksburg District of the Corps of

Engineers conducted a separate study of the feasibility of raising Caddo Lake to increase water supply. Close coordination was maintained with this district to share analyses and results to prevent duplication of effort. The Corps of Engineers Waterways Experiment Station developed a special aquatic habitat evaluation analysis on the streams of the basin to aid in the evaluation of alternatives. The Tulsa District of the Corps of Engineers provided hydropower analyses on several of the alternatives. Information was also shared with the architect-engineer firms of Kindle, Stone and Associates (KSA) and Freese and Nichols (FN). KSA had performed several water supply studies for cities in the study area. This firm also served as a source of information on future plans for water resources development in the area under study. The firm of FN served as a source of information on storage reallocation at Lake O' The Pines.

PRIOR STUDIES AND REPORTS

Several water resources planning studies for the Cypress Bayou Basin have been completed. Prior reports considered particularly pertinent to the current study are listed below.

- Review of Reports on Red River and Tributaries, Texas, Oklahoma, Arkansas, and Louisiana, Downstream from Denison Dam, Corps of Engineers, New Orleans District, April 1946.
- Review of Reports on White Oak, Cypress, and Little Cypress Creeks, Texas, Corps of Engineers, New Orleans District, October 1960.
- Comprehensive Basin study, Red River Below Denison Dam, Louisiana, Arkansas, Oklahoma, Texas, Interim Report on Navigation and Bank Stabilization, Corps of Engineers, New Orleans District, March 1966.
- Comprehensive Basin Study, Red River Below Denison Dam, Arkansas, Louisiana, Oklahoma, and Texas, Red River Basin Coordinating Committee, June 1968.
- Red River and Tributaries Downstream from Denison Dam - West Agurs Levee, Louisiana, Days Creek and Tributaries, Arkansas and Texas; and McKinney Bayou, Arkansas and Texas, Corps of Engineers, New Orleans District, April 1972.
- Water for Texas, A Comprehensive Plan for the Future, November 1984.
- Continuing Water Resources Planning and Development in Texas (Draft Report), Texas Water Development Board, May 1977.
- Geological Reconnaissance of the Sulphur River and Cypress Creek Basins, Texas, Waterways Experiment Station, November 1967.

- Texas Water Plan Study, Cypress Creek and Sulphur River Basins, Texas, New Orleans District, October 1968.
- Texas Water Plan, Water Storage and Conveyance Systems, Sulphur River and Cypress Creek Basins, Texas, and Withdrawal and Conveyance Systems, Mississippi River to Calcasieu - Sabine Watershed Divide, Louisiana Coastal Area, New Orleans District, September 1973.
- Projected Water Needs for Marshall and Harrison County, Texas, as Related to Available Water Supplies, Especially that from Added Storage in Caddo Lake, Texas-Louisiana, Lockwood, Andrews, and Newnam, Inc., 1970.
- Basic Perspective on Water Resources Potential of the Cypress Creek Basin, Freese and Nichols, Inc., August 1977.
- Marshall Water Supply Study, Kindle, Stone, and Associates, Inc., August 1979.
- Cypress Bayou Basin Study Reconnaissance Report, U.S. Army Corps of Engineers, Fort Worth District, July 1981.
- Area Economic Study of Cypress Bayou Basin, Texas-Louisiana, U.S. Army Corps of Engineers, Southwestern Division, September 1981.
- Little Cypress Water Supply, U.S. Army Corps of Engineers, Southwestern Division, July 1981.
- Cultural Resources Overview of the Proposed Black Cypress and Marshall Reservoirs, Environment Consultants, Inc., July 1981.
- Supplemental Data of Arkansas - Red River Basin Chloride Control, Red River Basin, Design memorandum No. 25, Phase I GDM, Volume I, U.S. Army Corps of Engineers, Tulsa District, November 1980.
- Red River Below Denison Dam, Comprehensive Basin Study, Arkansas, Louisiana Oklahoma, and Texas, Summary of Results, Texas and Louisiana, Caddo Lake Enlargement Study, U.S. Army Corps of Engineers, Vicksburg District, November 1985.
- Little Cypress Utility District, Preliminary Engineering Report for Little Cypress Reservoir, Kindle, Stone and Associates, Inc., February 1986.

CHAPTER 2 - EXISTING CONDITIONS

This chapter defines the study areas investigated, establishes base conditions, and discusses the opportunities for resource management.

GENERAL

The study area for this investigation is outlined in the study resolution. The study area encompasses the Texas counties of Camp, Cass, Franklin, Gregg, Harrison, Marion, Morris, Titus, Upshur, and Wood and includes Caddo Parish, Louisiana, see plate 1. (NOTE: All plates are located at the back of the main report.) These counties completely contain the Cypress Bayou Basin as shown on plate 2. The Longview-Marshall Standard Metropolitan Statistical Area (SMSA) and the Shreveport SMSA (part) are included in the study area.

BASIN DESCRIPTION

The Cypress Bayou Basin is the watershed upstream of Caddo Dam in northeast Texas and northwest Louisiana. The basin is bounded on the north by the Sulphur River Basin, on the west and south by the Sabine River Basin, and on the east by the Texas-Arkansas and Texas-Louisiana state boundaries.

The headwaters of Big Cypress Creek form in southeastern Hopkins County. The creek flows southeasterly and becomes Big Cypress Bayou in Marion County. In Marion County, Big Cypress Bayou is joined from the north by Black Cypress Creek. Big Cypress Bayou is then joined from the south by Little Cypress Bayou in Harrison County. Big Cypress Bayou then flows easterly into Caddo Lake.

CLIMATOLOGY

General

The factor that determines the climate of the study area is its variable exposure to differing air mass properties. The prevailing summer influence of moist tropical air from the Gulf of Mexico produces convective thunderstorms with occasional westerly and northerly winds bringing hotter and drier weather to the area. During the winter, portions of the study area can be subjected alternately to tropical and polar air masses, the latter being capable of large and sudden drops in temperature. Although rainfall is abundant, short periods of dry weather are frequent over small areas.

Temperature

The average annual air temperature ranges from 64 degrees to 67 degrees F. Normal monthly temperatures range from 84 degrees F. in August to 44 degrees F. in January. Temperatures, for northeast Texas, are given in table 1. (NOTE: All tables are located at the back of the main report in front of the plates.) Normal, as used in this and the following paragraph, is as published by the National Weather Service.

Precipitation

Precipitation is predominantly of the shower type except for occasional periods of continuous general rains during the late fall, winter, and early spring. The average number of days with measurable precipitation is 60 per year. Annual normal is 32.9 inches for northeast Texas. Average monthly normals for the basin range from 1.9 inches in January to 4.65 inches in May with the distribution as shown in table 1. Months with zero precipitation have occurred at many stations throughout the study area. Snowfall is a minor part of the area inflow, occurring about once every 2 to 3 years. Average snowfall varies from a maximum of 2.4 to 1.7 inches in the study area.

Evaporation

Evaporation records are available for various locations near the study area. The Daingerfield, Texas, and Sam Rayburn Dam, Texas, gaging stations indicate evaporation rates applicable to the area. The average monthly evaporation varies from 10.1 inches in July to 2.6 inches in January for the Daingerfield station and 8.3 inches in July to 3.0 inches in January for the Sam Rayburn Dam station. Monthly evaporation rates for these stations are given in table 1 and are published in the NOAA Technical Report NWS 34 by the National Weather Service.

GENERAL GEOLOGY AND GROUND WATER RESOURCES

The Cypress Bayou Basin is underlain by southeasterly dipping sand, clay, glauconite, and lignite of the Wilcox and Claiborne Groups of Tertiary age. Most of Texas iron ore production comes from formations within the basin.

The Carrizo-Wilcox aquifer extends throughout the Cypress Bayou Basin. It consists of the Wilcox Group and the overlying Carrizo Formation of the Claiborne Group. The aquifer is made up of fine to medium grained sand and sandstone interbedded with clay and silt, and minor amounts of lignite in the Wilcox Group. Yields of large capacity wells average about 200 gpm, but some in thicker sections produce up to 900 gpm. The water generally contains less than 500 mg/l total dissolved solids and is excessive only in its iron content.

The Queen City aquifer occurs in a wide band across the central part of the basin. It consists of fine to medium grained sand, interbedded with clay, glauconite, and lignite. Total thickness ranges up to about 500 feet. Well yields are generally small. However, wells tapping the aquifer may be capable of yielding as much as 20 gpm. Water quality in the aquifer generally is acceptable for municipal, some industrial, and irrigation uses. Dissolved solid content is less than 50 mg/l and meets the standard of drinking water; however, there is an excessive content of iron. Plate 3 shows the locations of the two ground water aquifers.

EXISTING WATER RESOURCES DEVELOPMENT

The nine major existing reservoirs in the Cypress Bayou and Twelvemile Bayou Basins are listed in table 2. Caddo Lake is a combination non-Federal and Corps of Engineers project. Lake O' The Pines is a Corps of Engineers project. The other reservoirs are owned and operated by non-Federal interests. All the projects provide municipal and industrial water supply and/or steam electric powerplant cooling water. Recreation facilities are provided at several projects. Lake O' The Pines is the only project with flood control storage.

Caddo Dam is located in Caddo Parish, Louisiana, about 19 miles northwest of Shreveport, at the head of Twelvemile Bayou. Caddo Lake is located in Louisiana and Texas. A natural lake existed prior to construction of the dam in 1914 by the Corps of Engineers. Construction of a new dam was completed by the Corps of Engineers in 1971. Prior to 1976, the dam was owned and maintained by the Caddo Lake Levee District. The Water Resources Development Act of 1976 transferred maintenance responsibility to the Corps of Engineers. The city of Marshall, which holds water rights to the flows of Big Cypress Bayou, diverts water from Big Cypress Bayou and backwaters of Caddo Lake. Oil City and Mooringsport, Louisiana, withdraw municipal water supplies from the lake. Cooling water is also withdrawn from the lake by a steam electric power plant located near Mooringsport. The city of Shreveport recently completed major elements of a pumping system which could be used to deliver water from Caddo Lake to Cross Lake (Shreveport's present supply) thence to the city for municipal use. Caddo Lake is very popular for fishing and other recreational activities. The Vicksburg District has studied the possibility of enlarging Caddo Lake to increase its yield.

Ferrell's Bridge Dam and Lake O' The Pines was constructed and is operated by the Corps of Engineers for flood control, water supply, and recreation. The dam is located on Big Cypress Bayou about 8 miles west of Jefferson, Texas. The lake contains a flood control pool of 587,200 acre-feet with an area of 38,200 acres, and a water supply pool of 254,900 acre-feet with an area of 18,700 acres. The Northeast Texas Municipal Water District has contracted for the conservation storage and presently supplies municipal and manufacturing water needs to the cities of Daingerfield and Hughes Springs, industrial water needs of the Lone Star Steel Plant, and powerplant cooling water.

Monticello, Ellison Creek, Welsh, and Johnson Creek Reservoirs are located on tributaries of Big Cypress Creek and all serve manufacturing and steam electric powerplant cooling water needs. Monticello Lake on Blundell Creek is owned by Dallas Power and Light Company. Welsh Lake on Swauano Creek and Johnson Creek Lake are owned by Southwestern Electric Power Company. Ellison Creek Reservoir is owned by Lone Star Steel Company and supplies water for its steel mill located near Daingerfield. These lakes are maintained at constant operating levels by pumping water from existing lakes on Big Cypress Bayou. These diversions are made under a contractual agreement described later.

Lake Cypress Springs and Franklin County Dam, located near the headwaters of Big Cypress Creek, is owned by Franklin County Water District. The district currently supplies raw water to the city of Mount Vernon and has commitments to serve rural areas in the Franklin County area through the South Franklin Water Supply Corporation. Water is also committed to Texas Utilities Generating Company for steam powerplant cooling.

Fort Sherman Dam and Lake Bob Sandlin, located on Big Cypress Creek just downstream from Franklin County Dam, is owned by the Titus County Fresh Water Supply District No. 1. The project is located at the previously proposed Titus County Reservoir site and has also been called the Cherokee Trail Lake. The project supplies the municipal and manufacturing water needs of the city of Mount Pleasant and cooling water for a Texas Utilities Generating Company steam electric plant.

Owing to the complexities arising from the appropriation of waters of the Cypress Creek Basin and the rapid development and use of the basin supplies, extensive hydrologic studies of the basin have been performed by the local interests/water districts, etc. which led to the development of an operating agreement between the Franklin County Water District, the Titus County Fresh Water Supply District No. 1, the Northeast Texas Municipal Water District, the Texas Water Development Board, and Lone Star Steel Company. This agreement governs the operation of Lake O' The Pines, Monticello Lake, Ellison Creek Lake, Welsh Lake, Johnson Creek Lake, Lake Cypress Springs, and Lake Bob Sandlin. The agreement, approved by the participants in 1972, includes rules for the operation of reservoirs owned by various entities and provisions for accounting for the waters held in storage. In 1973, the Texas Water Rights Commission adopted an order approving the operating agreement. Basically, the agreement provides that Lakes Cypress Springs and Bob Sandlin can impound and store water previously appropriated to downstream entities (specifically Lake O' The Pines and Lone Star Steel Company) subject to call for releases from upstream storage to satisfy downstream requirements as needed. The agreement establishes storage accounts in the main stem reservoirs and Ellison Creek Lake such that the basin waters are appropriately divided, in accordance with existing water rights, through exchange of storage.

Cross Lake is located on Cross Bayou at the northeast edge of Shreveport. The lake is the primary source of water supply for Shreveport.

Black Bayou Lake is located on Black Bayou about 2 miles northeast of the city of Vivian, Louisiana. The lake is owned by the State of Louisiana.

TERRESTRIAL HABITATS

The Cypress Bayou Basin is located entirely within the Austroriparian biotic province of Texas. Pine-hardwood forest dominates in upland areas. It consists of shortleaf and loblolly pine, red oak, overcup oak, blackjack oak, post oak, hickory, maple, beech, sweetgum, and sycamore. Bottomland hardwoods along the flood plains contain willow oak, water oak, black willow, bald cypress, blackgum, sweetgum, river birch, green ash, water hickory, winged elm, and water elm. Most of the bottomland area is considered to be wetlands. The original upland forest has been extensively cleared for agricultural purposes, particularly in the western portion of the basin. Some of the hardwood forest has been converted to monocultured pine forest for commercial lumbering. Bald cypress swamps are present along drainages in the eastern portion of the basin and are significant along Big Cypress upstream of Caddo Lake.

WILDLIFE

The mixed forest provides habitat for a number of game, nongame and furbearing species of wildlife. At least 47 species are supported, or have been supported in recent times, in this habitat. Game mammals include fox and gray squirrel and whitetail deer. Common small nongame mammals are armadillo, rabbits, opossum, raccoon, and several species of skunks, bats, and rodents. Bobcat, coyote, and gray fox are the principal predators. At least 29 species of snakes, 10 species of lizards, 2 species of land turtles, and 35 species of amphibians are supported.

At least 216 species of birds have been recorded within the Cypress Bayou Basin. Resident game species include bobwhite quail, wood duck, and turkey, with woodcock occasionally breeding locally. Numerous species of waterfowl migrate through or winter along streams, sloughs, and swamps in the basin and on impoundments. The Texas portion of the basin is located in the central flyway, with the Louisiana portion (lower Caddo Lake and Twelvemile Bayou) in the Mississippi flyway. Mourning dove are also present in fair numbers.

Nongame birdlife includes many woodpeckers, hawks, owls, warblers, thrushes, and other resident or migrating species found in wooded to partially wooded habitats. Shorebirds are common on impoundments during spring and fall migrations.

AQUATIC HABITATS

Aquatic habitats within the Cypress Bayou Basin are numerous and diverse. Manmade surface waters include Lake O' The Pines (18,700 acres), Lake Cypress Springs (4,500 acres), Lake Bob Sandlin (9,460 acres), Ellison Creek Reservoir (1,560 acres), Johnson Creek Reservoir (650 acres), Lake Monticello (2,000 acres), many smaller lakes and ponds, and Caddo Lake (26,800 acres), the only natural lake in Texas with a capacity greater then 5,000 acre-feet, at the eastern edge of the basin. Natural waters range from intermittent headwaters through fresh marshes and swamps to mature sluggish meandering streams.

Diversity of habitat is reflected in the diversity of aquatic species of the Cypress Bayou Basin, with more than 75 fish species reported. Darters include, among others, the dusky, gold-stripe, mud-darter, slough, and redfin. Shiners, suckers, top minnows, and finfish species all occur in rich diversity. Chain pickerel, bowfin, chestnut lamprey, banded pygmy sunfish, pirate perch, and flier are a few species which could be considered unique to streams or backwaters of the area. Sport species include largemouth black bass, spotted bass, blue and channel catfish, and black and white crappie.

Aquatic vegetation is found in low to moderate amounts in impoundments within the basin. Emergent and floating aquatic vegetation include pondweed, water primrose, pennywort, American lotus, and arrowhead. Submerged species include water milfail, coontail, and najas. American lotus, water milfail, longleaf pondweed, and arrowhead occur on some impoundments in problem quantities, restricting fisheries access from shoreline access. However, no major nuisance growths of aquatic weeds are recognized. Shoreline and wetland species include bald cypress, black willow, bullrush, and numerous species of sedges and rushes.

ENDANGERED AND THREATENED SPECIES

The USFWS and the Texas Organization for Endangered Species (TOES) have developed separate lists of endangered species known to occur within the Cypress Bayou Basin. These resident species are listed in table 3. There are no federally listed species of endangered fish or invertebrates found within the basin. There are also no listed species of endangered or threatened flora within the basin. However, there is one species of proposed endangered flora identified as occurring within the basin. This is Coreopsis intermedia from Franklin, Wood, and Upshur Counties. Aquatic habitats of the study area are described in detail by Planning Aid Letter from the USFWS dated July 1984. This Planning Aid Letter is contained in appendix H.

WATER QUALITY

Quality of the water in the Cypress Basin streams is generally good. Measurements have been made of the pH, temperature, dissolved oxygen, fecal coliform, total dissolved solids, chloride, and sulfate in the streams. With the exception of dissolved oxygen, these measurements have shown values to be within the approved standards for surface water set by the Texas Department of Water Resources. Dissolved oxygen in the water periodically falls below the standard of 5.0 mg/l. This appears to be due to the low rate of reaeration of the streams. In the past, isolated instances of oilfield pollution in small streams have occurred. These have mostly been eliminated due to new rules and monitoring of oilfield operations. Cypress Bayou is low in total dissolved solids, averaging 120 milligrams per liter (mg/l), and all concentrations are below the Texas Department of Health's drinking water standards. Most metals are found in very low concentrations. Iron and manganese are found in higher concentrations than the other metals as a result of the geology of the basin. Man-made organic compounds are seldom found in the water column. Only the herbicides 2,4,5-T and 2,4-D have been found more than once in measurable levels. The analyses of bottom sediments do show measurable levels of many man-made organic compounds. The water quality analysis report contained in appendix G discusses in detail the water quality in the Little Cypress watershed.

CULTURAL RESOURCES

The potential is high for finding historic and prehistoric cultural resources in the study area. The earliest published works concerning the prehistory of the basin noted the presence of mounds in the Caddo Lake area. In the 1930's, major field expeditions into the region began under the auspices of the Works Progress Administration. With the start of World War II, archeological field work in the area was halted and remained somewhat stagnant until 1951, when a survey report was prepared by the River Basin Surveys, Smithsonian Institution, on Ferrell's Bridge Reservoir (Lake O' The Pines) in Harrison, Marion, Upshur, Cass, Morris, Titus, and Camp Counties. In the 1960's and 1970's, a number of archeological salvage projects were also undertaken in the basin area.

A reconnaissance level investigation of the Cypress Bayou Basin was conducted in 1981. The study area focused in on the area between two potential lake sites and includes specifically Lake O' The Pines. Plate 4 shows the location of the study area.

Studies in and around the project area suggest occupation in the Archaic period from about 3000 B.C. to A.D. 500, followed by the Caddoan period, with sites dating from A.D. 500 to A.D. 1600. This time period is subdivided into several segments called focuses: Alto, Haley, Whelan, Titus, and possibly Kinsloe.

The investigation outlined a number of areas of high probability for prehistoric sites. In addition, local informants indicated the locations of eight prehistoric and five historic sites within the boundaries of the two investigated reservoirs. Although no sites currently listed on the National Register of Historic Places were noted within either potential lake boundary, a number of potentially eligible sites at both locations are thought to exist.

HUMAN RESOURCES

Population

The 1980 populations of the 10 Texas counties and 1 Louisiana parish located within the study area are shown in table 4. Also shown in table 4 are all cities with a population greater than 2,000. These cities are shown with their respective counties. The historical population trends for the study area are indicated in table 5. Population in the study area increased 35 percent from a 1950 total of 406,316 to a 1980 total of 549,367. Only one community, Jefferson, experienced a decline (16 percent) in population for the 30-year period. The area economic study included in appendix B contains additional data pertaining to population projections in the study area.

Employment

Employment in the study area in 1970 (table 6) totaled 170,139. Services, manufacturing, and trade were leading employment sectors of the study area economy. Approximately 27.3 percent of the study area work force was employed in the service sector. Manufacturing was the second-leading sector with approximately 21.6 percent of the work force employed. Trade (wholesale and retail) is the third leading economic sector with approximately 20.6 percent of the work force employed. Employment trends are discussed in detail in the area economic study included in appendix B.

Per Capita Personal Income

As shown on table 7 per capita personal income for the Cypress Bayou Basin study area increased 106 percent from $1,926 in 1959 to $3,965 in 1978. The 1978 through 2050 projected average annual per capita personal income growth rate for the study area is 1.87 percent. The area economic study, appendix B, includes additional discussion on per capita income projections.

Value Added by Manufacture

Value added by manufacture (VAM) for the study area increased by 77 percent from $388.2 million in 1967 to $688.2 million in 1977 at an average annual rate of 5.89 percent. Principal industries in the study area include fabricated metals, food and kindred products, and machinery (except electric) in that order of importance. Additional discussion on VAM is contained in the area economic study of appendix B.

Value of Farm Products Sold

Value of farm products sold (VFPS) in the study area in 1978 totaled $64.8 million. Livestock production accounts for the majority of the value of farm production sold (86.2 percent), with crop sales accounting for 13.8 percent. The VFPS is discussed in further detail in the area economic study of appendix B.

Value of Mineral Production

The oil and gas industry is the leading minerals industry in the Cypress Bayou Basin study area. The study area is part of what is known as the "East Texas Oil Field," with oil reserves considered to be among the largest in the continental United States. Crude oil production showed a general trend of decline over the period 1970 to 1979 from 109.2 million barrels to 83.7 million barrels. Natural gas production in the study area remained relatively constant with a production of 185.2 million MCF in 1970 to a production of 178.9 million MCF in 1979. Values of these mineral productions are shown in table 8.

Lignite is also present in the Cypress Bayou Basin study area as part of lignite deposits in south and east Texas and northwest

Louisiana. Lignite's value as a source of energy, under present technology and conditions, is mainly through its use in "mine-mouth" operations (burned at or near the lignite mine source). Currently, the use of lignite in the study area is limited to use as a fuel source at the Texas Power and Light Plant in Titus County, Texas. However, the Pirkey Power Plant, located in Harrison County, Texas, is currently being developed by Southwestern Electric Power Company. Ample supplies of lignite from various deposits nearby are available to meet the needs of the expected 30-year life of the Monticello Plant, and an adequate 25 year supply is available for the Pirkey Power Plant. The area economic study, appendix B, contains additional discussion on value of mineral production.

CHAPTER 3 - PROBLEM IDENTIFICATION

This chapter identifies the potential water resources problems in the study area and presents the forecasts of Federal action (without project) conditions. The period 1990 through 2040 was the planning timeframe considered in the analysis of without project conditions.

WATER SUPPLY

A water supply study for the Cypress Basin was completed in 1981. The water supply study area is shown on plate 5. The water demand for the Texas counties and Louisiana parish in the study area was projected to the year 2040 for the municipal, industrial, and power segments of the economy. Water supplies available in the area were also determined. Water is supplied by both ground water and the surface sources described earlier. Differences between demand and supplies indicate a need for additional supplies. Table 9 shows the demand, supplies, and net needs for each county in the study area. This tabulation shows some counties developing a need for new water supplies by 1990. Appendix B contains the detailed water supply study for the Cypress Basin.

Cass County shows a large industrial demand and will need new water supplies by the year 2020. This demand is from the International Paper Company which is located downstream of Wright Patman Lake. The paper company obtains its water from the lake, and both are located in the Sulphur River Basin. The International Paper Company has contracts for water which are triple the amount currently being used.

The paper company was contacted to determine what its plans were to meet the future water demand. A spokesperson for the company said no plans were being made to develop more water supplies and the demand projections seemed excessive. The spokesperson felt that current water supplies were adequate to meet all future demand of the International Paper Company. Based on this discussion and the fact that both the major supply and demand of Cass County lie outside of the Cypress Basin, it was decided to remove Cass County from the water supply analysis for the Cypress Bayou Basin.

The next county with a substantial demand is Gregg County. It shows a need for water by 2030. Municipal demands in Gregg County come from the urban areas of Longview, Kilgore, and Gladewater. These cities also provide water to smaller surrounding communities and water supply districts. The major industrial users are Texas Eastman Company, Joseph Schlitz Brewing Company, Southwest Steel Castings, Marathon-LaTouneau, and Joseph Schlitz Container Division.

Harrison County will need additional water supplies by 1990. Demand is from the city of Marshall and the industry located there. ICI Americas, Incorporated, and ALCOA Conductor Products Company are significant industrial water users. The city of Marshall is conducting studies to determine the best source of additional water supplies.

A large industrial demand occurs in Morris County. This demand comes from the Lone Star Steel Company. Projections indicate this county will require an additional source of water supply by 1990.

Caddo Parish, the only part of the study area located in Louisiana, has a high municipal demand due to the city of Shreveport. Caddo Parish will need additional water by the year 2000. There are several large users of industrial water in Caddo Parish such as Atlas Processing Company, General Motors Corporation, and Western Electric. Barksdale Air Force Base is provided water by the city of Shreveport. The Vicksburg District is responsible for studying water supply needs of northwest Louisiana. The Red River Compact, discussed in more detail later under planning constraints, allocates most of the water developed in the Cypress Basin to Texas users. Based on this fact, the Vicksburg District projected Shreveport's water needs will be met from sources within Louisiana. Therefore, the demand and supply of Caddo Parish has been removed from the analysis of water supply for the Cypress watershed.

The data in table 9 was modified by removing the needs of Cass County and Caddo Parish. Then, looking at the counties with needs and the counties with surpluses, it was analyzed as to where the surpluses could go to meet other counties' needs. Only the 2040 surplus in a county was considered for use elsewhere. Camp County has a 2040 surplus of 0.3 mgd from ground water wells. This small amount of ground water is not near any major demand center and was considered not transferable. Franklin County has no 2040 surplus. Its supplies will just meet its demand. Marion County has a 2040 surplus of 2.2 mgd from Lake O' The Pines. It was assumed that Lone Star Steel in Morris County could easily get access to this surplus, and the 2.2 mgd was subtracted from the Morris County needs. Titus County has a 2040 surplus of 8.3 mgd from Lake Cypress Springs. Wood County is the closest demand center and is within reasonable transmission distance. It was assumed that 4.2 mgd of this surplus would go to Wood County, thus eliminating its need for additional water supply. The remaining 4.1 mgd could be released downstream to Lake O' The Pines for use by Lone Star Steel. Therefore, an additional 4.1 mgd was subtracted from the Morris County needs. After removing Cass County and Caddo Parish and allowing for all surplus transfers, the needs in each county are as shown in table 10. The table shows two counties in the study area will develop a 5.0 mgd need for additional supplies of water by the year 1990. However, the total study area needs will reach 129.0 mgd by the year 2040. The lack of adequate water supplies for projected future growth is clearly a problem of the Cypress Bayou Basin.

FLOODING

The streams of the Cypress Bayou Basin are generally tortuous, unimproved, and overgrown in many locations by trees, saplings, and underbrush which cause these streams to frequently overflow. Caddo Lake dam has a spillway with a minimum elevation of 168.5 NGVD. Flows through Caddo lake must pass over this spillway which creates backwater effects in Caddo Lake, and these effects extend up Big Cypress Bayou. Floods in the basin generally rise and fall slowly and have relatively low velocities since the heavily timbered basin and flood plains retard surface runoff and overbank floodflows.

The nonfloodflow channel capacity of Big Cypress Bayou from the confluence of Little Cypress Bayou to Caddo Lake is 7,000 cubic feet per second (cfs). Flows in excess of this will cause flood damages. Floodflows first cover access roads, damaging them and creating a hazardous situation for the homes and businesses serviced by these roads. Higher flows begin to damage structures.

Lake O' The Pines, the only flood control lake in the study area, began to impound water in 1957. However, since that time, the uncontrolled tributary watersheds of the Little and Black Cypress Bayous have caused floodflows to occur along Big Cypress Bayou 12 times. The dates of these occurrences are:

April 1957
May 1958
December 1960
April 1966
May 1968
April 1973
December 1973
June 1974
February 1975
April 1979
May 1979
January 1980

Twelvemile Bayou which extends from Caddo Lake to Shreveport, is protected by Federal and non-Federal levees. Damages occur to agricultural operations, residences, farm buildings, and oilfield operations due to ponding of intense runoff during periods of high stages in Twelvemile Bayou. The 1968 Comprehensive Basin Study for the Red River Below Denison Dam determined solutions to the ponding problems were not economically feasible. Based on the findings of the 1968 report, flood problems along Twelvemile Bayou were not addressed in this study.

Development in the flood plains around Caddo Lake and along Big Cypress, Little Cypress, and Black Cypress Bayous is composed of roads, bridges, oilfield facilities, residences, and commercial businesses. Very little of the flood plain is utilized for agricultural purposes. The residences are a combination of year round homes placed linearly around the lake and along the stream to have access to water and take advantage of the esthetic value of the watercourses. Development is not continuous but occurs in small groups or communities. The businesses are related to the fishing and recreation pursuits of the area. Table 11 shows the estimated value of existing investments within the SPF flood plain. The type, number, and value of the structures within the SPF flood plain are shown in table 12. Single occurrence flood losses to the flood plain investment for various frequency floods are indicated in table 13 with table 14 giving the average annual flood losses for the flood plain. From table 14 it can be seen that 75 percent of the existing average annual flood damage is to urban structures, with the majority of losses occurring along the Caddo Lake and Big Cypress Bayou reaches.

RECREATION

The 1980 Texas Outdoor Recreation Plan (TORP) indicates that a wide deficit exists between the projected recreational needs in the Cypress Bayou Basin and the output capacities of all existing and proposed recreational outlets. Indications are recreation needs will continue to exceed the number of facilities being provided and additional recreational outlets will be needed to help reduce this deficit.

The need for preservation of natural areas for open space and fish and wildlife management is increasingly apparent as more existing areas are encroached upon by commercial or housing developments and more intensified land use. However, the TORP did not list any natural areas along Big Cypress, Little Cypress, and Black Cypress Bayous which were worthy of preservation.

Texas has many lakes, rivers, and streams; however, existing public recreation areas adjacent to many of these waters are crowded, while the waters themselves are underutilized. Land access to public waters should be increased. In providing additional lands, priorities should be given to lands for utilization as recreation areas in proximity to larger metropolitan areas where there is a considerable need for facilities such as picnic areas, campgrounds, and trails.

The section of Big Cypress Bayou from Lake O' The Pines to Caddo Lake State Park is one of the more popular waterways in Texas. Provision for better access and water depths would enhance this area's recreational potential. Table 15 depicts the rural and urban recreational resource requirements identified in the TORP for State Planning Regions 5 and 6, which encompass the Cypress Bayou Basin. The recreation needs of the study area are discussed in detail in appendix D.

HYDROPOWER

No existing hydroelectric generating facilities are in the study area. The Cypress Bayou Basin is located in the Southwest Power Pool (SPP) area which is comprised of the entire states of Kansas, Oklahoma, Arkansas, and Louisiana, and portions of Mississippi, Missouri, Texas, and New Mexico. The SPP is well interconnected electrically, and energy generated in one part of the SPP could be used in another part.

In 1980, electric utilities in the SPP served a population of about 21,000,000 rural, residential, and commercial customers. The energy requirements totaled 117,000 GWH which included heavy industrial loads. The noncoincident peak demand for the summer of 1980 for the region was 44,929 MW, and the installed capacity at that time was 52,361 MW, for an indicated reserve, without system interchanges, of about 16.6 percent. The projected growth for the period 1981-2000 is estimated to be about 4.0 percent for both capacity and energy. The SPP is a summer peaking area resulting from temperature sensitive air conditioning loads. The summer loads are estimated to increase to

90,042 MW in the year 2000. The ratio between winter and summer loads is about 70 percent. It is assumed that utilities considered load management, conservation, time of day peaking, etc. in all their load forecasts for future loads. Should all the capacity scheduled for the region be installed as planned, an additional 590 MW will be needed by the year 1986, and about 38,500 MW will be required by the year 2000 in order to meet the required summer loads and reserves.

Table 16, which was taken from reports to FERC filed by the utilities, shows the capability, peak demand, reserves, and annual energy for the SPP. After 1986, scheduled and planned capacity, as reported by the utilities to the Department of Energy, will not be sufficient to meet the load, and any hydroproject developed in the interim could be readily utilized on the load. It is evident that any hydroprojects developed during the 1981-2000 year study period can be utilized on the load of the SPP, provided construction schedules are coordinated with the other utilities in the region.

WATER QUALITY

Quality for the streams within the basin is generally good. Dissolved oxygen deficits have occurred in some reaches of the stream. These are generally due to low stream discharge rates, low reaeration rates, and localized decaying vegetation characteristic of streams in the Cypress Basin. In the past, oilfield brine disposal was a problem for some reaches. Recent water quality rules and monitoring have eliminated these problems, and if proper disposal techniques are continued, oilfield wastes should not be a problem.

There are some industrial waste discharges in the basin. Observations at a water quality station on Little Cypress Creek have detected no dangerous levels of pollutants. Chromium concentrations have ranged from 0 to 0.02 mg/l, which is below the 0.05 mg/l limitation required for domestic water supply. Zinc concentrations have ranged from 0 to 0.48 mg/l with no known fish kills in Little Cypress Creek.

Traces of other contaminants have been found but not at dangerous levels. Mercury, lead, PCB's, and other pesticides have been detected. High levels of iron and manganese have been found in Little Cypress Creek. These metals are not hazardous to public health, and their presence is attributed to runoff and the geology of the basin. As stated before, the waters of the Cypress Bayou Basin are of good quality and are suitable for all purposes, ranging from contact recreation to water supply. Further detailed investigation of the existing water quality in the Little Cypress watershed is presented in Appendix G - Water Quality Analysis.

FISH AND WILDLIFE

Upland forested habitat in the Cypress Bayou Basin remains generally dense in the eastern half of the basin, but substantial clearing of the mixed pine-hardwood forest has occurred in the western half. Wildlife populations are a product of habitat, and the use of wildlife resources is intimately related to land use changes and management. Water resource development decisions will affect land use and human population in the basin and thus wildlife resources.

Hunting activities are eagerly pursued by a significant portion of the basin's population. However, public hunting is generally available only at Lake O' The Pines (Federal) and on commercial forest lands (International Paper Company). Problems related to hunting are the high costs of leasing private lands, crowded conditions on public lands, uneven distribution of wildlife, and lack of public access to high quality areas.

Created impoundments in the basin are a major sport fisheries resource and most are publicly accessible. Several of these reservoirs are relatively recent and provide quality fishing. As long as newly impounded public water becomes available, demands for quality sport fishing can usually be met. As fishing pressure increases, the demand for more intensive fishery management of the older reservoirs will increase to provide publicly acceptable sport fishing. Also, any new water resource improvements have the potential of providing instream flows which could enhance or optimize downstream fishery resources.

Opportunities for environmental quality preservation or enhancement abound in the Cypress Bayou Basin. Scenic, botanical, and wildlife resources remain plentiful in many areas within the basin and should be available for scientific or nature study and such nonconsumptive uses as wildlife photography or birdwatching. Although there are no major areas on a scale of a national park within the basin, there are locally important and significant biological features which are of interest either as unique communities or as survivors of the original natural environment. One natural area, the Alligator Bayou Islands, located in the upper reaches of Caddo Lake, has been identified as worthy of preservation in the Texas Natural Area Survey of 1966-67.

Other priority habitats which should be preserved consist primarily of the flood plain or bottomland hardwood forest and associated cypress/tupelo swamps, sloughs, and wetland areas. Based on preliminary estimates, there may be as little as 60,000-90,000 acres of quality bottomland hardwoods remaining along the major streams of the Cypress Bayou Basin. These areas are highly productive wildlife habitats. The cypress/tupelo swamps and other wetland habitats, in addition to their esthetic value, also provide high quality wildlife habitat and are limited in extent. Of lower priority, but still sensitive and important to wildlife, are the mixed hardwood/pine upland forests. While these areas are relatively extensive, they continue to be cleared for agriculture or pine monoculture.

NAVIGATION

There are no navigation facilities in the study area. The River and Harbor Act of August 1968 authorized a navigation project on the Red River from the Mississippi River to Shreveport, Louisiana, and on Twelvemile and Cypress Bayous from Shreveport, Louisiana, to Daingerfield, Texas. Construction has been initiated on the Red River reach. A transportation economics reanalysis of the Shreveport to Daingerfield reach was completed in February 1980 by the New Orleans District. The result of this reanalysis was a recommendation for a more comprehensive study. This study would encompass not only the transportation benefits but all categories of benefits attributable to the project and would include a complete environmental analysis and project reformulation.

The vast majority of the commodities identified as potential cargo for waterborne transportation in the study area are related in some manner to primary metals. Table 17 shows the prospective commerce for the Shreveport to Daingerfield reach as identified in the transportation reanalysis. In addition to these commodities, a study commissioned by the Red River Valley Association identified soybeans, sawtimber, and pulpwood as commodities in the area which would lend themselves to water transport.

In 1985, the Fort Worth District conducted interviews in the study area to determine what existing and future commodities might travel a waterway. These interviews determined that no new prospective commodities exist. Primary metal raw materials and finished products are still the principal commodities, with Lone Star Steel being the main shipper. This company is operating at reduced capacity. Presently the Lone Star plant is shipping selected steel products for export through the Port of Houston. The steel products are hauled by truck to Houston where the articles are then loaded on ocean going vessels for final overseas shipment. The firm plans to analyze the costs of shipping these products via the Red River Waterway when the project is completed to Shreveport. Instead of trucking the products to Houston, they would haul these items to Shreveport which is slightly over 90 road miles from the plant. Construction of the proposed waterway to Daingerfield obviously would shorten the truck haul distance and make barge shipment of these export products and other commodity movement economically more feasible. Transportation savings could result from these reduced haul distances.

PROJECTED CONDITION WITHOUT FEDERAL ACTION

The following paragraphs present estimates of the future conditions in the study area without Federal action. These projections are necessary to determine what problems may worsen or develop in the area of interest. Much of the data was taken from the area economic study done by the Southwestern Division of the Corps of Engineers. Future water resource development is based on conversations with area architect-engineer firms and local authorities. Environmental changes were developed by personnel in the Fort Worth District.

SOCIOECONOMIC FACTORS

Population

The factors used to forecast population were developed by the Texas Water Development Board (TWDB) and the Southwestern Division. These alternate projections were used in lieu of OBERS Series E for two reasons. One, 1980 population estimates were greater than the OBERS projected 1980 value. Furthermore, OBERS data is not indicative of the historical growth trends. The TWDB provided data to the year 2000 with Southwestern Division extending these values to 2050. Overall, from 1980 to 2050 the study area population is forecasted to grow by 77 percent, as compared to 70 and 42 percent for Texas and the United States, respectively. Table 18 presents the population projections for the study area.

Employment

Table 18 also shows the projected employment for the study area. As with population, projections are for continued growth. Employment by 2050 is expected to be almost twice what it was in 1980.

Per Capita Income

Per capita income shows the greatest rate of growth of the three socioeconomic factors discussed. Per capita income projections are shown on table 18. By 2050, per capita income is expected to be 3.64 times as large as the 1980 per capita income.

ENERGY RESOURCE DEVELOPMENTS

Most of the oil and gas fields in the study area have been developed. The value of production is projected to increase but at a much slower rate than the value of production for Texas and Louisiana. The large differences in rates are due to expected depletion of oil and gas resources in the study area and the larger areas available for exploration throughout the states of Texas and Louisiana. The value of oil and gas production is expected to increase by 5 percent from 1980 to 2050 for the study area, while Texas will increase by 92 percent and Louisiana by 121 percent.

The future of lignite use in the study area appears favorable. In the near term, uses may be limited primarily to mine-mouth consumption for purposes of direct energy conversion. From 1980 to 2000, lignite will likely remain more attractive than coal. After the year 2000, western coal use may surpass lignite as the lignite reserves are depleted.

WATER RESOURCES DEVELOPMENT

In addition to the existing water resources development in the Cypress Basin, there is potential for others. The Texas Water Development Board has two sites designated as potential future lakes. They are located on Little Cypress Bayou and Black Cypress Bayou. In addition, the possibility of enlarging Caddo Lake is also part of the State water resources development plan. The Vicksburg District has evaluated this as one of the alternatives in the Caddo Lake Enlargement Study.

Several cities in the study area are actively seeking additional water supply sources. Marshall, Longview, and Kilgore have all had recent water supply studies done, either in conjunction or separately. Close coordination has been maintained with the architect-engineer firms doing these studies. The possibilities with the most potential at this time are sites on Little Cypress Bayou identified as Little Cypress Reservoir, Big Sandy Lake, and a small lake on Prairie Creek. Little Cypress Reservoir is under investigation by the Little Cypress Utility District (LCUD), a conservation and reclamation district created in 1985 and subsequently ratified by voters within the District. Big Sandy Lake would be located on Big Sandy Creek, a tributary of the Sabine River, in Wood County. The Bureau of Reclamation is studying this site for municipal and industrial water supply. The Prairie Creek project would be located on Prairie Creek, a tributary of the Sabine River, about 12 miles west of Longview. This project would involve a "scalping" operation of the Sabine River where floodflows would be pumped into and stored in the Prairie Creek Lake. This is the smallest of the three projects.

The most probable project to be developed in the watershed would be the Little Cypress Reservoir under consideration by the LCUD. If funds are not made available for the Little Cypress Reservoir, and the Bureau of Reclamation recommends a project on Big Sandy Creek, this would become the most probable project. However, Big Sandy Lake faces severe opposition by environmental groups and local landowners. In the absence of any help from outside sources, the local interests would probably resort to construction of small yield lakes on Prairie Creek or Little Cypress Bayou or both.

ENVIRONMENTAL CHANGES

The future of fish, wildlife, and ecological systems in the Cypress Bayou Basin is highly dependent on land use change. The dominant land use in the basin is woodland, followed closely by agricultural (pasture). Urban areas, urban fringe, rural settlements, and industrial sites constitute a relatively small percentage of the land use in the basin.

A slight increase in urban type land uses is projected, which mostly will occur near existing cities and towns, and this will have limited impact on wildlife populations through 2000. Rural settlements also will adversely impact wildlife habitat both quantitatively and qualitatively on upland areas. A 5-10 percent decrease overall in woodland through 2000 is expected with a similar decrease in agricultural land. Much of this decrease, however, is attributed to possible future water resource development in the area.

The only other major change which can be projected to significantly affect wildlife habitat in the basin is lignite mining. The timing and ultimate development of lignite reserves are also very difficult to project. It is expected that existing and future mining of lignite reserves will continue to reduce woodland acreage to pastureland use after reclamation.

The general land use trend of decreasing upland hardwood forest and decreasing agricultural land is expected to occur but at a slow rate. Upland woodlands, due to their potential for rural homesites, expansion of urban environments, and removal of lignite reserves, will decrease in quantity and quality at a faster rate than the bottomland forest. The only significant factor of change identified to date affecting the bottomland forest is potential water resource development.

Water quality in the study area is expected to remain good and even improve. Increased monitoring of municipal and industrial discharges and improved treatment processes will aid this improvement. The improvement will not be substantial due to the present good quality of water in the streams. The occasional occurrence of dissolved oxygen levels below 5.0 mg/l will continue to occur due to nutrient loading from rural land uses and periodic episodes of low to zero flow.

CHAPTER 4 - PLANNING OBJECTIVES AND CONSTRAINTS

This chapter describes the national objectives, enumerates the study planning objectives, and concludes with the planning constraints and formulation criteria imposed on meeting these objectives.

PLANNING PROCESS

The nature of the planning process is iterative, thus resulting in optimum formulation, evaluation, effect assessment and recommendation. Throughout the planning process and study both the Corps of Engineers and the public, in a cooperative effort, have exchanged ideas and information to determine goals for the study. Planning objectives or goals stem from national, State and local water related land resources management needs specific to each individual study area. These objectives are developed through problem analysis and continuing interaction with the affected public interests. The objectives or goals are the basis for the future study activities of formulating alternatives, alternative evaluation, impact assessment, and study recommendation.

NATIONAL OBJECTIVES

The national objective of water and related land resource project planning is to contribute to national economic development (NED) consistent with protecting the nation's environment. NED is achieved through increases in the net value of the nation's output of goods and services and improving national economic efficiency. Alternate plans for the study area must be developed consistent with this national objective.

To facilitate the evaluation and display the effects of alternative plans, four accounts have been established. The NED account is required. Other information that is required by law or that will have material bearing on the decision making process should be included in the other accounts, or in some other appropriate format used to organize information on effects. A summary of the four accounts follows:

a. The NED account displays changes in the economic value of the national output of goods and services.

b. The environmental quality (EQ) account displays nonmonetary effects on significant natural and cultural resources.

c. The regional economic development (RED) account registers changes in the distribution of regional economic activity that result from each alternative plan. Evaluations of regional effects are to be carried out using nationally consistent projections of income, employment, output, and population.

d. The other social effects (OSE) account registers plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts.

PLANNING OBJECTIVES

The problems and needs of the study area have been identified and discussed in chapter 3. Problem and opportunity statements for this study have been based on those specific problems and needs which have a potentially realistic solution. The final list of problem and opportunity statements has been revised several times during the course of the study and reflects several iterations of the planning process. Thus the problems and opportunities listed below provide the basis for the plan formulation presented later in this report.

- Contribute to reduction of flood damages and associated health and safety hazards to development along Caddo Lake, Big Cypress Bayou, Little Cypress Bayou, and Black Cypress Bayou during the 1990-2040 period of analysis.
- Contribute to municipal and industrial water supply needs in the Cypress Bayou Basin study area during the 1990-2040 period of analysis.
- Contribute to recreational opportunities in the Cypress Bayou Basin study area during the 1990-2040 period of analysis.
- Contribute to the generation of hydroelectric power for reduction of need for fossil fuel plants from resources in the Cypress Basin during the 1990-2040 period of analysis.
- Contribute to the preservation or conservation of fish and wildlife habitat in the Cypress Bayou Basin during the 1990-2040 period of analysis.
- Contribute to the preservation or enhancement of the water quality of the streams in the Cypress Bayou Basin during the period of analysis 1990-2040.

PLANNING CONSTRAINTS

Guidelines for the formulation and evaluation of alternative plans for Federal water and related land resources activities are contained in the Water Resources Council's Principles and Guidelines.

Formulation and evaluation of the plans of improvement for the study area are based on technical, economic, and other criteria with varying emphasis on the different economic, social, and environmental components reflected in the planning objectives. Principles and Guidelines require that one of the alternative plans must optimize NED. The NED Plan is the alternative that reasonably maximizes net economic benefits consistent with preserving the Nation's environment while addressing the range of identified planning objectives. It is noted that the following criteria cannot always be met and that full response may be sacrificed for overriding considerations.

Two primary planning constraints were identified during the course of this study. One was public acceptance of a project in the study area, and the second was the the institutional constraint of dealing with the sharing of the waters of the Cypress Bayou Basin. Public concerns about loss of land, wildlife, and lack of immediate need were all considered in the development of alternative plans which would satisfy engineering, environmental, and social criteria.

Red River Compact

The institutional constraints of the Red River Compact also need to be considered in planning for water resource development in the Cypress Bayou Basin, since it provides an equitable apportionment of the waters among the affected states.

The Red River Compact, Public law, 96-564, approved by Congress on December 22, 1980, allocates the waters of the Red River and its tributaries to the States of Texas, Louisiana, Arkansas, and Oklahoma. The Compact was established to remove causes of controversies between each of the affected states by governing the use, control, and distribution of the water. Each state may use the waters allocated to it in any manner deemed beneficial by that state and may freely administer water rights and uses in accordance with the laws of that state, subject to the availability of water apportionments made by the Compact.

Article VI, Section 6.03, of the Compact deals specifically with the apportionment of waters from the Cypress Basin. The section, presented in its entirety, states:

SECTION 6.03. Subbasin 3 - Interstate stream - Texas and Louisiana.

(a) This Subbasin includes the Texas portion of all tributaries crossing the Texas-Louisiana State boundary one or more times and flowing into Caddo Lake, Cypress Creek-Twelve Mile Bayou or Cross Lake, as well as the Louisiana portion of such tributaries.

(b) Texas and Louisiana within their respective boundaries shall each have the unrestricted use of the water of this subbasin subject to the following allocation:

(1) Texas shall have the unrestricted right to all water above Marshall, Lake O' The Pines, and Black Cypress damsites, however, Texas shall not cause runoff to be depleted to a quantity less than that which would have occurred with the full operation of Franklin County, Titus County. Ellison Creek, Johnson Creek, Lake O' The Pines, Marshall, and Black Cypress Reservoirs constructed, and those other impoundments and diversions existing on the effective date of this Compact. Any depletions of runoff in excess of the depletions described above shall be charged against Texas' apportionment of the water in Caddo Reservoir.

(2) Texas and Louisiana shall each have the unrestricted right to use fifty (50) percent of the conservation storage capacity in the present Caddo Lake for the impoundment of water for state use, subject to the provision that supplies for existing uses of water from Caddo Lake, on date of Compact, are not reduced.

(3) Texas and Louisiana shall each have the unrestricted rights to fifty (50) percent of the conservation storage capacity of any future enlargement of Caddo Lake, provided, the two states may negotiate for the release of each state's share of the storage space on terms mutually agreed upon by the two states after the effective date of this Compact.

(4) Inflow to Caddo Lake from its drainage area downstream from Marshall, Lake O' The Pines, and Black Cypress damsites and downstream from other last downstream dams in existence on the date of the signing of the Compact document by the Compact Commissioners, will be allowed to continue flowing into Caddo Lake except that any manmade depletions to this inflow by Texas will be subtracted from the Texas share of the water in Caddo Lake.

(c) In regard to the water of interstate streams which do not contribute to the inflow to Cross Lake or Caddo Lake, Texas shall have the unrestricted right to divert and use this water on the basis of a division of runoff above the state boundary of sixty (60) percent to Texas and forty (40) percent to Louisiana.

(d) Texas and Louisiana will not construct improvements on the Cross Lake watershed in either state that will affect the yield of Cross Lake; provided, however, this subsection shall be subject to the provisions of Section 2.08.

Formulation Criteria

The following criteria were also adopted for use in developing, evaluating, and comparing alternative plans:

a. A plan recommending Federal action is to be the alternative plan which reasonably maximized benefits over costs consistent with protecting the Nation's environment (the NED plan), unless there are overriding reasons for recommending another plan, based on other Federal, state or local concerns.

b. The plan must be technically feasible using engineering methods and equipment available in this region.

c. The alternative must be acceptable to the general public as far as can be established.

d. The plan should be complete within itself and should not require additional future improvements.

e. Reduce loss of life and property, and hazards to health and safety of the people should be eliminated.

f. Community cohesion and desirable community and regional growth should be preserved, maintained, or enhanced.

g. The plan should be effective and efficient with regard to alleviating the specified problems and achieving the specified opportunities.

CHAPTER 5 - PLAN FORMULATION RATIONALE

INTRODUCTION

The problems and opportunities of the Cypress Bayou Basin study area have been identified and discussed in chapter 3 of this report. Preliminary plans were formulated which addressed these problems and took advantage of the opportunities. Impacts of the plans were then determined, and the plans were evaluated with respect to meeting the problem and opportunity statements or planning objectives identified in chapter 4. The most successful preliminary plans were then selected for more detailed planning studies.

PLAN FORMULATION RATIONALE

Formulation and evaluation criteria, level of detail, and Corps of Engineers engineering regulations all intertwine with plan formulation. This section describes the rationale behind plan formulation for the Cypress Bayou Basin Feasibility Report.

Discount Rate

The preliminary nonstructural and structural alternatives were evaluated using the Federal 8.375 percent rate in effect at the time of preliminary plan formulation. However, the current 8.625 percent rate has been applied to the economic evaluation of the plans selected for detailed evaluation. The preliminary alternatives were not reevaluated using the new 8.625 percent rate because it was not expected to change the relative "performance" of the alternatives.

Cost and Benefit Data

As the plan formulation process progressed, the cost and benefit data were updated due to price level, level of detail, and the aforementioned plan formulation changes. For these reasons, to avoid confusion close attention should be paid to footnotes and other information presented on tables.

Major Steps in Plan Formulation

The plan formulation process used to arrive at a report recommendation consisted of the following steps:

- Specify the water and related land resources problems and opportunities associated with the Federal objective and specific State and local concerns.

- Inventory, forecast, and analyze the water and related land resource conditions within the planning area relevant to the identified problems and opportunities.

- Formulate preliminary alternative plans to meet the planning objectives with emphasis or incremental feasibility of purposes.

- Screen preliminary alternatives which best meet planning objectives, plan formulation criteria, and desires of local interests.

- Evaluate in detail final alternatives, including identification and evaluation of impacts.

- Prepare a report recommendation.

MANAGEMENT MEASURES CONSIDERED

All plans were formulated with the national objective and the problem and opportunity statements as guides. A broad and comprehensive range of nonstructural and structural measures were considered during plan formulation. Since providing flood damage reduction is one of the primary objectives of this study, all possible management measured considered, with the exception of navigation channels, were evaluated as to their effectiveness to reduce flood damages with regard to attaining net positive economic and environmental benefits. Several alternative measures satisfying the problems and needs of the study area are possible. The solutions may be divided into the two broad categories of nonstructural and structural measures. The measures considered are listed below.

1. Nonstructural Measures
   - Water Conservation
   - Change Operating Procedures at Lake O' The Pines
   - Floodproofing/Raising of Structures
   - Permanent Evacuation of the Structures from Flood Plain
2. Structural Measures
   - Ground Water Utilization
   - Levees
   - Channel Modification
   - Lakes
     - Marshall Site
     - Black Cypress Site
   - Enlargement of Existing Caddo Lake
   - Navigation Channels

- Addition of Hydropower Facilities to Lakes

3. No Action

The nonstructural and structural measures listed above essentially include all of the preliminary alternatives investigated. It should be noted in the context of the report, the terms "measure" or "alternative" refer to one project, while the term "plan" generally refers to a group of measures or alternatives, but is often used interchangeably with alternative. In order to determine which measures would best satisfy certain problems and needs (and related planning objective), a matrix was developed. Table 19 displays the matrix and shows that some alternatives would meet a greater number of planning objectives than others.

CHAPTER 6 - PRELIMINARY ANALYSIS OF ALTERNATIVES

This chapter presents the preliminary analysis of alternatives. The nonstructural alternatives considered were: water conservation, floodproofing/raising of structures, permanent evacuation of the structures from flood plain, and changing operating procedures at Lake O' The Pines. The structural alternatives considered were: ground water utilization, levees, channel modifications, lakes, enlargement of existing lakes for water supply, navigation channels and addition of hydropower facilities to lakes.

NONSTRUCTURAL ALTERNATIVES

Alternative 1 - Water Conservation

Conservation has been established as a cornerstone of Federal water resources policy. Factors accounting for the growing emphasis on water conservation include: rising demand, scarcity of new reservoir sites, declining ground water levels, rising costs of water resources development, and increasing concern for environmental quality. Water conservation has also become of interest to State planners as well. The new water resources development plan passed in November 1985 by the Texas Legislature contains a requirement that entities seeking funds for development have water conservation plans and rules in effect before funds will be approved for local interests' projects.

Several measures can be used to encourage or implement water conservation. Public education through the use of television, radio, and newspapers can be used to communicate the need to the public of conserving water and describe methods to achieve this objective. The use of water conservation devices such as shower flow controls, toilet inserts, and modified lawn sprinkling devices are relatively inexpensive and may be effective in reducing demand. Plumbing codes can be revised to require low flow showerheads and faucets and water saving toilets for new construction or replacement plumbing. Pricing and metering techniques can be employed to encourage conservation.

For the purpose of the water conservation alternative, it will be assumed that several of these measures will be put into effect. The impact of these measures on water demand will be determined and new projections of net needs with conservation will be calculated. These new needs will guide how much additional water supply is needed in the study area.

Baseline industrial water use projections have not been modified because the projections reflect increasing recirculation of water used in the industrial processes. Thus, these projections automatically reflect conservation.

Conservation projections of municipal water needs include both interior and exterior residential conservation estimates. For interior residential use, it was assumed that water saving toilets, faucets, and showerheads would be required in all new construction and that replacement of these items in existing residences would occur gradually over a period of 50 years. For exterior conservation savings, the seasonal component (extra water used in the months of June through October) for landscape irrigation, swimming pools, etc. was estimated for the year 1980 and this ratio applied to projected water use data. The seasonal component was reduced by 10 percent to obtain the projected savings through conservation for exterior water use. Table 20 reflects the new water needs assuming water conservation measures in effect and is a modification of table 10 developed earlier in the report. As shown, the net 2040 need of 125.7 mgd is a 2.5 percent decrease from the 2040 net need without conservation of 129.0 mgd.

Alternative 2 - Change Operating Procedure of Lake O' The Pines

This alternative reduces flood damages by changing the flood release operating procedure of Lake O' The Pines. In the past, the procedure has been to begin flood releases any time the conservation pool was exceeded without regard to downstream flows. The only limitation was that releases would be limited to 3,000 cfs and, to simulate the sluggish nature of the hydrologic response in the watershed, the gates would be opened gradually over a 5-day period. Following floods in May 1979 and January 1980, downstream property owners complained about the fact that releases were being made from Lake O' The Pines while their property was being flooded. They requested that releases be delayed until peak flows from the Little and Black Cypress Bayous have passed.

An analysis was made to determine the effects of changing the release procedure. The new procedure would be to monitor the flows in Little and Black Cypress Bayous and make releases from Lake O' The Pines such that the sum of the three flows would not exceed 3,000 cfs. Results were there would be slight decreases in some frequency discharges downstream of the lake and a slight increase in the frequency lake elevation. An economic analysis was conducted to determine changes in average annual damages. Table 21 presents the results of this analysis.

The cost associated with this alternative would be the $14,700 increase in average annual damages around Lake O' The Pines. Also, two problems associated with higher levels in the lake are a slight hindrance to recreation and increased bank erosion. Marinas around the lake may experience some difficulty in operation due to the higher levels. However, these marinas are usually designed to operate at varying lake levels, and the increased levels are not significant enough to cause major operational difficulties. Bank erosion is an ever present problem in lakes in this area because the high bluffs and sandy soils are especially susceptible to erosion. To determine what amount of erosion is extra or what amount of this extra is due only to higher levels is extremely difficult to ascertain. No cost was assigned to these two problems because the amount of analysis required to do so would not justify the small increase in cost expected. Benefits of this alternative are the reduced average annual damages along Big Cypress Bayou and Caddo Lake which amount to $58,400.00. This results in net benefits of $43,700.

Since the Fort Worth District assumed operation of Lake O' The Pines in 1979, the operating procedure has been modified as described in this alternative. For this reason, this alternative is considered to be in place, and all subsequent analyses reflect the new operating procedure as the existing condition.

Alternative 3 - Raise Existing Structures

One method of reducing the susceptibility of a structure to flood damage is to raise the structure above the floodwaters. This is a very promising alternative for the structures in the Cypress Basin flood plain. Most of the structures are built on pier and beam foundations, and approximately 24 percent are already elevated to heights of 5 feet or more. After raising the structures, residual damage will remain to yards and to contents outside of the structure.

In determining which structure to raise, it was necessary to determine how many and the value of structures in each flood zone. Table 22 presents this information. This table is separated into the different streams and reaches within the streams. As mentioned in the problem and opportunity section, development in the flood plain is not continuous but occurs in small clumps. This gives rise to the different reaches. Another fact to consider is the higher flood zones even with equal development will contribute less to average annual damages than lower flood zones. Looking at the data in table 22, it becomes apparent that some reaches are not good candidates for this alternative. As can be seen from table 22, most of the development is in the 25-year flood plain. Reaches with few or no structures in the 25-year flood plain were eliminated from consideration. Based on this criterion, it was decided to investigate reaches 1, 2, 3, 4, 5, and 6 of Big Cypress Bayou and reaches 1, 2, 3, and 6 of Caddo Lake. Plate 6 shows the location of these reaches. Average annual damages for each flood zone in the considered reaches was computed and is presented in table 23.

Costs associated with raising a structure include disconnecting and reconnecting all plumbing, wiring, and utilities, placing steel beams and jacks beneath the structure, bracing the structure, raising the structure, and extending or replacing the existing foundation. Most of this cost will be incurred regardless of how high the structure is raised. For this reason, a fixed sum of $7,250 per structure was assumed at this stage of the analysis. This cost figure was based on information developed by the Corps of Engineers Hydrologic Engineering Center and adjusted to current prices. This cost also includes a 15 percent contingency. A 2-year construction period was assumed, and costs were amortized over a 100-year period. No O&M cost was assumed. Benefits were assumed to be equal to the average annual damages. Table 24 presents the economic analysis of raising structures in the different flood zones.

For different reaches, optimization for raising structures occurs at different zones. Three reaches, Big Cypress 1 and 7 and Caddo Lake 2 optimize at the 5-year zone. However, the Caddo Lake 2 reach involves only one structure. It would appear overly selective to only raise one structure in a group. For this reason, Caddo Lake 2 was dropped from the analysis. Five reaches, Big Cypress 3, 4, and 5 and Caddo Lake 1 and 6, optimize for the 10-year zone. That is, all homes in the 10-year flood plain would be raised above the 100-year flood elevation. Two reaches, Big Cypress 2 and Caddo Lake 3, optimize at the 25-year level. One of these reaches exhibits an anomaly in that raising structures in the 5- and 10-year flood plain would not produce net benefits. A strict interpretation of the NED objective would mean that only the structures in the 10- to 25-year flood zone would be raised. However, it would disrupt community cohesion if structures in higher flood zones were raised and more frequently flooded structures were not. For this reason, all of the structures within the 25-year flood zone for Big Cypress 2 are included in the preliminary alternative. Grouping the most feasible reaches results in 555 structures being raised for this alternative with an annul cost of $365,300 and annual benefits of $630,100. This alternative warrants further consideration based on the favorable total net economic benefits of $269,800.

Alternative 4 - Evacuate Flood Plain

This alternative would consist of relocating a structure and its contents to a new flood free site. Cost involved would be new site purchase and preparation, moving of structure to new site, and relocation assistance. Again using updated data developed by the Hydrologic Engineering Center, average cost per structure for evacuation was estimated at $25,500 per structure. This is about three and one half times the amount estimated for raising the existing structures (alternative 3), clearly making this alternative economically infeasible. Also, by relocating the inhabitants, they are removed from the esthetic and recreation experiences which attracted them to the flood plains. This alternative would prove to be very unpopular with the structure inhabitants and was not considered further.

STRUCTURAL ALTERNATIVES

Alternative 5 - Ground Water Utilization

One way of reducing future water supply needs would be to develop the ground water resources of the study area as additional water supply. This would involve developing well fields near the areas of demand. The major aquifer in the study area is the Carrizo-Wilcox aquifer. Another aquifer which could be utilized is the Queen City aquifer. TWDB has determined that the safe annual yields of these aquifers are 13 mgd for the Carrizo-Wilcox and 209 mgd for the Queen City. However, the Queen City aquifer in the area has high concentrations of iron and high acidity and should not be considered a suitable source of water for municipal and most manufacturing purposes.

Another problem in utilizing either of these aquifers is their low coefficients of transmissibility. This means that many small capacity wells would be required to develop the ground water resources of the study area. The performance of existing wells in Harrison County was demonstrated by an investigation in a water supply study done for the city of Marshall by a consulting engineer firm. Data presented in the study indicated that many wells were drilled before developing a producing well, e.g., 9 dry wells in 12 attempts in one case and 6 dry wells out of 7 attempts in another. The data also showed that the average yield in the area is about 75 gpm, although a few wells produce in excess of 200 gpm.

Notwithstanding all of these obstacles to developing ground water, an economic analysis was made on a ground water only alternative. The analysis was based on providing 125.7 mgd, the 2040 water supply needs of the study area established in table 20. Table 25 presents the economic analysis. This data was taken from information developed for the water supply benefit analysis.

The annual cost of the ground water alternative is estimated at $38,000,000.00. Annual transmission cost for this alternative 4 is estimated to be approximately $30,000,000.00. Neither of these costs include cost for treatment which would be necessary for the iron laden ground water of the study area. Benefits for a water supply alternative are equal to the least costly other water supply alternative minus the difference in transmission cost. The least costly alternative to ground water utlilization would be a lake alternative having an annual cost, including transmission facilities, of $24,000,000.00. Subtracting the ground water transmission cost from this gives benefits of -$6,900,000.00. Obviously, the total dependence on ground water utilization is not economically feasible and is dropped from further consideration.

Alternative 6 - Levees

One method of preventing flood damage is to construct a levee between the flood source and the developed area. In the case of the Cypress Basin, much of the development is linear along the shores of Caddo Lake and the bayous. Thus, levee construction would require removal of many of the structures which are to be protected and would obstruct access and viewing esthetic attributes of the watercourse.

An economic analysis was done for the levee alternative for the most promising reaches. Levees were investigated for the reaches shown on plate 6. The levee was assumed to have a 10-foot crown width and 1 on 3 side slopes. No costs were developed for interior drainage, and it was assumed that no structures would have to be relocated. Therefore, the costs presented reflect an optimistic (i.e. low) estimate of the actual levee construction costs. Levees were sized to prevent flooding from the 25-year and SPF floods. Costs were estimated for the reaches of Big Cypress 1, 2, 3, 4, 5, and 6 and Caddo Lake 1, 2, 3, and 6. The flood damage reduction benefits were computed by taking all average annual damages within the flood zones of the two designs. This presents an optimistic view of the potential benefits for the levee systems.

Table 26 presents an economic analysis for the SPF design and table 27 for the 25-year. As can be seen by the negative net annual benefits, none of the levee designs for the 25-year and SPF frequencies proved to be economically feasible. Using the average annual structure damage by flood zone data shown in table 23, it was determined that several smaller frequency designs might prove feasible for certain reaches. A 10-year design was considered for Caddo Lake reaches 1 and 6 and a 5-year design for Big Cypress reach 5. Table 28 presents the economic analysis for these reaches. As indicated, none of the low frequency levee designs were economically justified, even though optimistic cost and benefit estimates were used. Levees were therefore dropped from further consideration.

Alternative 7 - Enlarge Channel

Existing channels can be enlarged to increase their capacity to convey flows. This decreases flood heights and associated flood damages. In the case of the Big Cypress Bayou, not only would the channel have to be enlarged, but the spillway of Caddo Lake would also have to be enlarged. The Caddo Lake spillway creates backwater effects which extend into the damage reaches of Big Cypress Bayou. Excavation of the bayou would destroy many of the cypress trees which grow along its banks and which provide prime wildlife habitat and a rich esthetic experience.

A preliminary screening of this alternative was based on the assumption that Big Cypress Bayou would be enlarged enough to contain the 5-year flood flow to a nondamaging elevation. It was also assumed that the Caddo Lake spillway would be modified to pass the 5-year flow at nondamaging elevations. However, costs associated with the spillway modification were not included in the cost estimates. Plate 7 shows the limits of the enlarged channel. The channel would be trapezoidal with a 110-foot bottom width and 1:3 side slopes. Benefits for the channel were assumed to be equal to the total average annual damages for the Big Cypress and Caddo Lake economic reaches. This test provides a comparison of minimum costs against maximum benefits. Table 29 gives the economic analysis for the enlarged channel alternative. Even with the very optimistic cost and generous benefit assumptions made for this alternative, annual costs exceeded annual benefits by $745,200. Enlarging the channel was, therefore, dropped from further consideration.

Alternative 8 - Diversion Channel

Flood damage can be reduced by diverting floodflows away from damage areas. This is accomplished by excavating a bypass channel on an alignment which does not pass through developed areas and by making the channel large enough to contain floodflows. This alternative would preserve the existing channel and still allow inhabitants to enjoy recreation on the existing stream. Plate 8 shows the alignment of a proposed diversion channel. For purposes of an economic analysis, the diversion channel would be a trapezoidal channel with a 50-foot bottom width, 1 on 3 side slopes, and a depth of 20 feet. This size channel would not convey large floodflows but was used for a screen test analysis. Benefits were assumed to be equal to total average annual damages for the Big Cypress and Caddo Lake economic reaches. These assumptions will provide a very optimistic economic analysis. The results of this analysis are shown on table 30. As can be seen by the negative net annual benefits of $952,700, a diversion channel is not an economically viable alternative and was, therefore, dropped from further consideration.

Alternative 9 - Lakes

Lakes are a means to meet many of the opportunities and alleviate some of the problems of the basin. Conservation storage can provide additional water supply while providing a permanent pool for recreation. Flood control storage can help to reduce downstream flooding. Also, there is a chance for hydropower generation. Lakes in the Cypress Basin will inundate large areas of productive wildlife habitat, convert stream fishery to flat water fishing, and necessitate the relocation of some families. In evaluating the impacts of the lakes, the benefits gained will have to be weighed against the costs to construct, the value of opportunities lost, and the cost of mitigation for unavoidable adverse impacts. Two sites were investigated as alternatives. One site is on Little Cypress Bayou and is identified as Marshall Lake. The other site is on Black Cypress Bayou and is identified as Black Cypress Lake. Plate 9 shows the proposed location of the two sites.

Marshall Lake would be located at River Mile (RM) 21.3 on Little Cypress Bayou, approximately 9 miles northwest of the city of Marshall. The drainage area for the lake would be 617 square miles. The dam would be earthfill, and a standard outlet works would be provided. A concrete ogee crest emergency spillway with stilling basin would also be a part of the project. For this formulation phase, the spillway for the alternatives has a width of 600 feet. The spillway crest is set at the top of conservation pool for all water supply only alternatives and at the top of the flood control pool for all alternatives with flood control as a purpose. Plate 10 shows the extent of a proposed lake at the Marshall site.

Black Cypress Lake would be located at RM 17.0 on Black Cypress Bayou approximately 7 miles northwest of the city of Jefferson and would have a drainage area of 342 square miles. The dam, outlet works, and spillway would be the same as described for the Marshall Lake alternative. Plate 11 shows the extent of a proposed lake at the Black Cypress site.

Different sizes of lakes were formulated for different purposes at each site. These purposes were taken both singularly and in combination. Many alternatives were developed in an attempt to identify the best solution. Pertinent data, costs, and benefits for many of the alternatives were developed by using cost curves. These curves were developed from detailed data provided by appropriate support sections on alternates formulated to cover the range of alternatives which would be considered. Use of these curves allowed any type of lake alternative to be investigated efficiently. The cost curves are discussed in more detail as part of Appendix E, Cost Estimates, while the benefit curves for flood control, water supply, and recreation benefits are presented in Appendix A, Economic Analysis, and Appendix D, Recreation, respectively.

Water supply yields were spread over a range starting low and extending to close to the maximum yield for both sites. Both maximum yields were in excess of the 2040 water supply needs of the Cypress Basin study area. Recreation potential was based on the conservation pool surface area provided by the water supply pool. Flood control storages ranged from zero to a storage required to hold the 50-year flood, 413,000 acre-feet for Marshall Lake and 230,000 acre-feet for Black Cypress Lake. Tables 31 and 32 show the pertinent data for the alternatives investigated for the Marshall Lake site and Black Cypress Lake site, respectively.

Tables 33 and 34 present the economic analysis for the alternatives at the Marshall Lake site and Black Cypress lake site, respectively. These alternatives match the indicated ones on tables 31 and 32. As previously noted, costs in tables 33 and 34 were developed utilizing cost curves. Mitigation costs were based on purchasing lands to mitigate for habitat losses and managing these lands at an average management level to optimize wildlife benefits on the mitigation lands. Cultural resource costs were estimated to equal 1 percent of the construction costs. On tables 33 and 34, economic costs are equal to financial costs minus the costs for relocation replacements above in kind: cultural resource preservation; and engineering and design and supervision and administration for these two items. Net benefits and benefit-cost ratios are computed using the economic costs.

To aid in the interpretation of Tables 33 and 34, a net economic benefit grid was prepared for the Marshall and Black Cypress Lake alternatives. These grids are shown on plates 12 and 13, respectively. Certain areas on the grid represent different purpose alternatives. Along the vertical axis, going down, are single purpose water supply alternatives, increasing in yield in the downward direction. Along the vertical axis, going up, are dual purpose water supply and recreation projects, increasing with water supply yield in the upward direction. Along the horizontal axis are single purpose flood control projects, increasing in storage in the outward direction. The lower right quadrant reflects dual purpose water supply and flood control alternatives with yields and storages as indicated by the axes. The upper right quadrant reflects triple purpose water supply, recreation, and flood control alternatives with yields and storages as indicated by the axes.

The numbers shown in the circles represent the net economic benefits for the respective alternative, that is, the sum of all annual benefits minus the sum of all annual economic costs. For example, at the Marshall site, an alternative with a water supply yield of 125 cfs, with recreation as a purpose and with 100,000 acre-feet of flood control storage would have net economic annual benefits of $-861,000. Negative numbers obviously indicate economically infeasible alternatives. By noting gradients to higher net benefits, the identification of the alternative with the maximum net economic benefits, the NED alternative, is made easier. Changes in net economic benefits along a line indicate the economic feasibility of adding an extra increment of a purpose to an alternative or adding a purpose to an alternative. A decrease in net economic benefits indicates economic infeasibility of adding an increment or a purpose.

Analysis of the net benefit grids indicates that, in general, a multipurpose lake at the Marshall site provides greater net economic benefits than the Black Cypress site with the exception of the 125 cfs Black Cypress water supply alternative. Black Cypress flood control only alternatives have higher net economic benefits than Marshall flood control only alternatives, but all are economically not feasible.

In analyzing the Marshall Lake alternatives for water supply, it can be seen that all have positive net benefit values. The least costly alternative for water supply benefit evaluation was Marshall Lake as an alternative to Black Cypress Lake and Black Cypress Lake as an alternative to Marshall Lake. Black Cypress Lake has lower raw water costs and lower yields, but the larger costs of transmission to the areas of demand result in Marshall having the larger water supply benefits. Plate 14 is a plot of net economic benefits for the two lake site alternatives. As was noted earlier, both lake alternatives can supply yields past the 2040 needs of the study area. Even though this analysis shows increasing benefits for yields greater than the 2040 needs, the willingness of the user to buy or pay for water supply this far in the future can be expected to be very small. Thus, these benefits would not be realized. Therefore, for the purpose of water supply, formulation was considered only to the 2040 needs of 125.7 mgd. Plate 14 shows that the Marshall Lake alternative gives the maximum net benefit for water supply at the formulation point. Plate 15 shows the cost of water for the two lake alternatives.

Adding recreation to any lake alternative is economically justified. Plates 12, 13, and 14 illustrate this. Marshall Lake still has the maximum net benefits at the formulation point of 125.7 mgd.

A single purpose flood control lake is not economically feasible at either site. Plate 16 shows the net benefits for flood control only alternatives. Plate 16 also shows the results of adding flood control to a Marshall water supply and recreation lake with a yield of 180 cfs. The plot shows that adding flood control results in decreasing the net economic benefits. The water supply only alternatives produce some flood reduction effects due to surcharge as the floodflows pass through the emergency spillway. This results in flood reduction benefits for which there are no incremental costs. Plate 17 has a plot of flood control benefits versus flood control storage for the 180 cfs yield water supply, recreation, and flood control alternatives at the Marshall site. This plate also shows the incremental costs associated with adding flood control storage to a water supply and recreation alternative. As indicated, at approximately 11,000 acre-feet flood control benefits just equal incremental costs. If justifiable reasons are found to deviate from the criteria of obtaining maximum net economic benefits, this is the maximum amount of flood control storage that could be justified based on a premise that flood control benefits must equal incremental flood control costs.

Either of the lake sites could have some slight impact on lignite deposits in the area. An evaluation done by the Department of Interior, Bureau of Mines, in 1982 estimated deposits of 6 million tons in the upper reaches of the Black Cypress Lake site and 30 million tons near the damsite of Marshall Lake. These estimates were based on limited drilling and a large amount of proprietary data. No plans exist to mine these deposit. Interest is in larger, more profitable deposits near Hallsville. The deposits at the lake sites are considered to be of little interest to mining operators, and no cost for lignite has been associated with either of the alternatives during formulation.

Coordination with USFWS has brought about questions on required instream flow releases. The District is working in coordination with WES, USFWS, and the Texas Parks and Wildlife Department to develop a dependable, mutually acceptable method of determining instream flow needs for low gradient warm water streams. All parties have agreed, however, that before mitigation of stream losses can be discussed, a determination of "maintenance flow" requirements must be made. In the interim, the USFWS has provided the following "maintenance flow" recommendation.

MINIMUM CONTINUOUS DISCHARGE
FOR INSTREAM MAINTENANCE
(Marshall Damsite - cfs)

J	F	M	A	M	J	J	A	S	O	N	D	Year
100	100	100	100	100	100	75	75	75	75	75	100	90

The above flows were used for preliminary planning purposes only. Upon completion of the Corps' aquatic investigations, the recommended "maintenance flow" may differ significantly. For instance, the study team is considering spring spawning requirements and the fact that the period of record hydrology indicates in every year an out-of-banks flushing flow occurs in April or May. Indications are that a more appropriate "maintenance flow" would be lower than that indicated above (i.e., 50 cfs from December through June and 10 cfs from July through November) with an overbank discharge of about 2,000 cfs for 1 or 2 weeks duration during April.

Once the "maintenance flow" regime is defined and agreed upon by the different agencies, mitigation or enhancement flows may be determined. The USFWS considers the stream aquatic system to be Resource Category 2, which means that full and in-kind mitigation will be recommended. Flows downstream of the proposed damsites will be analyzed to determine the appropriate flow regimes to compensate for those habitat values (habitat units) which are lost due to any project. Flows which could constitute desirable stream enhancement measures will also be determined and the level of enhancement quantified. Aquatic habitat values created by the lake will also be quantified to determine any potential gains in habitat values.

Based upon data available at this time, it appears that some reservoir storage may be required to provide maintenance of "without project" stream habitat downstream of either damsite. Likewise, mitigation and/or enhancement of the stream resource may require reservoir storage for regulation of streamflow. With concurrence of the local sponsors and through State water allocation procedures, a fish and wildlife enhancement purpose of either alternative could be realized for aquatic resources. There would, however, be a monetary cost to meeting such a project purpose which would require local cost sharing. Additionally, based upon terrestrial habitat evaluations, it appears that losses to terrestrial habitats, which cannot be mitigated, would detract somewhat from a fish and wildlife enhancement purpose. However, without a Federal multipurpose project, it is possible that fish and wildlife enhancement opportunities (as well as recreation) could be foregone with development of a single-purpose water supply by local interests.

In conclusion, the lake alternatives alleviate many of the problems of the basin and take advantage of opportunities offered. They provide for water supply, recreation, and flood control, and help to maintain water quality. In the process, a lake impacts fish and wildlife habitat and possible cultural resource sites. However, plans to mitigate for these impacts are included for each alternative. Marshall Lake appears to be the most promising alternative thus far since it develops the maximum net benefits at the formulation point of 125.7 mgd. Therefore, Marshall Lake will be recommended for further study.

Alternative 10 - Addition of Hydropower to Lake Alternatives

Lake alternatives offer the opportunity to develop hydropower generation. This can be done supplemental to water supply releases or with dedicated storage for hydropower releases. Studies were performed to investigate the feasibility of adding hydropower to water supply lake alternatives. These studies indicated that several sizes of hydropower installations are economically feasible. At the Marshall site, an installation of 1.0 MW is feasible. At the Black Cypress site, 0.5 MW and 4.0 MW were feasible. However, installation below the size of 2.0 MW is considered too small to warrant Federal development and would be better left for local interests to develop. The 4.0 MW installation at Black Cypress is not considered for further consideration because the

Marshall site has been shown to be the better alternative for water supply development. Therefore, no hydropower development as incidental to water supply operations is considered to warrant further Federal involvement.

Studies were also conducted to investigate the feasibility of using dedicated hydropower releases to generate power. Alternatives were investigated with hydropower only projects and with dedicated hydropower added to a water supply project. Tables 35 and 36 show the results of these studies for the Marshall Lake and Black Cypress Lake sites, respectively. These tables indicate the size of units which are technically feasible at the two lake sites. Tables 37 and 38 give the pertinent data for the hydropower alternative lakes, and tables 39 and 40 show the economically analysis for the different hydropower alternatives. Tables 39 and 40 show that none of the dedicated hydropower alternatives are economically feasible. Most have negative net benefit values. Of the two alternatives, Marshall Lake with a 2.9 MW addition and Marshall Lake with a 9.7 MW addition which show positive net benefits, an incremental benefit-cost analysis shows that the addition of the hydropower is not incrementally economically justified. As shown on table 41, benefit-to-cost ratios for the 2.9 MW and 9.7 MW alternatives are 0.13 and 0.29, respectively. The dedicated hydropower analysis used very low plant factors. It would be hard to use these size plant factors in an electrical system. Higher plant factors would result in smaller unit sizes and lower hydropower benefits. Thus, higher plant factors would not improve economic viability. The addition of dedicated hydropower and single purpose hydropower only alternatives have been shown to not be economically feasible and are dropped from further consideration.

Alternative 11 - Navigation Channel

A navigation channel from Shreveport, Louisiana, to Daingerfield, Texas, has been authorized, see plate 18. This reach would be an extension of the navigation channel from the Mississippi River to Shreveport reach along the Red River which is under construction. The Shreveport to Daingerfield reach would proceed along Twelve Mile Bayou to Caddo Lake where a lock would be constructed in the existing dam. Then it would continue through Caddo Lake to Big Cypress Bayou and along Big Cypress Bayou to Lake O' The Pines. A lock and dam would be constructed in Big Cypress Bayou near Jefferson. Another lock would be required in the existing Lake O' The Pines dam. Navigation would continue through Lake O' The Pines to a point near Lone Star, Texas, the head of navigation. The channel would be 200 feet wide and provide a minimum depth of 9 feet. There are approximately 84 miles of channel involved, 3 locks required, 1 dam, and 12 highway and railroad relocations.

Investigation of this alternative was basically a reevaluation of the authorized project. An analysis of potential commodities in the area and an update of costs were done. Alternative route alignments were considered, as well as extending the channel to the Dallas-Fort Worth area. No new traffic was found that would use a waterway. The principal commodities would still be connected with the steel industry and would mostly be used by one company, the Lone Star Steel Company. Table 42 shows the updated costs for the authorized channel. These costs were updated by taking quantities from the 1979 reanalysis report and applying present unit costs for some items and using a cost index factor for others. Benefits for the authorized channel are the annual transportation savings benefit and the area redevelopment benefits. Because this project was authorized prior to 1969, it was analyzed at the 3 1/4 percent interest rate.

Table 43 presents the economic analysis of the authorized Shreveport to Daingerfield reach at the authorized 3 1/4 percent evaluation rate and the current 8-3/8 percent evaluation rate. As can be seen, by using updated costs and benefits the authorized navigation channel would have negative net annual benefits at both evaluation rates and does not appear to be economically feasible at this time.

In an attempt to reduce costs, two off-channel alignments were investigated. One channel went north of the authorized alignment and one south. Off-channel alignments would avoid much of the environmental damage to the special areas which exist in Caddo Lake and along Big Cypress Bayou. However, these off-channel alignments increase relocation costs and excavation costs, and require fill areas where the channels cross major tributary streams to Big Cypress Bayou. Also, there is the technical problem of passing tributary flows across an off-channel alignment. Table 44 presents the costs of the two off-channel alignments. A comparison of this table to table 42 shows that the authorized alignment is still the least expensive. Environmental mitigation costs have not been calculated for any of the alignments. However, it is not expected the differences between the authorized alignment and the off-channel alignments will make up the $83,749,000 difference. Therefore, the authorized alignment is still considered to be the least expensive route for the Shreveport to Daingerfield navigation reach.

Another investigation considered extending the authorized project to the Dallas-Fort Worth area, Plans B, C, and D. This extension could provide a waterway for the commodities projected to use the authorized Trinity River channel. Three different alignments were considered and were identified as Plans B, C, and D. Plates 19, 20, and 21 show the alignments for Plans B, C, and D, respectively. Two of the alignments, Plans B and C, proceed from the Cypress Basin into the Sabine Basin, then up the Sabine River, and then into the Trinity River Basin. The third alignment, Plan D, proceeds up Big Cypress Bayou to Lake Cypress Springs, overland through the Sabine Basin, and then into the Trinity River Basin. Only costs for basic items for these alignments were computed. Table 45 shows the costs of the three alternative alignment extensions. Channel costs include lands and relocations, as well as excavation. Engineering and design, supervision and administration, and contingencies have been included in all costs. Plan D is the least expensive of the three alignments investigated. This is the alignment which proceeds up the Big Cypress Bayou, overland through the Sabine Basin, and then into the Trinity River Basin. As an economic test of this extension, it was assumed that all traffic which would have used the Trinity River channel would use this navigation extension. Therefore, the transportation benefits for the Trinity River channel were assumed as the navigation benefits for the Plan D navigation extension. The costs used for the extension are the costs for Plan D minus the authorized channel costs, $3,911,490,000 - $684,802,000 = $3,226,688,000. Table 46 presents the economic analysis of the navigation extension. As can be seen, using the least costly extension plan could not be justified economically even though optimistic estimates of benefits (transportation savings) were used. The transportation savings of $2,225,000 for this navigation extension do not come close to justifying the $419,119,000 in estimated annual cost. An extension of the Shreveport to Daingerfield navigation reach is not an economically viable alternative. Therefore, none of the navigation alternatives considered in the Cypress Basin warrant further Federal investigation at this time.

Alternative 12 - Caddo Lake Enlargement

The prospect of enlarging Caddo Lake for additional water supply has been under consideration for many years. When the present dam was constructed in 1971, provisions were made so that the water surface of the lake could be increased easily. The Vicksburg District of the Corps of Engineers has conducted a special study on the feasibility of raising Caddo Lake. Close coordination has been maintained during their efforts. A Caddo Lake Enlargement Study and Summary of Results Report was completed by the Vicksburg District in December 1985. The feasibility and effects of raising Caddo Lake are detailed in that report.

Based on the findings of the report, it was determined that it would be economically viable to raise Caddo Lake by 2 feet. This 2-foot raise would provide 186,500 additional acre-feet of storage which would supply a yield of approximately 84 mgd. The cost of the necessary modifications is estimated at $154,000,000. However, implementing this alternative is questionable because of long standing opposition. Additionally, The Summary Report does not recommend Federal action, since, based on current policy, there is no Federal authority at this time allowing for Corps involvement in the construction of single purpose water supply projects. For additional details on the Caddo Lake Enlargement alternative, see attachment 1 of this feasibility report. Attachment 1 is a notice of Issuance of Summary Report for the Caddo Lake Enlargement Study, Louisiana and Texas, prepared by the Vicksburg District on January 21, 1986.

SCREENING OF PRELIMINARY ALTERNATIVES

This chapter has presented the analyses of several nonstructural and structural alternatives. All of the alternatives have been analyzed primarily on the basis of economic feasibility and practicality, although it is recognized some of the alternatives might have additional intangible benefits. Table 47 shows the alternatives evaluated, those deleted in the screening process, and those selected for detailed studies. Note table 47 includes a Lake O' The Pines storage reallocation alternative which was not evaluated during preliminary plan formulation but was added in light of the requests of local interests (see RESULTS OF PUBLIC MEETING at the end of this chapter).

The following presents the screening of preliminary nonstructural and structural alternatives and a discussion of the advantages, disadvantages, and decision for inclusion as a candidate for detailed studies for each alternative.

Water Conservation.

Advantages of water conservation would be reduced need for future sources, lower costs to consumers for current uses, and preservation of the existing resource. Disadvantages of water conservation would be institutional constraints and public resistance to implementation of conservation measures. Also permanent water conservation measures allow less flexibility during periods of drought. As a result of permanently reducing water usage, there is less room for changes when a drought condition occurs. Detailed studies are not warranted; net water supply needs have been adjusted to reflect implementation and usage of water conservation measures.

Change Operating Procedure of Lake O' The Pines

Advantages of changing the operating procedure of Lake O' The Pines result in a slight decrease in frequency discharges downstream and associated damages. Disadvantages include slight increases in the frequency lake elevation and additional bank erosion associated with higher lake levels. Additional detailed studies are not warranted because the operating procedure has been modified to take advantage of the increased reduction of damages downstream.

Raise Existing Structures

Advantages of raising the existing structures would be retention of the current flood plain uses and limited detrimental environmental and community life disruptions. Disadvantages of raising the existing structures would be possible negative esthetic results from elevated structures. Also, potential hazardous conditions would develop if structure inhabitants remain in raised structure during severe flooding events. Detailed studies are warranted because of preliminary economic feasibility.

Evacuate Flood Plain

Advantages of flood plain evacuation would be the removal of flood prone structures and corresponding elimination of future flood damage, reductions in flood insurance premiums, reductions in flood relief payments, and recreational use of the evacuated flood plain. Disadvantages of flood plain evacuation would be high cost, along with tremendous disruptions to community life and community cohesion.

Detailed studies are not warranted based on lack of economic feasibility.

Ground Water Utilization

Advantages of utilizing ground water for water supply would be less adverse effects on the environment compared to the water supply alternatives and ability to further utilize the potential of the resource. Disadvantages of utilizing ground water for water supply would be some adverse environmental effects due to the well field and extensive pipeline system required and high first costs and operational costs. Detailed studies of utilizing ground water for water supply are not warranted because of lack of economic feasibility.

Levees

Advantages of levees would be limited loss of natural resource, few housing displacements and impacts to community life, and location of project in the problem area. Disadvantages of levees would be esthetic degradation and potential for catastrophic damages and loss of life in the event of levee overtopping or breaching. Detailed studies are not warranted because of economic infeasibility.

Enlarge Channel

Advantages of enlarging the existing channels would be reduction of flood stages, limited loss of natural resources, few housing displacement, and location of project in the problem area. Disadvantages of enlarging the existing channel would be severe damage to the riverine environment and esthetics and economic viability. Detailed studies of enlarging the channel are not warranted because of economic infeasibility.

Diversion Channel

Advantages of a diversion channel would be reduction of flood stages, preservation of the existing channel, does not pass through developed areas, and location of project in the vicinity of the problem area. Disadvantages of a diversion channel would be severe environmental damage and economic feasibility. Detailed studies of a diversion channel are not warranted due to lack of economic feasibility.

Lakes

Advantages of lakes are they can alleviate several problems. Conservation storage can provide additional water supply providing a pool for recreation. Flood control storage can help reduce downstream flooding. Lakes also provide potential for hydroelectric power development. Disadvantages of lakes would be adverse impacts to the environment such as inundation of large areas of wildlife habitat and conversion of riverine habitat to lake habitat; relocations of families, roads, and utilities; and high cost. Detailed studies of the Marshall Lake site are warranted because based on preliminary economic analysis this alternative is economically feasible and provides the greatest positive net benefit values.

Addition of Hydropower to Lakes

Advantages of hydropower additions would be reduction in depletion of nonrenewable energy resources, development of nonpolluting renewable energy resource, and lower cost to consumers. Disadvantages include adverse impacts associated with transmission facilities. Detailed studies are not warranted because the feasible developments are considered too small to warrant Federal development.

Navigation Channel

Advantages of a navigation channel would be to provide commodities access to waterway movement on the Mississippi River. Disadvantages of a navigation channel would be adverse environmental impacts and economic viability. Detailed studies are not warranted because of economic infeasibility.

RESULTS OF PUBLIC MEETING

Since the initiation of the detailed investigation of the water resources problems and needs of the Cypress Bayou Basin, several public coordination activities have been integrated into the total planning process for the area and were beneficial in developing information concerning the flood and water supply problems and public concerns and preferences. This data was incorporated into the planning effort directed at the development of alternative plans. The most recent significant public involvement effort was the February 6, 1986, public meeting held in Marshall, Texas. See the public meeting notice included as attachment 2.

The purpose of the meeting was to present the results of preliminary plan formulation, especially in regard to the economic feasibility of the preliminary alternatives and their potential to be considered for detailed plan formulation.

The meeting drew a standing room only audience, with the majority of the speakers expressing general opposition to any lake project. However, much of the opposition exhibited appeared to be focused on the Little Cypress Utility District's (LCUD's) reservoir plan (see Detailed Plan Formulation by Others in chapter 7) and not directly at the Corps' proposal. It appeared as though the local interests were using the Corps meeting as a forum for expressing views against the LCUD proposal and apparent lack of public coordination on their part. In spite of this, the public presented a clear message to the Corps that they oppose any lake projects in the Little or Black Cypress watersheds.

Through much discussion at the meeting concerning the alternatives addressing water supply needs, interest was expressed by the local water districts for the Corps to evaluate the potential of reallocating flood control storage at Lake O' The Pines to water supply storage. Potential storage reallocations at Lake O' The Pines could meet the more immediate study area water supply needs, thereby delaying further into the future the need to construct a new major lake.

To properly address this issue, it was decided the potential for storage reallocation at Lake O' The Pines would be evaluated during detailed plan formulation studies as discussed in chapter 7. Table 47 reflects detailed studies will consider reallocation of storage at Lake O' The Pines.

SUMMARY

This chapter presented the results of the preliminary analysis of 12 alternatives. Based on the preliminary analysis, the nonstructural raising alternative and the structural lake alternative were the only ones found to be economically feasible, warranting further detailed study. During late stage public coordination, local interest was expressed in addressing the potential for storage reallocation at Lake O' The Pines. To properly evaluate this alternative, Lake O' The Pines storage reallocation would be evaluated during the detailed plan formulation studies.

CHAPTER 7 - DETAILED ANALYSIS OF SELECTED PRELIMINARY ALTERNATIVES

The alternatives identified in table 47 for detailed analysis were subjected to a detailed planning iteration to further investigate the feasibility of the alternatives. For example, the nonstructural alternative of raising structures was reevaluated on the fiscal year 1986 project evaluation interest rate of 8.625 percent. In addition, actual benefits were determined in lieu of using damages and cost estimates were refined and updated. Caution must be exercised in comparing pertinent data in this chapter with data shown in Chapter 6 and later chapters. This is because these data have been refined and updated due to refined analytical procedures, more detailed designs, and price and interest level changes. Thus this chapter presents detailed information and should be considered to supersede previous information where discrepancies occur.

RAISING EXISTING STRUCTURES

Raising of the existing structures in the 25-year flood plain was found to be economically feasible based on 8.375 - percent interest and optimistic cost(i.e. low) and benefit (i.e. high) estimates. The areas where structure raisings were determined to be feasible under the preliminary evaluation assumptions and considered for detailed evaluations are presented on Table 24 and highlighted on plate 22.

The following presents the results of detailed formulation of the plan using additional screening criteria, refined cost estimates, actual benefits and the current 8.625 percent interest rate used for project evaluation. Where the first iteration of structure raising investigated the feasibility of raising all structures to an elevation above the 100 year flood level, the detailed planning efforts incorporated decision-making criteria to screen the structures further.

The preliminary evaluation considered a significant number of residences for raising even though the estimated cost for raising the structure was greater than the estimated value of the structure, thereby, raising doubt as to their economic feasibility. Additionally, to achieve mainfloor elevations above the 100-year level, the preliminary analysis considered raising structures in excess of 10 feet. Therefore, as part of the detailed formulation of a raising plan decision-making criteria were established to further screen the structures. This criteria screened the structures based on the estimated structure value being greater than the revised detailed per structure raising cost. On this basis alone, 212 of the 555 structures considered preliminarily were screened from further analysis, leaving 343 structures for additional study. Also, for practical and aesthetic reasons the maximum height of raising considered was limited to the mainfloor elevations not exceeding 8-feet above the ground elevation.

Plan Description

The 343 structures identified for detailed plan formulation are all within the 25-year flood plain and located in the damages Reaches 1, 2, 3, 4, 5, and 6 along Big Cypress and 1, 2, 3, and 6 along Caddo Lake. Plate 22 shows the locations of these reaches.

Costs associated with raising a structure were based on cost data developed by the Hydrologic Engineering Center and data developed by other Corps of Engineers Districts. In developing costs the structures were separated into two categories. The first contained all structures constructed on post and beam foundations, and mobile homes. The second category consisted of all structures constructed on slab foundations. The homes were separated into these categories because it was evident raising a structure on a slab foundation would be costlier, as well as more difficult, than raising either a mobile home or structure with a post and beam foundation. For structures in the first category, the major cost items associated with raising include: bracing and loading the structure, disconnecting and reconnecting utilities, updating the structure to code (electrical, plumbing), removing the old foundation, extending the new foundation, relandscaping, reconstructing stairs and porches, and temporary housing during construction. Structures on slab foundation would incur, in addition to these items, additional significant cost items associated with constructing a new floor and support system and potential interior reconstruction.

Considering the above items, the reconstruction costs on a per structure basis for raising structures with post and beam and slab foundations were estimated at $14,900 and $45,400, respectively, based on January 1986 price levels. Table 48 summarizes the results of the detailed evaluation. Included on the table are numbers of structures to be raised by reach along with pertinent costs and benefits. The operation and maintenance costs were estimated as a percentage of the amortized construction costs for raising a particular structure. Unlike the preliminary analysis which included interest during construction, interest during construction was not included in the economic evaluation of the detailed plan due to the relatively short construction period, on a per structure basis, and the ability of each structure to accrue benefits at the completion of construction.

The first cost of raising 343 structures is estimated at $5,736,600. As shown on table 48, raising of structures in the flood plain is not economically feasible on an overall or individual reach basis. Consequently this alternative was dropped from further consideration.

It should be noted the detailed analysis of raising the structures still afforded an optimistic look at the alternative, in that existing hydrologic and hydraulic conditions were used as the basis for determining the height of raising and frequency of damages. The flood damage reduction impacts of a potential new lake located in the basin, such as the Little Cypress Reservoir discussed later in this chapter, were not taken into consideration when computing the benefits for this nonstructural measure. Therefore, the annual benefits used in evaluating the alternative may be somewhat higher than could be expected to accrue in the future if a new lake were constructed in the watershed.

MARSHALL LAKE

Of the two lake sites evaluated, Marshall Lake, plate 10, was determined to be the alternative which would best meet the needs of the study area. Although the preliminary analysis of Marshall Lake considered developing Marshall Lake with water supply yields of 180 cfs and 250 cfs, the detailed analysis focused on the evaluation of a Marshall Lake with a water supply yield of 200 cfs. The 200 cfs (129 mgd) yield was selected to better approximate the future needs of the study area, estimated to be about 125.7 mgd with implementation of conservation measures and 129 mgd without implementation of conservation measures.

Marshall Lake would be located at river mile 21.3 on the Little Cypress Bayou, approximately 9 miles northwest of the City of Marshall. As part of the detailed analysis further refinements in pertinent data, costs, and benefits were made. These refinements are discussed in more detail below. Physical features of Marshal Dam are highlighted on plate 23.

Pertinent Data

Consideration in developing Marshall Lake with a water supply yield of 200 cfs resulted in revisions to the pertinent data as shown on table 49.

Costs

Costs obtained from cost curves contained in appendix E were updated from July 1984 price levels used in the preliminary analysis to January 1986 price levels using ENR indexes.

Benefits

Benefits were updated from the July 1984 levels used in the preliminary analysis to reflect effect of interest rate changes, detailed analysis of flood damage reduction and price level increases to January 1986.

Spillway Length Optimization

To evaluate the optimum spillway length - dam height configuration for the Marshall Lake dam, two additional scales of spillway length - dam height configurations were analyzed hydrologically and hydraulically with each scale maintaining the water supply yield of 200 cfs. The lengths of these two spillways were 400 and 1,000 feet. Water supply outputs were maintained so future projected needs could be met. Recreation considered was based on the conservation pool. Since the conservation pool was maintained, recreation outputs were also maintained. Downstream flood damage reduction outputs were allowed to change based on the effects the spillway lengths would have on surcharge storage. Table 50 presents the pertinent data for Marshall Lake with the different spillway lengths. Table 51 contains the pertinent economic data for the detailed analysis of Marshall Lake. Table 51 also includes an analysis of a Marshall Dam with a 200 foot spillway. The 200 foot long spillway was subsequently included into the analysis when it became apparent that the net benefits looked to be increasing at the 400 foot scale and that the optimum length could not be properly identified.

The results of this evaluation indicate the Marshall Dam spillway optimizes at approximately the 400 foot length; see plate 24. At this scale the economic cost of the project would be approximately $153,617,000 and the total annual cost would be about $15,801,000. The project would yield approximately $20,809,000 in annual benefits, resulting in excess annual benefits of $5,008,000 and a benefit to cost ratio of 1.3.

Economics of the Marshall Lake Alternative

The economic justification of Marshall Lake was determined by comparing the estimated annual charges (i.e., interest, amortization, and operation and maintenance costs) with the estimated annual benefits anticipated to accrue over the economic life of the project. A discount rate of 8.625 percent was used to obtain comparable annual costs and benefits. In accordance with the economic criteria for the project, a 100-year project life was used in the economic analysis.

Marshall Lake is expected to be constructed within 48 months. Therefore, interest during construction was included for this period. The economic evaluation of Marshall Lake is shown on Table 52.

Estimate of First Costs. The estimated economic first costs of the Marshall Lake plan are $153,617,000. This estimate includes allowances for contingencies, engineering and design, supervision, planning, surveys, appraisals and administration. All estimates are based on January 1986 price levels.

Estimate of Annual Charges. The estimated annual charges for the Marshall Lake plan are based on an interest rate of 8.625 percent. Charges for amortization of the first costs of this plan and real estate are based on a 100-year useful life expectancy. The total annual costs for the selected plan are $15,801,000 including operation, maintenance, replacement costs, and interest during construction.

Estimate of Annual Benefits. The benefits accruing to Marshall Lake consists of the expected annual flood damages prevented, and benefits from water supply, and recreation. As shown on Table 52, the annual benefits estimated to accrue to Marshall Lake are as follows:

° Flood Control	-	$	340,000 (1.6% of total)
° Water Supply	-	$	15,902,000 (76.4% of total)
° Recreation	-	$	4,567,000 (22.0% of total)

The total expected annual benefits from this plan are estimated at $20,809,000.

Economic Justification. The comparison of annual benefits and the annual costs in a benefit-to-cost ration (BCR) of 1.32 for Marshall Lake. The incremental BCR's for the flood control, water supply and recreation purposes are 1.01, 1.46 and 1.00, respectively, as shown on table 52.

Cost Allocations

A cost allocation provides a breakdown of project costs based on project purposes. For Marshall Lake, costs were allocated to the project purposes of flood control, water supply, and recreation. The Separable Cost-Remaining Benefits Method was used to determine the preliminary cost allocations for including each purpose in the multiple-purpose project, and determining an equitable distribution of the joint costs incurred for several purposes in common. The separable cost for each project purpose is the difference between the cost of the multiple-purpose project and the cost of a project with the purpose omitted. Joint costs as used in the method, is defined as the difference between the cost of the multi-purpose project as a whole and the total of the separable costs for all project purposes. From the estimated benefits or alternate cost, whichever is less, separable cost is deducted to give remaining benefits. Joint cost is distributed in proportion to the remaining benefits for each purpose. The sum of separable cost and distributed joint cost for each purpose constitutes the total cost allocated to that purpose. By subtracting separable cost from the benefits or alternate cost, whichever is less for a purpose, the cost allocated to that purpose is limited to the separable cost as a minimum and benefits as a maximum. Table 53 displays the allocation analysis by the Separable Costs - Remaining Benefits Method. Based on this analysis first costs for Marshall Lake would be allocated as follows:

° Flood Control	- $	3,204,700 (2.1% of total)
° Water Supply	- $	103,747,500 (67.5% of total)
° Recreation	- $	46,664,800 (30.4% of total)
TOTAL FIRST COST	- $	153,617,000

Apportionment of Costs

The cost apportionment assigns project costs to the proper Federal or Non-Federal entity. Table 54 presents the apportionment of costs based on the Water Resources Development Act of 1986 (PL 99-662). This legislation decreased the Federal responsibility for flood control related costs in major reservoir projects from 100 percent to 75 percent with the remaining 25 percent being the responsibilities of the non-Federal sponsor. Based on PL 99-662, costsharing percentages, the Federal share of first cost would be $25,735,900 or 16.8 percent of the total, while the non-Federal share would be $127,881,100 or 83.2 percent of the total first cost. The total annual cost of $15,801,000 would be shared in the following manner: Federal $2,167,200 and non-Federal $13,633,800, 13.7 and 86.3 percent, respectively. Based on superceded traditional cost sharing policies for a multipurpose reservoir the Federal and non-Federal share of the total annual cost of $15,801,000 would have been shared in the following manner: Federal $3,128,100 and non-Federal $12,672,900, 19.8 and 80.2 percent, respectively. This information is presented in detail on Table 55 for comparison purposes only.

Financial Cost to Non-Federal Interests

Current policy recognizes a significant Federal interest in long range management of water supplies, but generally assigns the financial burden of supply to the non-Federal sponsor. Section 301 (Water Supply Act of 1958) provided that the cost of providing water supply at a Corps project plus interest is to be repaid by non-Federal entities within the life of the project but not to exceed 50 years after first use for water supply. In accordance with provisions of Section 301, interest rates used in the calculation of interest during construction and repayment of construction costs allocated to water supply are determined by the Department of the Treasury. The Department of the Treasury has determined the rate applicable for fiscal year 1986 to be 11.070 percent. It should be noted that these rates also apply to repayment of designated recreation costs. Based on this 11.070 percent interest rate potential annual costs of repayment by the non-Federal interest were developed, and are presented on Table 55. With the financial non-Federal cost of water supply estimated at $14,927,700 annually, the resulting cost of water per 1,000 gallons would be $0.32.

Environmental Effects

The environmental effects of Marshall Lake are discussed in the USFWS planning aid letters contained in appendix H, with the significant impacts summarized below. Some of the impacts are associated with construction and would only be temporary, but others of a more enduring nature are involved.

Terrestrial Habitats. Construction and impoundment of Marshall Lake would eliminate all wildlife habitat within the 15,763-acre conservation pool. About 11,350 acres of the area that would be inundated are productive bottomland hardwoods. Management activities of Government fee-lands not inundated could improve their value. Management activities would consist primarily of revegetation and natural succession of bottomland hardwoods. An additional positive impact of the reservoir on wildlife would be the creation of open water habitat. The littoral zone of the lake would provide more lacustrine habitat for species such as wood duck and belted kingfishers than is currently available in the project area. Upland hardwoods on Government lands surrounding the lake could also be expected to increase in value with succession and management.

The Habitat Evaluation Procedures (HEP) conducted by the USFWS (appendix H) indicate that an average of about 35,088 acres would have to be acquired and managed to achieve full and in-kind compensation for bottomland hardwood losses. Additionally, an average of 14,730 acres of riparian habitat would be required to provide full and in-kind compensation for riparian habitat losses. Both of these habitat types are considered to be Resource Category 2 by the USFWS, and their full and in-kind compensation would be the mitigation goal. A detailed habitat mitigation plan has not, however, been developed due to lack of Federal interest in the project.

Aquatic Habitats. Two studies of aquatic habitats and streamflows necessary to obtain various levels of stream aquatic productivity (stream habitat) were conducted. The water surface profile hydraulic simulation was conducted by USFWS and results submitted in a planning aid letter dated July 1984 (appendix H). The USFWS's recommended monthly flow to maintain the stream system downstream of the damsite is 100 cfs for the months of December-June and 75 cfs from July-November. The USFWS's recommended flows do not include a recommendation for flushing. Flushing flows are important to stream ecosystems because of their role in nutrient exchange and removal of sediment and debris from riffles and pools.

The second stream aquatic analysis was conducted as a joint effort between the USFWS, Texas Parks and Wildlife Department, Waterways Experiment Station, and Fort Worth District, Corps of Engineers (appendix I). That study was conducted during 1984 and 1985 and is based upon extensive biological sampling of the stream at various flows. The joint study identifies maintenance flows for the stream reach below the dam and compensation flows to replace habitat unit losses due to inundation. It also identifies aquatic habitat unit gains associated with the lake. The stream system is, however, considered to be a rare and diminishing natural resource and not replaceable by lake habitat gains. Maintenance flow recommendations contained in the joint study range from a high of 270 cfs in April and May to a minimum of 3 cfs from August through October. Compensation flow recommendations include flushing flow recommendations of greater than 425 cfs for short durations (about 2 weeks) periodically from January through May with maintenance flows released the remainder of those months. Compensation flow recommendations also include a minimum of 10 cfs during the dry months of August-October. The USFWS does not necessarily endorse the flow recommendations of the joint study but did participate and contribute significantly to the study. Any flow released from the dam for maintenance of compensation of stream habitats would probably require a specific water rights allocation or at least a coordinated water supply release.

Water Quality. An evaluation of the future water quality of a lake at the Marshall Damsite and quality of release waters was conducted for the Fort Worth District through contract to Plummer and Associates, Inc. (appendix G). That analysis indicates that the relatively good quality of water in Little Cypress Creek will probably be maintained in the future. Water from a lake at the Marshall Damsite would be suitable for all municipal and industrial uses. Although the lake would be classified as eutrophic, high dissolved oxygen levels would probably be maintained in the epilimnion. Marshall Lake would receive a lower biochemical oxygen demand and nutrient load than Lake O' The Pines so quality may be slightly better. The dissolved oxyen analysis indicates that the larger the conservation pool, the better the quality in the reservoir. Selection of depths of outlet works and release patterns would be important to the quality of the stream below the dam. Multilevel outlet works would enhance the ability to selectively release waters of higher quality. Quality of Little Cypress Bayou below the reservoir could be improved by maintaining some year round flow.

Federal Implementation

It has been a long-standing policy that the Federal Government not construct single-purpose municipal and industrial (M&I) water supply projects. Such projects have traditionally been the responsibility of non-Federal interests. However, since all dams provide some flood control benefits, however slight, it was necessary to establish a common definition of a single-purpose M&I project. Recent policy from the Executive Office of the President, Office of Management and Budget, dated May 28, 1986, regarding the designation of single or multi-purpose water supply projects, states:

"A project should be defined as a single-purpose M&I water supply project, other than a modification of an existing Federal structure, where less than 20% of the anticipated national economic development (NED) benefits are attributable to flood control, navigation, and/or agricultural water supply. An exception would be made for a project where at least 10% of the anticipated NED benefits are attributable to flood control, navigation, and/or agricultural water supply that requires separable, economically justified storage in order to develop the anticipated benefits from these purposes."

Since the flood control benefits attributable to Marshall Lake are less than 2% of the total project benefits and there is no separable economically justified storage included to develop the anticipated benefits, based on the above definition Marshall Lake would be classified as a single purpose M&I water supply project. Therefore, at this time, there is no Federal authority for the Corps of Engineers to pursue development of Marshall Lake and development of M&I water supply lake would be the responsibility of non-Federal interests.

STORAGE REALLOCATION AT LAKE O' THE PINES

Lake O' The Pines Background

Lake O' The Pines is a part of the comprehensive plan for flood control in the Red River Basin. The project was authorized by the Flood Control Act approved 24 July 1946, Public Law No. 526, 79th Congress, 2nd Session. The reservoir is located on Big Cypress Creek, about 9 miles West of Jefferson, Texas. It has a maximum height of 97 feet above the streambed and is 10,600 feet in length. The reservoir provides 587,200 acre-feet of flood control storage and 251,000 acre-feet of water supply storage. Additional data concerning Lake O' The Pines is presented on Table 57. Plate 25 presents the area and capacity curves for Lake O' The Pines.

Introduction to Storage Reallocations

Reallocation or addition of storage at existing projects that would have a significant effect on other authorized purposes or that would involve major structural or operational changes requires Congressional approval. Providing the above criteria are not violated, 15 percent of total storage capacity allocated to all authorized project purposes or 50,000 acre-feet, whichever is less, may be allocated from storage authorized for other purposes or may be added to the project to serve as storage for municipal and industrial water supply at the discretion of the Chief of the U.S. Army Corps of Engineers. Reallocations which exceed the Chief's authority may be approved at the discretion of the Secretary of the Army if such reallocations do not require Congressional approval, as described above. Since requests for reallocation or addition of storage should be within the context of satisfying immediate needs, the 10-year interest free portion is not appropriate.

Computing Cost of Reallocated Storage

Based on the Corps' planning guidelines, the cost allocated to the local interests will normally be established as the highest of the benefits or revenues foregone, replacement cost, or the updated cost of storage in the Federal project. In the updating method, the construction cost of the project will be updated from the midpoint of the physical construction period to the beginning of the fiscal year in which the contract for the reallocated storage is approved by use of the Engineering News Record construction index. Such cost is to be repaid at the water supply rate current at the time of contract approval and within the remaining physical life of the project, but not to exceed 50 years. In those projects which already have water supply storage space, the payout period shall not exceed 50 years from the time the project was first used for water supply. All new construction costs allocated to water supply shall be paid during the construction period of the modification. Local interests shall also be responsible for an appropriate share of the specific and joint use operation, maintenance, and replacement costs.

Storage Reallocation Analysis

The increased water supply yield which would be available in Lake O' The Pines as a result of reallocating flood control storage was evaluated by FN for the Northeast Texas Municipal Water District, local sponsors for the lakes' water supply conservation storage. The Northeast Texas Municipal Water District has also expressed interest in being the local sponsor for any potential storage reallocations at Lake O' The Pines.

The results of the FN preliminary yield study are presented on table 58 and plate 26. As shown on table 58, water supply yields at Lake O' The Pines could increase by 136,400 acre-feet per year (122 mgd) if all the 587,200 acre-feet of flood control storage could be reallocated to water supply storage. However, reallocating all the flood control storage to water supply would be unacceptable since flood control is an authorized Federal purpose. The storage reallocation analysis was therefore limited to the maximum 50,000 acre-feet of storage that could be reallocated under the Chief of Engineers descretionary authority. Another advantage of limiting the reallocation to 50,000 acre-feet would be that the increase in the conservation pool elevation would only be about 2.5 feet; low enough not to significantly impact existing recreation facilities at the lake.

Based on the results of the FN yield study, reallocating 50,000 acre-feet of flood control storage to water supply storage would increase the water supply yields at the lake by about 15,700 acre-feet per year (14 mgd). This increase in water supply yield, however, would be at the expense of increased lake levels and loss of valuable flood control storage at the lake. As shown on plate 27, the reallocation of 50,000 acre-feet of flood control storage to water supply storage would reduce the frequency of the existing 50-year flood control storage at elevation 249.5 NGVD to about the 40-year level at elevation 249.5 NGVD.

Detailed Plan Evaluation

This alternative involves the reallocation of 50,000 acre-ft of flood control storage by raising the conservation storage elevation by 2.5 feet from 228.5 to 231 feet NGVD (National Geodetic Vertical Datum). This pool raise would result in an initial dependable yield increase of 14 mgd. The dam embankment and spillway features of the dam would be expected to remain as they presently exist. The top of flood control pool elevation would remain at 249.5 ft NGVD.

The proposed pool raise would destroy some terrestrial habitat while creating additional aquatic habitat. The loss of terrestrial habitat would be minimal, based on preliminary surveys. However, additional environmental surveys would be needed to fully assess the impacts of a pool raise. Although relocations of recreation facilities are not expected, potential relocation of impacted facilities would require additional extensive investigations. It is expected the pool raise would most affect the cultural resources located adjacent to the lake. A preliminary assessment regarding impacts of a pool raise on the cultural resources of Lake O' The Pines is presented in appendix J.

The total cost of this alternative would be the value of the reallocated flood control storage and is described in detail in the following sections.

(1) Value of Flood Control Storage. As stated earlier, according to the Corps' planning guidelines, the value of the water supply storage gained by reallocation of flood control storage is normally established as the largest of (a) the flood control benefits foregone, (b) the flood control replacement cost, or (c) the updated cost of reallocated flood control storage in the Federal project. These "pricing methods" are described and analyzed as follows.

(a) Value of Flood Control Benefits Foregone. The value determined by this pricing method is based on the reduction in benefits resulting from the reallocation of flood control storage to water supply. The 50,000 acre-feet reallocation represents an 8.5-percent loss in the existing total net flood control storage of 587,200 acre-feet. The effect of this reallocation would reduce the existing level of flood control storage from the 50-year to the 40-year level. Considering only the dollar value of the benefits foregone and not the relative importance of this loss to the project beneficiaries - it is anticipated the reallocation would result in a comparatively small dollar value in relation to the dollar value of storage obtained using the pricing methods considered in items (b) and (c). Therefore, the value of flood control benefits foregone pricing method was not considered further in this analysis.

(b) Flood Control Replacement Cost. This pricing method involves the determination of the replacement cost of equivalent protection associated with the reallocated flood control storage. It was determined a nonstructural solution consisting of raising any effected structures would be a more cost effective and logical alternative than raising the dam to accommodate the 50,000 acre-feet of replacement flood control storage, or the construction of a completely new upstream flood control only reservoir. In lieu of performing a detailed evaluation to determine the extent and number of structures requiring raising, the flood control replacement cost was based on the detailed analysis of raising the existing structures discussed in this chapter. Using the findings of that analysis, 343 structures in the flood plain could be raised as much as 10 feet at a first cost of approximately $5,737,000, resulting in an annual cost of approximately $526,000. It should be recognized this dollar amount would be a conservative (i.e. high) estimate since this alternative would afford the structures a higher level of protection than was lost due to the storage reallocation. Additional detailed studies would need to be performed to further refine this alternative to provide the level of protection equivalent to that associated with the reallocated storage. Therefore, the value of the flood control replacement cost was estimated at $526,000 annually, and will be used in comparison with the value of the updated cost of reallocated storage pricing method used in item (c).

(c) Updated Cost of Reallocated Storage. This third method is based on the updated cost of storage in Lake O' The Pines. This value is calculated with the total joint use construction cost multiplied by the percent of reallocated storage to total usable (net) storage and an ENR index multiplier. This latter multiplier is the ratio of the price index at the midpoint of construction of Lake O' The Pines to January 1986 price levels.

Per the cost apportionment for Lake O' The Pines, the total Federal flood control allocated construction cost, less recreation costs, is approximately $6,900,000. The percentage of reallocated storage to the total usable storage is as follows:

$$\frac{\text{Storage Reallocated}}{\text{Total Usable Storage}} = \frac{50{,}000 \text{ acre-feet}}{838{,}300 \text{ acre-feet}}$$

$$= 0.05964 \text{ or } 5.964 \text{ percent}$$

The original cost of this reallocated storage would be:

$$\$10{,}100{,}000 \times 0.05964 = \$602{,}410$$

The ENR index multiplier to convert this original cost to a January 1986 price level is calculated as follows, based on a September 1957 midpoint of the construction period.

$$\frac{\text{ENR index for Jan 86}}{\text{ENR index for Sep 57}} = \frac{4{,}166}{723.8} = 5.76$$

The updated value of this storage is, therefore, the proportional original cost for this reallocated storage multiplied by the ENR index multiplier. This calculation is as follows:

$$\$602{,}410 \quad \times \quad 5.76 = \$3{,}469{,}900$$

The value of flood control storage is therefore determined to be $3,469,900. The annual charges for this alternative are based on a repayment period not to exceed 50 years from the time the project was first used for water supply. Following this policy, the repayment period would be 24 years (50 years less 26 years in operation), and using the current Federal interest rate of 8-5/8 percent the annual cost is $346,900. Based on the fiscal year 1985 total annual operation and maintenance cost of $1,425,000, the proportionate annual operation and maintenance cost for this reallocation alternative is $121,300. The resulting total annual cost of this alternative is estimated to be $468,200.

In summary, based on the above three pricing methods, it was interpreted the value of flood control benefits foregone would be small in relation to the values obtained utilizing the flood control replacement cost or the updated cost of storage pricing methods. Using the results of the raise existing structures alternative as a proxy for the replacement cost of equivalent protection, it was determined that a conservative (i.e. high) estimate for this pricing method would be approximately $526,000 annually. The final pricing method considered updating the cost of the reallocated storage. Based on this pricing method, the reallocated storage was valued at $468,200 annually; approximately 10 percent less than the value obtained using the replacement cost method.

As noted earlier, the value of the water supply storage gained by reallocation of flood control storage is normally established as the largest of the values of the three pricing methods reviewed. However, in this instance it was deemed appropriate to deviate from selecting the largest of the values and choosing the value determined using the updated cost of storage procedure. The following reasons are cited: (1) the value as determined using this method is based on actual documented costs and updated using the prescribed procedure removing the "guesswork" or "unknowns" out of the analysis, and (2) this value is within the same range as that determined by the flood control replacement cost, recognizing the alternative used as a proxy for this analysis provided a conservative estimate for this method.

Cost of Water. With the cost of storage estimated at $468,200 annually, the unit cost of water for this alternative based on an initial dependable yield of 14 mgd was calculated to be $0.09 per 1,000 gallons based on a Federal interest rate of 8.625 percent. The local sponsor would be required to repay the storage reallocation costs at the reimbursable interest rate of 11.07 percent for fiscal year 1986 as determined by the Department of the Treasury in accordance with provisions of the Water Supply Act of 1958 if it is financed by the Federal Government. Therefore, based only on the change to a higher interest rate, the amortized capital cost would increase to $417,700 and the resulting total annual charges would be $539,000. The corresponding unit cost of water would be $0.11 per 1,000 gallons.

When costs assigned to the local sponsor are based on the updated cost of storage, as would be the case here, current policy allows the local sponsor a ten (10) percent reduction in the updated cost. However, this offer is applicable only if the local sponsor is willing to pay the reduced cost during the period of construction of the modification. If there is no modification required for the reallocation, then the entire reduced cost must be repaid within thirty (30) days after signing of the contract by the Assistant Secretary of the Army (Civil Works).

Based on this option, the updated cost of storage would be reduced to $3,122,900. The annual charges for this option based on the 24-year repayment period noted above, and using the current Federal interest rate of 8.625 percent, would be approximately $312,200. Adding the proportionate operation and maintenance cost of $121,300 would result in a $433,500 total annual cost for this option. The unit cost of water for this option based on an initial dependable yield of 14 mgd was calculated to be about $.08 per 1,000 gallons.

Implementation Timing

Based on the study area's water supply needs projected on table 20 and graphically presented on Plate 28, the study area will develop a need for an additional 14 mgd by the year 1998. This 14 mgd need could be met by storage reallocation at Lake O' The Pines, thereby, providing an interim solution to the study areas water supply needs, and postponing to the year 1998, the need to construct a major reservoir to meet the remaining requirements. However, a second scenario remains, whereby the need to reallocate storage at Lake O' The Pine could be delayed into the future, since as discussed in this chapter under DETAILED PLAN FORMULATION BY OTHERS the local interests are pursuing development of the Little Cypress Reservoir, this reservoir would afford the study area with an additional 112 mgd in dependable water supplies. Based on the Little Cypress Utility District's (LCUD) projected timetable for this project, Little Cypress Reservoir may be constructed by 1991 with the lake full by 1995. Under this scenario, with an additional 112 mgd yield available study area needs could be met until the year 2038 negating the need to reallocate storage at Lake O' The Pines until then.

DETAILED PLAN FORMULATION BY OTHERS

During the course of the Fort Worth District's detailed plan formulation, the LCUD, a conservation and reclamation district, was created in 1985 via H.B. No. 2457 of the 69th Legislature of the State of Texas, and subsequently ratified by voters within the District. The District is composed of all the territory within the corporate boundaries of the cities of Longview, Marshall, and Kilgore and Harrison County. In addition, a feasibility study was authorized by the cities of Longview, Marshall and Kilgore and Harrison County in 1985 to evaluate a regional water supply reservoir to be located on the Little Cypress Creek in Harrison County, Texas. The reservoir would be owned and operated by the LCUD.

The feasibility study, prepared by KSA, determined it would be feasible to locate a reservoir entitled Little Cypress Reservoir, in Harrison County, 10 miles northwest of Marshall and 20 miles northeast of Longview. The proposed reservoir would have a surface area of 13,760 acres at normal pool elevation of 230.0 feet NGVD. The yield of this reservoir would be approximately 112 mgd. Coordination with KSA has determined that the locally proposed Little Cypress Reservoir would be located in approximately the same location as the Marshall Lake investigated by the Corps. The one major difference between the two alternatives is that the conservation pool for Marshall Lake would be about 3 feet higher, providing an additional 17 mgd in dependable yield. The pertinent project data for the Little Cypress Reservoir is presented on table 59. This data was taken from the Preliminary Engineering Report for Little Cypress Reservoir prepared by KSA. KSA has estimated the first cost of this project at $105,500,000 and annual cost as

$10,570,000. This would result in a raw water cost of 25.1 cents per thousand gallons.

Based on a projected schedule prepared by the LCUD, if no problems are encountered and funding is available, Little Cypress Reservoir could be constructed as early as 1991 with the lake being operational by 1995. As of September 1986, the LCUD is in the process of obtaining water rights permits from the Texas Water Commission.

COMPARISON OF DETAILED PLANS

Flood Control

Both raising of the existing structures and Marshall Lake provided flood control benefits to the major damage reaches in the study area. However, providing flood control by raising the existing structures was found economically not feasible. It was determined Marshall Lake could provide some flood control to the study area, limited to the surcharge storage effects resulting from different length spillways at the proposed Marshall Lake Dam. As discussed in this chapter, Marshall Lake would accrue optimum flood damage reduction benefits with a spillway having a length of 400 feet. Although no detailed studies were undertaken, the local alternative, Little Cypress Reservoir, would most likely provide flood control benefits comparable to the Marshall Lake alternative. Unlike these alternatives, the alternative of storage reallocation at Lake O' The Pines would not provide any additional flood control. On the contrary, reallocation of flood control storage to water supply storage would reduce the level of existing flood control afforded by Lake O' The Pines. As indicated in this chapter, implementation of the proposed reallocation would result in a decrease in flood control storage from the 50-year level to about the 40-year level. In addition, the frequency elevation of lake levels would increase with the proposed reallocation.

Water Supply

The total water supply needs of the study area would exceed the maximum available water supply yield in the study area by the year 1990, with the total net needs in the study area reaching 126 mgd by the year 2040. The Marshall Lake alternative would provide 129 mgd, the reallocation of storage at Lake O' The Pines would provide 14 mgd, while the Little Cypress Reservoir proposed by local interests would provide 112 mgd. The nonstructural raising alternative would not provide any water supply.

Wildlife Habitat

The Corps' Marshall Lake and the local interests' Little Cypress Reservoir would severely impact upon the wildlife habitat of the study area with Marshall Lake being more damaging due to the 3 foot higher conservation pool. The reallocation of storage at Lake O' The Pines would be the least damaging of the water supply alternatives. The nonstructural raising plan would most probably maintain the existing environment.

Recreation

A portion of the recreation needs of the area could be met by a lake in the study area. Marshall Lake would provide the opportunity for approximately 2,900,000 visitation days per year out of a projected need of 4,600,00 visitation days per year. The Little Cypress Reservoir could provide similar opportunities; however, a recreation plan has not been developed at this time. Future plans call for a recreation plan to be developed in coordination with the Texas Parks and Wildlife Department. The increased lake levels resulting from a storage reallocation at Lake O' The Pines would have minimal impacts on the existing recreational output at the facility. The nonstructural raising alternative would not provide any additional recreation outputs to the study area.

SUMMARY

This chapter presented the results of the detailed plan formulation effort including detailed plan formulation by non-Federal interests. The nonstructural raising alternative was found to be economically infeasible. Based on current guidelines, it was determined, there is no Federal interest in development of Marshall Lake. In regard to storage reallocation at Lake O' The Pines depending on progress of the Little Cypress Reservoir, the additional yield that could be provided by Lake O' The Pines storage reallocation may not be needed until 2038. The results of this report were coordinated with State and local officials. Any comments received regarding the report are presented in Attachment 3, Pertinent Correspondence.

CHAPTER 8 - CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

As District Engineer for the Fort Worth District, Corps of Engineers, I have reviewed and evaluated, in light of overall public interest, the data, information and alternatives for water resources development pertaining to the Cypress Bayou Basin, Texas. The principal elements considered in my review included engineering feasibility, environmental impacts, economic factors of regional and national resource development and social well being. The data and information reviewed included investigations and studies prepared by my staff, documents and information furnished by local interests, and the stated views of these interests and agencies relative to the various practical alternatives developed to accomplish the plan for effective water resource development in the Cypress Bayou Basin, Texas.

The study has identified the potential for: significant annual economic losses due to flood damage, significant water supply deficits, and need for additional recreation resources. The study has found the water supply deficit to be the most serious water resource problem in the Cypress Bayou Basin.

Full consideration was given to alternative flood control measures including structural and non-structural measures. The possible consequences of the alternative plans were evaluated according to engineering and economic feasibility, and for environmental, social, and economic effects in accordance with the Principles and Guidelines.

The considered alternatives documented in this report have been coordinated with interested agencies at the Federal, State, and local level. Coordination with the U.S. Department of the Interior, Fish and Wildlife Service resulted in the incorporation of measures into the plans to minimize adverse effects to the environment from the lake alternatives. Local meetings with officials and citizens provided input used in formulating the alternative plans.

Based on the findings of this feasibility study, the Marshall Lake alternative is the most economical alternative for providing water supply and flood control to the study area. However, based on current policy, Marshall Lake would be classified as a single purpose municipal and industrial water supply project since less than 20 percent of the NED benefits are attributable to flood control, navigation, and/or agricultural water supply, and there is no Federal authority at this time for construction of a single purpose municipal and industrial water supply project. The only other feasible alternative identified was reallocation of storage at Lake O' The Pines. This alternative is considered implementable with the only question remaining the time of implementation. If local interests develop the Little Cypress Reservoir, the additional water supply yield obtainable by reallocating flood control storage to water supply at Lake O' The Pines would not be needed until the year 2038. However, if local interests decide not to pursue the Little Cypress Reservoir, there will be a definite need to develop additional water supply as early as 1990, and storage reallocation at Lake O' The Pines could meet this need.

RECOMMENDATIONS

Based on the data presented, I recommend to take no Federal action at this time and to defer further study regarding storage reallocations at Lake O' The Pines until such time water supply needs develop within the study area.

The recommendation contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of a national Civil Works construction program nor the perspective of higher review levels with the Executive Branch. Consequently, the recommendation may be modified before they are transmitted to the Congress as proposals for authorization and/or implementation funding.

A. J. GENETTI, JR.
Colonel, CE
District Engineer

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

TABLES

TABLE 1

CLIMATOLOGIC DATA FOR NORTHEAST TEXAS - TEMPERATURE PRECIPITATION AND MEAN MONTHLY CLASS "A" PAN EVAPORATION

MONTH	MONTHLY NORMAL TEMPERATURE (DEGREES FARENHEIT)	AVERAGE PRECIPITATION (INCHES)	MEAN MONTHLY CLASS "A" PAN EVAPORATION (INCHES)	
			DAINGERFIELD, TEXAS (1959-1979)	SAM RAYBURN DAM, TEXAS (1968-1979)
January	44.5	1.93	2.61	3.00
February	48.5	2.31	3.35	4.00
March	55.0	2.19	5.60	5.21
April	65.5	3.99	6.99	6.27
May	72.6	4.65	8.38	7.31
June	80.3	3.19	9.33	8.09
July	84.3	2.04	10.14	8.32
August	84.4	2.08	9.74	7.78
September	77.1	3.37	7.07	6.06
October	67.2	3.00	5.58	5.35
November	55.2	2.18	3.56	3.92
December	47.4	2.01	2.82	3.00

TABLE 2

EXISTING RESERVOIRS OF THE CYPRESS BAYOU BASIN

Project	Stream	County	Conservation Surface Area (Acres)	Conservation Storage Capacity (acre-feet)	Flood Control Capacity (acre-feet)
Caddo Lake	Cypress Creek	Harrison, Marion	26,800	129,800	-
Lake O' The Pines	Big Cypress Creek	Marion, Camp Morris, Upshur Harrison	18,700	254,900	587,200
Ellison Creek	Ellison Creek	Morris	1,516	24,700	-
Lake Cypress Springs	Big Cypress Creek	Franklin	3,400	72,800	-
Johnson Creek	Johnson Creek	Marion	650	10,100	-
Monticello	Blundell Creek	Titus	2,000	40,000	-
Lake Bob Sandlin	Big Cypress Creek	Titus, Franklin	9,460	213,350	-
Twelvemile Bayou Basin					
Cross Lake	Cross Bayou	Caddo Parish	8,840	77,600	-
Black Bayou Lake	Black Bayou	Caddo Parish	3,960	17,800	-

TABLE 3

ENDANGERED SPECIES OF THE CYPRESS BAYOU BASIN

Scientific Name	Common Name
Picoides borealis	Red-cockaded woodpecker
Canis Rufus	Red wolf
Campephilus principalis	Ivery-billed woodpecker
Corepsis intermedia	Tick seed (unnamed)
Falco peregrinus	Peregrine falcon
Halieetus leucocephalus	Bald eagle
Vermivora bachmenii	Bachman's warbler
Alligator mississippiensis	American alligator
Polyodon spathula	Paddlefish

TABLE 4

POPULATION OF COUNTIES AND MAJOR CITIES WITHIN THE STUDY AREA (1980 Census)

COUNTY	POPULATION	CITY	POPULATION
Caddo	252,294	* Shreveport	204,943
		Vivian	4,146
Gregg	99,487	** Longview	62,762
		Kilgore	10,968
		** Gladewater	6,548
		**White Oak	4,415
Harrison	52,265	* Marshall	24,921
Cass	29,430	Atlanta	6,272
		Linden	2,443
		Hughes Springs	2,196
Upshur	28,595	Gilmer	5,167
Wood	24,697	** Mineola	4,346
		* Winnsboro	3,458
Titus	21,442	Mount Pleasant	11,003
Morris	14,629	Daingerfield	3,030
		Lone Star	2,036
Camp	9,275	Pittsburg	4,245
Marion	10,360	Jefferson	2,643
Franklin	6,893	** Mount Vernon	2,025

* City located partially in Cypress or Twelvemile Bayou Basins.
** City located outside of Cypress and Twelvemile Bayou Basins.

TABLE 5

HISTORICAL POPULATION OF STUDY AREA (1950-1980)

YEAR	POPULATION
1950	406,316
1960	450,157
1970	465,477
1980	549,367

TABLE 6

EMPLOYMENT BY INDUSTRY SECTOR - 1970

INDUSTRY SECTOR	Texas	Louisiana	Cypress Bayou Basin Study Area
Agriculture, Forestry and Fisheries	194,635	47,999	4,526
Mining	103,075	46,584	5,679
Construction	317,758	96,609	11,699
Manufacturing	765,119	184,024	36,762
Transporattion, Communication, and Utilities	286,195	95,757	11,934
Wholesale and Retail Trade	918,693	245,661	35,093
Finance, Insurance, and Real Estate	213,261	51,250	7,012
Services	1,116,993	336,841	46,430
Public Administration	225,800	53,520	6,393
Armed Forces	166,831	3,326	4,611
Total	4,308,360	1,161,571	170,139

TABLE 7

PER CAPITA PERSONAL INCOME - 1959-1978
TEXAS, LOUISIANA, CYPRESS BAYOU BASIN STUDY AREA

	TEXAS		LOUISIANA		STUDY AREA	
YEAR	PER CAPITA INCOME	AVERAGE ANNUAL % CHANGE	PER CAPITA INCOME	AVERAGE ANNUAL % CHANGE	PER CAPITA INCOME	AVERAGE ANNUAL % CHANGE
1959	2,163		1,857		1,926	
		3.44		3.54		3.73
1969	3,034		2,630		2,778	
		3.86		3.31		4.03
1978	4,265		3,644		3,965	
		2.41		2.67		2.27

TABLE 8

VALUE OF CRUDE OIL AND NATURAL GAS
PRODUCTION 1970 - 1979
CYPRESS BAYOU BASIN STUDY AREA

YEAR	VALUE (MILLION $)
1970	375.1
1973	400.7
1974	389.8
1979	294.4

TABLE 9

CYPRESS BASIN WATER SUPPLY ANALYSIS
(MGD)

County	1980	1990	2000	2010	2020	2030	2040
Camp							
Demand							
Municipal	.4	.5	.6	.6	.7	.7	.8
Industrial	.1	.2	.2	.2	.3	.3	.4
Total	.5	.7	.8	.8	1.0	1.0	1.2
Supply	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Net Needs	-	-	-	-	-	-	-
Cass							
Demand							
Municipal	.8	1.0	1.2	1.4	1.6	1.8	2.0
Industrial	30.9	53.9	78.5	102.5	135.0	181.8	242.9
Total	31.7	54.9	79.7	103.9	136.6	183.6	244.9
Supply	111.9	111.9	111.9	111.9	111.9	111.9	111.9
Net Needs	-	-	-	-	24.7	71.7	133.0
Franklin							
Demand							
Municipal	.4	.6	.7	.8	.9	1.0	1.1
Industrial	.4	.4	.4	.4	.4	.4	.4
Total	.8	1.0	1.1	1.2	1.3	1.4	1.5
Supply	1.2	1.2	1.2	1.2	1.3	1.4	1.5
Net Needs	-	-	-	-	-	-	-
Gregg							
Demand							
Municipal	13.5	16.6	20.7	24.0	27.7	30.6	36.2
Industrial	10.6	12.9	16.3	19.8	24.5	30.7	39.0
Power	3.0	2.0	2.0	2.0	2.0	2.0	2.0
Total	27.1	31.5	39.0	45.8	54.2	63.3	77.2
Supply	50.6	61.7	61.7	61.7	61.7	61.7	61.7
Net Needs	-	-	-	-	-	1.6	15.5

TABLE 9 (continued)

County	1980	1990	2000	2010	2020	2030	2040
Upshur							
Demand							
Municipal	1.2	1.5	2.0	2.4	3.0	3.4	3.6
Industrial	.7	1.0	1.4	1.9	2.6	3.3	4.3
Total	1.9	2.5	3.4	4.3	5.6	6.7	7.9
Supply	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Net Needs	-	-	.7	1.6	2.9	4.0	5.2
Wood							
Demand							
Municipal	1.1	1.6	2.0	2.5	3.0	3.4	3.9
Industrial	.8	.9	1.1	1.3	1.5	1.8	2.2
Total	1.9	2.5	3.1	3.8	4.5	5.2	6.1
Supply	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Net Needs	-	.6	1.2	1.9	2.6	3.3	4.2
Caddo Parish, Louisiana							
Demand							
Municipal	31.2	34.6	38.0	40.2	44.7	47.2	49.7
Industrial	6.2	7.7	9.1	10.7	12.3	14.7	17.8
Total	37.4	42.3	47.1	50.9	57.0	61.9	67.5
Supply	44.5	44.5	44.5	44.5	44.5	44.5	44.5
Net Need	-	-	2.6	6.4	12.5	17.4	25.0

TABLE 10

CYPRESS BAYOU BASIN STUDY AREA
WATER SUPPLY NEEDS BY COUNTY
(MGD)

County	1980	1990	2000	2010	2020	2030	2040
Camp	-	-	-	-	-	-	-
Franklin	-	-	-	-	-	-	-
Gregg	-	-	-	-	-	-	-
Harrison	-	-	-	-	-	1.6	15.5
Marion	-	1.4	5.9	11.5	18.6	25.3	33.6
Morris	-	-	-	-	-	-	-
Titus	-	3.6	11.5	25.0	35.8	50.0	74.7
Upshur	-	-	-	-	-	-	-
Wood	-	-	0.7	1.6	2.9	4.0	5.2
Totals	-	5.0	18.1	38.1	57.3	80.9	129.0

NOTE: Cass County and Caddo Parish are removed form the study area.

TABLE 11

ESTIMATED VALUE OF EXISTING INVESTMENTS SUBJECT TO FLOODING WITHIN THE SPF FLOOD PLAIN
(July 1984 prices and April 1981 development)
($1,000)

Reach	Agricultural Crops	Agricultural FPOTC	Rural Non-Agricultural	Urban Suburban	Total
Black Cypress	84.0	30.0	80.3	2,519.7	2,714.3
Little Cypress	419.2	165.9	400.2	228.6	1,213.9
Big Cypress	741.3	293.3	707.7	15,388.9	17,131.2
Caddo Lake	0.0	0.0	413.3	16,431.2	16,844.5
Total	1,244.5	489.5	1,601.5	34,568.4	37,903.9

TABLE 12

NUMBER AND VALUE OF STRUCTURES IN THE SPF FLOOD PLAIN
(July 1984 prices and April 1981 development)
($1,000)

Type of Structure	Number	Value
Black Cypress		
Residential	17	1,852.9
Commercial	0	0.0
Public	0	0.0
Industrial	3	371.2
Agricultural	1	44.3
Marine	0	0.0
Transportation	0	111.2
Communications and utilities	0	140.1
Subtotal	21	2,519.7
Little Cypress		
Residential	4	190.0
Commercial	0	0.0
Public	0	0.0
Industrial	0	0.0
Agricultural	1	3.2
Marine	0	0.0
Transportation	1	23.4
Communications and Utilities	0	12.0
Subtotal	6	228.6
Big Cypress		
Residential	348	13,305.4
Commercial	7	188.5
Public	1	141.9
Industrial	0	0.0
Agricultural	1	9.1
Marine	0	0.0
Transportation	5	733.1
Communications and utilities	1	1,010.9
Subtotal	363	15,388.9
Caddo Lake		
Residential	359	13,379.5
Commercial	31	448.6
Public	6	698.1
Industrial	0	0.0
Agricultural	1	44.3
Marine	1	6.3
Transportation.	4	939.3
Communications and utilities	0	915.1
Subtotal	402	16,431.2
TOTAL	792	34,568.4

TABLE 13

ESTIMATED SINGLE OCCURENCE FLOOD LOSSES FOR VARIOUS FREQUENCY EVENTS
(July 1984 prices and April 1981 development)
($1,000)

Reach	Flood Event					
	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr	SPF
Black Cypress	36.2	88.4	188.5	367.7	569.6	1,073.1
Little Cypress	23.6	24.4	28.3	62.9	116.3	191.1
Big Cypress	254.3	885.7	3,081.8	4,902.0	5,990.7	9,493.2
Caddo Lake	33.9	362.7	2,606.4	4,920.5	6,490.1	9,875.6
Total	348.0	1,361.2	5,905.0	10,253.1	13,166.7	20,633.0

TABLE 14

ESTIMATED EXISTING AVERAGE ANNUAL FLOOD LOSSES
(July 1984 prices and April 1981 development)
($1,000)

Reach	Agricultural	Nonagricultural	Urban/ Suburban	Total
Black Cypress	8.2	5.2	32.9	46.1
Little Cypress	41.6	27.3	2.4	71.3
Big Cypress	73.1	48.8	395.4	517.3
Caddo Lake	0.0	40.0	307.0	347.0
Total	122.9	121.7	737.7	982.3

TABLE 15

RESOURCE REQUIREMENT FOR RECREATION FACILITIES
ON TORP REGIONS 5 AND 6

		Urban			Rural		
	Unit of	Existing	Required		Existing	Required	
Recreation Resource	Measure	1980	1985 :	2000	1980	1985 :	2000
Recreation Land	Acres	2,490	3,471	6,634	49,172	6,418	12,404
Camping	Sites	-----	0	0	2,480	7,834	15,923
Playgrounds	Acres	28	60	87	9	31	60
Picnicking	Tables	776	11	52	1,681	4,704	8,200
Boat Ramps	Lanes	5	28	50	244	283	523
Fishing Facilities	Lin Yds	245	89	183	2,580	10,278	17,183
Bicycle Trails	Miles	-----	-----	-----	-----	7	14
Horseback Riding Trails	Miles	0	2	4	0	48	100
Combined Trails (walk, hike nature study, bicycle)	Miles	18	41	79	-----	-----	-----
Combined Trails (walk, hike nature study)	Miles	-----	-----	-----	23	201	378
Recreation Water	Surface Acres	0	953	1,630	142,494	0	0
Swimming Beaches	Sq Yds	0	97	173	242	3,093	5,862

NOTE: Dashes indicate needs have not been projected

TABLE 16

SUMMER AND WINTER CAPABILITY, PEAK DEMAND, RESERVES AND ANNUAL ENERGY
SOUTHWEST POWER POOL REGION
1981-2000

	1981		1982		1983		1984		1985	
	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)
Planned Capability	53,600	55,047	56,781	58,966	61,205	62,400	64,013	64,365	65,688	66,585
Net (Imports-Exports)1/	795	(606)	813	(491)	941	(107)	707	248	440	105
Peak Demand	44,383	32,781	46,398	34,133	48,238	35,560	50,317	37,051	52,302	38,547
Total Reserve	10,012	21,660	11,196	24,342	13,908	26,733	14,403	27,562	13,826	28,143
Total Reserve %	22.6	66.7	24.0	71.3	28.8	75.2	28.6	74.4	26.4	73.0
Scheduled Maintenance	0	5,945	301	6,368	331	6,724	354	6,933	360	7,171
Full Forced Outages 2/ & Unavailable Capacity	4,567	5,234	4,824	5,593	5,288	6,014	5,593	6,237	5,707	6,392
Actual Reserve 3/	5,445	10,481	6,071	12,381	8,289	13,995	8,456	14,392	7,759	14,580
Actual Reserve %	12.3	32.0	13.1	36.3	17.2	39.4	16.8	38.8	14.8	37.8
Capacity Needed 4/ but Unscheduled	0	0	0	0	0	0	0	0	0	0
Annual Energy GWh	216,003		226,074		235,006		245,218		255,389	
Annual Load Factor %	55.6		55.6		55.6		55.6		55.7	

1/ () denotes negative figures.
2/ Full forced outages and unavailable capacity are calculated based on historical data.
3/ Reserve less scheduled maintenance and ful force outages.
4/ Assuming a minimum of 25% of peak needed for total reserves and 15% actual reserve for winter

TABLE 16 (con't)

	1986		1987		1988		1989		1990	
	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)
Planned Capability	67,031	68,262	68,881	68,894	70,306	71,898	72,310	73,009	74,682	75,714
Net (Imports-Exports)1/	356	24	348	19	294	(31)	107	(216)	(28)	(368)
Peak Demand	54,382	40,125	56,342	41,633	58,535	43,275	60,728	44,941	63,069	46,738
Total Reserve	13,005	28,161	12,887	27,280	12,065	28,592	11,688	27,852	11,585	28,068
Total Reserve %	23.9	70.2	22.9	65.5	20.6	66.1	19.2	62.0	18.4	60.1
Scheduled Maintenance	363	7,355	377	7,423	383	7,736	401	7,855	413	8,085
Full Forced Outages2/ & Unavailable Capacity	5,800	6,589	5,996	6,647	6,120	6,990	6,371	7,079	6,572	7,298
Actual Reserve3/	6,842	14,217	6,514	13,210	5,562	13,866	4,917	12,918	4,600	12,685
Actual Reserve %	12.6	35.4	11.7	31.7	9.5	32.0	8.1	28.7	7.3	27.1
Capacity Needed4/ but Unscheduled	590	0	1,198	0	2,568	0	3,494	0	4,182	0
Annual Energy GWh	266,543		277,729		289,760		300,414		313,362	
Annual Load Factor %	56.0		56.3		56.5		56.5		56.7	

1/ () denotes negative figures.

2/ Full forced outages and unavailable capacity are calculated based on historical data.

3/ Reserve less scheduled maintenance and ful force outages.

4/ Assuming a minimum of 25% of peak needed for total reserves and 15% actual reserve for winter

TABLE 16 (con't)

	1991		1992		1993		1994		1995	
	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)
Planned Capability	78,696	79,080	76,199	76,799	76,350	77,500	76,926	76,926	75,917	75,917
Net (Imports-Exports)1/	0	0	0	0	0	0	0	0	0	0
Peak Demand	65,497	48,654	67,986	50,673	70,535	52,801	73,145	55,045	75,815	57,411
Total Reserve	13,199	30,426	8,213	26,126	5,815	24,699	3,781	21,881	102	18,506
Total Reserve %	20.2	62.5	12.1	51.6	8.2	46.8	5.2	39.8	0.1	32.2
Scheduled Maintenance	429	8,369	446	8,664	464	8,972	483	9,262	503	9,625
Full Forced Outages2/ & Unavailable Capacity	6,795	7,576	7,032	7,866	7,285	8,169	7,554	8,485	7,841	8,816
Actual Reserve3/	5,975	14,481	735	9,596	(1,934)	7,558	(4,256)	4,134	(8,242)	65
Actual Reserve %	9.1	29.8	1.1	18.9	0	14.3	0	7.5	0	0.1
Capacity Needed4/	3,175	0	8,784	0	11,819	362	14,505	4,123	18,852	8,547
Annual Energy GWh	326,465		340,063		353,431		367,149		381,216	
Annual Load Factor %	56.9		57.1		57.2		57.3		57.4	

1/ () denotes negative figures.
2/ Full forced outages and unavailable capacity are calculated based on historical data.
3/ Reserve less scheduled maintenance and ful force outages.
4/ Assuming a minimum of 25% of peak needed for total reserves and 15% actual reserve for winter

TABLE 16 (con't)

	1996		1997		1998		1999		2000	
	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)	(Summer) (MW)	(Winter) (MW)
Planned Capability	75,025	75,025	74,057	74,057	73,255	73,255	72,385	75,085	74,054	74,054
Net (Imports-Exports)1/	0	0	0	0	0	0	0	0	0	0
Peak Demand	78,544	59,850	81,332	62,363	84,178	64,951	87,082	67,613	90,042	70,351
Total Reserve	(3,519)	15,175	(7,275)	11,694	(10,923)	8,304	(14,697)	7,472	(15,988)	3,703
Total Reserve %	0	25.4	0	18.8	0	12.8	0	11.1	0	9.5
Scheduled Maintenance	525	9,972	548	10,334	573	10,711	600	11,100	628	11,510
Full Forced Outages2/ & Unavailable Capacity	8,146	9,161	8,471	9,521	8,818	8,897	9,188	9,250	9,593	9,620
Actual Reserve3/	(12,190)	(3,958)	(16,294)	(8,161)	(20,314)	(11,304)	(24,485)	(12,878)	(26,209)	(17,427)
Actual Reserve %	o	0	0	0	0	0	0	0	0	0
Capacity Needed4/ but Unscheduled	23,155	12,936	27,608	17,515	31,968	21,047	36,467	23,020	38,498	27,980
Annual Energy GWh	396,314		411,094		426,216		440,920		466,696	
Annual Load Factor %	57.6		57.7		57.8		57.8		57.9	

1/ () denotes negative figures.
2/ Full forced outages and unavailable capacity are calculated based on historical data.
3/ Reserve less scheduled maintenance and ful force outages.
4/ Assuming a minimum of 25% of peak needed for total reserves and 15% actual reserve for winter

TABLE 17

PROSPECTIVE COMMERCE
SHREVEPORT TO DAINGERFIELD REACH

Commodity	Upbound traffic (net tons)	Downbound traffic (net tons)	Total traffic (net tons)
Iron and steel articles	3,500	133,000	136,500
Iron and steel pipe	36,000	124,000	160,000
Scrap iron and steel	72,000	-	72,000
Ferro-manganese	4,500	-	4,500
Silico-manganese	2,000	-	2,000
Chemicals (nec)	-	20,000	20,000
Fuel oil	30,000	-	30,000
Coke	172,000	-	172,000
Iron ore	75,000	-	75,000
Coal	90,000	-	90,000
Total base year (1971)	485,200	277,000	762,200

TABLE 18

PROJECTED SOCIOECONOMIC FACTORS
CYPRESS BAYOU STUDY AREA

Year	Population	Average Annual % Change	Employment	Average Annual % Change	Per Capita Income	Average Annual % Change
1980	549,367		210,029		4,147	
1990	611,300	1.07	242,400	1.44	5,188	2.26
2000	681,700	1.10	282,500	1.54	7,041	3.10
2010	736,800	0.78	305,300	0.80	9,319	2.84
2020	799,400	0.82	331,300	0.82	11,951	2.52
2030	856,800	0.70	355,100	0.70	13,653	1.34
2040	913,300	0.64	378.500	0.64	14,596	0.67
2050	971,600	0.62	402,600	0.62	15.059	0.34

Factors of Change From 1980

1980	1.00	1.00	1.00
1990	1.11	1.15	1.25
2000	1.24	1.35	1.70
2010	1.34	1.45	2.25
2020	1.46	1.58	2.88
2030	1.56	1.69	3.29
2040	1.66	1.80	3.52
2050	1.77	1.92	3.64

TABLE 19

MATRIX OF PRELIMINARY ALTERNATIVES AND ABILITY TO MEET PLANNING OBJECTIVES

	Reduction of Flood Damages along Caddo Lake; Big, Little and Black Cypress Bayous	Municipal and Industrial Water Supply	Recreational Opportunities	Hydropower	Preservation of Fish and Wildlife Habitat	Wate Qualit
NONSTRUCTURAL						
° WATER CONSERVATION	0	+	0	0	+	+
° CHANGE OPERATING PROCEDURES AT LAKE O' THE PINES	+	0	0	0	0	0
° FLOODPROOFING/RAISING OF STRUCTURES	+	0	0	0	+	+
° PERMANENT EVACUATION STRUCTURES FROM THE FLOODPLAIN	+	0	+	0	+	+

LEGEND:

+ Meets Objective

0 No Impact

\- Adverse Impact to Objective

TABLE 19 (con't)

	Reduction of Flood Damages along Caddo Lake; Big, Little and Black Cypress Bayous	Municipal and Industrial Water Supply	Recreational Opportunities	Hydropower	Preservation of Fish and Wildlife Habitat	Water Quality
STRUCTURAL						
° GROUND WATER UTILIZATION	0	+	0	0	+	+
° LEVEES	+	0	0	0	-	0
° CHANNEL MODIFICATIONS	+	0	0	0	-	-
° LAKES						
- MARSHALL SITE	+	+	+	+	-	+
- BLACK CYPRESS SITE	+	+	+	+	-	+
° ENLARGEMENT OF CADDO LAKE	-	+	0	+	-	0
° NAVIGATION CHANNEL	0	0	0	0	-	-
° ADDITION OF HYDRO-POWER TO LAKES	0	0	+	+	-	0
NO ACTION						
NO ACTION	0	0	0			

LEGEND:

+ Meets Objective

0 No Impact

- Adverse Impact to Objective

TABLE 20

CYPRESS BAYOU BASIN STUDY AREA
WATER SUPPLY NEEDS BY COUNTY
(MGD)

County	1980	1990	2000	2010	2020	2030	2040
Camp	-	-	-	-	-	-	-
Franklin	-	-	-	-	-	-	-
Gregg	-	-	-	-	-	-	13.2
Harrison	-	1.2	5.6	11.1	18.1	24.7	32.9
Marion	-	-	-	-	-	-	-
Morris	-	3.5	11.4	24.8	35.6	49.7	74.4
Titus	-	-	-	-	-	-	-
Upshur	-	-	0.7	1.6	2.9	4.0	5.2
Wood	-	-	-	-	-	-	-
Totals	-	4.7	17.7	37.5	56.6	78.4	125.7

NOTE: Cass County and Caddo Parrish are removed from the study area.

TABLE 21

EFFECTS OF CHANGING LAKE O' THE PINES RELEASES ON AVERAGE ANNUAL DAMAGES
(July 1984 prices, April 1981 development)

Area	Release Procedure	
	Original	Modified
Lake O' The Pines	$ 21,900	$ 36,600
Big Cypress Bayou	561,700	517,300
Caddo Lake	361,000	347,000
Total	$944,600	$900,900

TABLE 22

NUMBER AND VALUE OF RESIDENTIAL AND COMMERCIAL STRUCTURES IN SPF FLOOD PLAIN BY FLOOD ZONES
(July 1984 prices, April 1981 development)
($1,000)

Stream	Reach	Zone	Number of Structures	Value of Structures
Black Cypress	1	SPF/100	0	0.0
		100/50	0	0.0
		50/25	0	0.0
		25/10	0	0.0
		10/5	0	0.0
		5/Bank	0	0.0
	2	SPF/100	11	1,040.3
		100/50	0	0.0
		50/25	0	0.0
		25/10	2	228.5
		10/5	0	0.0
		5/Bank	0	0.0
	3	SPF/100	0	0.0
		100/50	2	247.4
		50/25	1	190.4
		25/10	3	304.7
		10/5	0	0.0
		5/Bank	2	257.1
Little Cypress	1	SPF/100	0	0.0
		100/50	0	0.0
		50/25	1	3.0
		25/10	5	213.6
		10/5	0	0.0
		5/Bank	0	0.0
Big Cypress	1	SPF/100	0	0.0
		100/50	0	0.0
		50/25	0	0.0
		25/10	0	0.0
		10/5	3	63.4
		5/Bank	14	341.8
	2	SPF/100	0	0.0
		100/50	4	109.3
		50/25	6	156.2
		25/10	25	1,258.6
		10/5	21	689.4
		5/Bank	2	38.4
	3	SPF/100	0	0.0
		100/50	0	0.0
		50/25	0	0.0
		25/10	4	115.5
		10/5	2	134.4
		5/Bank	11	305.3

TABLE 22 (con't)

Stream	Reach	Zone	Number of Structures	Value of Structures
Big Cypress	4	SPF/100	0	0.0
		100/50	0	0.0
		50/25	0	0.0
		25/10	17	821.2
		10/5	23	906.8
		5/Bank	22	945.6
	5	SPF/100	0	0.0
		100/50	0	0.0
		50/25	0	0.0
		25/10	1	42.2
		10/5	9	530.0
		5/Bank	112	3,751.1
	6	SPF/100	0	0.0
		100/50	0	0.0
		50/25	7	218.9
		25/10	4	163.2
		10/5	4	168.9
		5/Bank	67	3,064.4
	7	SPF/100	0	0.0
		100/50	0	0.0
		50/25	4	121.6
		25/10	1	23.0
		10/5	0	0.0
		5/Bank	0	0.0
Caddo Lake	1	SPF/100	18	758.8
		100/50	21	1,069.6
		50/25	13	465.1
		25/10	25	842.0
		10/5	80	3,056.1
		5/Bank	16	938.4
	2	SPF/100	0	0.0
		100/50	0	0.0
		50/25	17	576.7
		25/10	7	230.7
		10/5	3	39.8
		5/Bank	1	45.4
	3	SPF/100	6	4.5
		100/50	0	0.0
		50/25	0	0.0
		25/10	5	215.5
		10/5	6	177.7
		5/Bank	0	0.0

TABLE 22 (con't)

Stream	Reach	Zone	Number of Structures	Value of Structures
Big Cypress	4	SPF/100	0	0.0
		100/50	0	0.0
		50/25	0	0.0
		25/10	17	821.2
		10/5	23	906.8
		5/Bank	22	945.6
	5	SPF/100	0	0.0
		100/50	0	0.0
		50/25	0	0.0
		25/10	1	42.2
		10/5	9	530.0
		5/Bank	112	3,751.1
	6	SPF/100	0	0.0
		100/50	0	0.0
		50/25	7	218.9
		25/10	4	163.2
		10/5	4	168.9
		5/Bank	67	3,064.4
	7	SPF/100	0	0.0
		100/50	0	0.0
		50/25	4	121.6
		25/10	1	23.0
		10/5	0	0.0
		5/Bank	0	0.0
Caddo Lake	1	SPF/100	18	758.8
		100/50	21	1,069.6
		50/25	13	465.1
		25/10	25	842.0
		10/5	80	3,056.1
		5/Bank	16	938.4
	2	SPF/100	0	0.0
		100/50	0	0.0
		50/25	17	576.7
		25/10	7	230.7
		10/5	3	39.8
		5/Bank	1	45.4
	3	SPF/100	6	4.5
		100/50	0	0.0
		50/25	0	0.0
		25/10	5	215.5
		10/5	6	177.7
		5/Bank	0	0.0

TABLE 22 (con't)

Stream	Reach	Zone	Number of Structures	Value of Structures
Caddo Lake	4	SPF/100	0	0.0
		100/50	0	0.0
		50/25	26	305.0
		25/10	4	134.2
		10/5	3	109.6
		5/Bank	0	0.0
	5	SPF/100	0	0.0
		100/50	0	0.0
		50/25	0	0.0
		25/10	0	0.0
		10/5	6	323.3
		5/Bank	0	0.0
	6	SPF/100	1	34.1
		100/50	1	75.7
		50/25	10	557.8
		25/10	31	1,068.3
		10/5	34	1,338.0
		5/Bank	6	209.9
	7	SPF/100	0	0.0
		100/50	0	0.0
		50/25	0	0.0
		25/10	0	0.0
		10/5	4	102.2
		5/Bank	0	0.0
	8	SPF/100	1	41.6
		100/50	9	287.4
		50/25	32	926.5
		25/10	4	313.8
		10/5	0	0.0
		5/Bank	0	0.0
	9	SPF/100	0	0.0
		100/50	0	0.0
		50/25	3	153.8
		25/10	1	34.1
		10/5	1	37.8
		5/Bank	2	63.1
	10	SPF/100	0	0.0
		100/50	0	0.0
		50/25	0	0.0
		25/10	0	0.0
		10/5	5	151.3
		5/Bank	0	0.0

TABLE 23

AVERAGE ANNUAL STRUCTURE DAMAGE BY FLOOD ZONE
(July 1984 prices, April 1981 development
($1,000)

Stream	Reach	Zone	Damage
Big Cypress	1	25/10	0.0
		10/5	1.8
		5/Bank	21.8
	2	25/10	22.8
		10/5	13.3
		5/Bank	0.7
	3	25/10	1.8
		10/5	2.0
		5/Bank	9.3
	4	25/10	9.4
		10/5	16.9
		5/Bank	71.9
	5	25/10	0.0
		10/5	11.6
		5/Bank	134.9
	6	25/10	0.1
		10/5	0.3
		5/Bank	64.4
Caddo Lake	1	25/10	12.8
		10/50	84.5
		5/Bank	47.5
	2	25/10	4.0
		10/5	1.4
		5/Bank	1.4
	3	25/10	5.3
		10/5	8.8
		5/Bank	0.0
	6	25/10	18.7
		10/5	50.7
		5/Bank	13.3

TABLE 24

ECONOMIC ANLAYSIS OF RAISING STRUCTURES
(July 1984 prices, 8-3/8% interest, 100-year period of analysis)
($1,000)

Reach	Raise all Structures In This Flood Zone	Number of Structures	Construction Costs	Interest During Construction	Total First Costs	Annual Costs	Annual Benefits	Net Annual Benefits
Big Cypress Reach 1	5-year	14	101.4	8.6	110.0	9.2	21.8	12.6
	10-year	17	123.2	10.4	133.6	11.2	23.6	12.4
	25-year	17	123.2	10.4	133.6	11.2	23.6	12.4
Big Cypress Reach 2	5-year	2	14.5	1.2	15.7	1.3	0.7	-0.6
	10-year	23	166.6	14.1	180.7	15.1	14.0	-1.1
	25-year	48	347.8	29.4	377.2	31.6	36.4	4.8
Big Cypress Reach 3	5-year	11	79.7	6.7	86.4	7.2	9.3	2.1
	10-year	13	94.2	8.0	102.2	8.6	11.3	2.7
	25-year	17	123.2	10.4	133.6	11.2	13.1	1.9
Big Cypress Reach 4	5-year	22	159.4	13.5	172.9	14.5	71.9	57.4
	10-year	45	326.0	27.6	353.6	29.6	87.8	58.2
	25-year	62	449.2	37.9	487.1	40.8	97.2	56.4
Big Cypress Reach 5	5-year	112	811.4	68.6	880.0	73.7	134.9	61.2
	10-year	121	876.6	74.1	950.7	79.7	146.5	66.8
	25-year	122	883.9	74.7	958.6	80.3	146.5	66.2

TABLE 24 (con't)

Reach	Raise all Structures In This Flood Zone	Number of Structures	Construction Costs	Interest During Construction	Total First Costs	Annual Costs	Annual Benefits	Net Annual Benefits
Big Cypress Reach 6	5-year	67	485.4	41.0	526.4	44.1	64.4	20.3
	10-year	71	514.4	43.5	557.9	46.7	64.8	18.1
	25-year	75	543.4	45.9	589.3	49.4	64.9	15.5
Caddo Lake Reach 1	5-year	16	115.9	9.8	125.7	10.5	47.5	37.0
	10-year	96	695.5	58.8	754.3	63.2	132.0	68.8
	25-year	121	876.6	74.1	950.7	79.7	144.8	65.1
Caddo Lake Reach2	5-year	1	7.2	.6	7.8	0.7	1.4	0.7
	10-year	4	29.0	2.4	31.4	2.6	2.8	0.2
	25-year	11	79.7	6.7	86.4	7.2	6.8	-0.4
Caddo Lake Reach 3	5-year	0	0.0	0.0	0.0	0.0	0.0	0.0
	10-year	6	43.5	3.7	47.2	4.0	8.8	4.8
	25-year	11	79.7	6.7	86.4	7.2	14.1	6.9
Caddo Lake Reach 6	5-year	6	43.5	3.7	47.2	4.0	13.3	9.4
	10-year	40	289.8	24.5	314.3	26.3	64.0	37.7
	25-year	71	514.4	43.5	557.9	46.7	82.7	36.0

TABLE 25

ECONOMIC ANALYSIS OF GROUND WATER ALTERNATIVE

(July 1984 prices, 8.375 percent interest, 100-year period of analysis)
(Yield = 125.7 mgd)

Ground Water Total Annual Cost	$38,000,000
Least Costly Alternative Annual Cost	24,000,000
Ground Water Transmission Annual Cost	30,000,000
Net Annual Benefits	-6,900,000

TABLE 26

ECONOMIC ANALYSIS FOR SPF LEVEE
(July 1984 prices, 8-3/8% interest, 100-year period of analysis)
($1,000)

	Reach									
	Big Cypress						Caddo Lake			
	1	2	3	4	5	6	1	2	3	6
Lands	15.3	40.0	32.1	75.0	76.6	56.8	87.4	27.4	45.6	76.8
Relocations	0.0	357.5	110.0	20.0	1,100.0	110.0	425.0	0.0	27.5	27.5
Levee	805.3	2,080.6	1,647.5	3,773.6	3,645.0	2,712.4	4,004.5	1,249.1	2,066.7	3,480.7
Constingencies (15%)	123.1	371.7	268.4	580.3	723.2	431.9	677.5	191.5	321.0	537.0
Subtotal	943.7	2,849.8	2,058.0	4,448.9	5,544.8	3,311.1	5,194.4	1,468.0	2,460.8	4,122.9
E&D (8%)	75.5	228.0	164.6	355.9	443.6	264.9	415.6	117.4	196.9	329.8
S&A (7%)	66.1	199.5	144.1	311.4	388.1	231.8	363.6	102.8	172.3	288.6
Total First Cost	1,085.3	3,277.3	2,366.7	5,116.2	6,376.5	3,807.8	5,973.6	1,688.2	2,829.9	4,741.2
Amortization	90.9	274.6	198.3	428.6	534.2	319.0	500.5	141.4	237.1	397.2
O&M	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Total Annual Cost	93.9	277.6	201.3	431.6	537.2	322.0	503.5	144.4	240.1	400.2
Annual Benefits	24.1	37.9	13.1	107.5	146.5	65.9	149.8	10.4	14.2	86.2
Net Annual Benefits	-69.8	-239.7	-188.2	-324.1	-390.7	-256.1	-353.7	-134.0	-225.9	-314.0
B/C Ratio	0.26	0.14	0.07	0.25	0.27	0.20	0.30	0.07	0.06	0.22

TABLE 27

ECONOMIC ANALYSIS FOR 25-YEAR LEVEE
(July prices, 8-3/8% interest, 100-year period of analysis)
($1,000)

	Reach									
	Big Cypress						Caddo Lake			
	1	2	3	4	5	6	1	2	3	6
Land	10.5	27.3	21.9	51.0	51.7	38.4	59.7	18.8	31.3	52.6
Relocations	0.0	357.5	110.0	20.0	1,100.0	110.0	425.0	0.0	27.5	27.5
Levee	282.7	725.2	567.6	1,1279.9	1,231.6	1,1034.2	1,339.2	420.0	698.1	1,175.8
Constingencies(15%)	44.0	166.5	104.9	202.6	357.5	177.4	273.6	65.8	113.5	188.4
Subtotal	337.2	1,276.5	804.4	1,553.5	2,740.8	1,360.0	2,097.5	504.6	870.4	1,444.3
E&D (8%)	27.0	102.1	64.4	124.3	219.3	108.8	167.8	40.4	69.6	115.5
S&A (7%)	23.6	89.4	56.3	108.7	191.9	95.2	146.8	35.3	60.9	101.1
Total First Cost	387.8	1,468.0	925.1	1,786.5	3,151.9	1,564.0	2,412.2	580.3	1,001.0	1,660.9
Amortization	32.5	123.0	77.5	149.7	264.1	131.0	202.1	48.6	83.9	139.2
O&M	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Total Annual Cost	35.5	126.0	80.5	152.7	267.1	134.0	205.1	51.6	86.9	142.2
Annual Benefits	23.6	36.8	13.1	98.2	146.5	64.8	144.8	6.8	14.1	82.7
Net Annual Benefits	-11.9	-89.2	-67.4	-54.5	-120.6	-69.2	-60.3	-44.8	-72.8	-59.5
B/C Ratio	0.67	0.29	0.16	0.64	0.55	0.48	0.71	0.13	0.16	0.58

TABLE 28

ECONOMIC ANALYSIS FOR LOW FREQUENCY LEVEE DESIGN
(July 1984 prices, 8-3/8% interest, 100-year period of analysis)
($1,000)

Reach	Caddo Lake 1	Caddo Lake 6	Big Cypress 5
Design Frequency	10-Year	10-Year	5-Year
Lands	46.9	43.9	39.5
Relocations	425.0	27.5	1,100.0
Levee	731.3	639.2	494.6
Contingencies(15%)	180.5	106.6	245.1
Subtotal	1,383.7	817.2	1,879.2
E&D (8%)	110.7	65.4	150.3
S&A (7%)	96.9	57.2	131.5
Total First Cost	1,591.3	939.8	2,161.0
Amortization	133.3	78.7	181.0
O&M	3.0	3.0	3.0
Total Annual Cost	136.3	81.7	184.0
Annual Benefits	132.0	64.0	134.9
Net Annual Benefits	-4.3	-17.7	-49.1
B/C Ratio	0.97	0.78	0.73

TABLE 29

ECONOMIC ANALYSIS FOR ENLARGED CHANNEL ALTERNATIVE

(July 1984 prices, 8-3/8% interest, 100-year period of analysis)

($1,000)

Lands	$ 515.0
Excavation	13,740.5
Contingencies (15%)	2,138.3
Subtotal	$16,393.8
E&D (8%)	1,311.5
S&A (7%)	1,147.6
Total First Cost	$18,852.9
Amortization	1,579.5
O&M	30.0
Total Annual Cost	$ 1,609.5
Annual Benefits	864.3
Net Annual Benefits	-745.2
B/C Ratio	0.54

TABLE 30

ECONOMIC ANALYSIS FOR DIVERSION CHANNEL ALTERNATIVE

(July 1984 prices, 8-3/8% interest, 100-year period of analysis)
($1,000)

Lands	$ 640.0
Excavation	15,488.0
Contingencies (15%)	2,419.2
Subtotal	$18,547.2
E&D (8%)	1,483.8
S&A (7%)	1,298.3
Total First Cost	$21,329.3
Amortization	1,787.0
O&M	30.0
Total Annual Cost	$ 1,817.0
Annual Benefits	864.3
Net Annual Benefits	-952.7
B/C Ratio	0.48

TABLE 31

PERTINENT DATA MARSHALL LAKE ALTERNATIVES

	FC271000	FC360000	FC413000	WS180	WS250	WS360	WS180 R180	WS250 R250	WS360 R360	WS180 FC271000	WS180 FC360000	WS180 FC413000	WS250 FC271000	WS250 FC360000	WS250 FC413000	WS360 FC271000	WS360 FC360000	WS360 FC413000	WS180 R180 FC271000	WS180 R180 FC360000	WS180 R180 FC413000
TOP OF DAM (ELEV.)	255.8	258.8	261.3	251.2	258.5	272.8	251.2	258.5	272.8	264.5	267.3	268.7	270.3	272.7	273.9	279.4	281.0	282.0	264.5	267.3	268.7
MAXIMUM DESIGN WATER SURFACE (ELEV.)	251.3	254.3	256.8	246.7	254.0	268.3	246.7	254.0	268.3	260.0	262.8	264.2	265.8	268.2	269.4	274.9	276.5	277.5	260.0	262.8	264.2
FEE ACQUISITION LINE (ELEV.)	243.7	246.1	248.6	235.7	245.8	260.0	235.7	245.8	260.0	250.6	254.2	256.2	257.4	260.5	262.2	268.1	270.4	272.0	250.6	254.2	256.2
FEE ACQUISITION LINE (ACRES)	21270.0	22874.0	24922.0	17481.0	22634.0	34780.0	17481.0	22634.0	34780.0	26445.0	28527.0	30184.0	31390.0	35205.0	36661.0	41827.0	43977.0	45713.0	26445.0	28527.0	30184.0
TOP FLOOD CONTROL POOL (ELEV.)	236.3	241.1	243.6							245.6	249.2	251.2	252.4	255.5	257.2	263.1	265.4	267.0	245.6	249.2	251.2
TOP FLOOD CONTROL POOL (ACRES)	17725.0	19847.0	21215.0							22476.0	25426.0	26787.0	27477.0	29492.0	31187.0	37444.0	39470.0	40832.0	22476.0	25426.0	26787.0
TOP FLOOD CONTROL POOL (AC-FT)	271480.0	360328.0	412979.0							453106.0	541954.0	594605.0	626794.0	715642.0	768293.0	970766.0	1059282.0	1122242.0	453106.0	541954.0	594605.0
TOP CONSERVATION POOL (ELEV.)				230.7	240.8	255.0	230.7	240.8	255.0	230.7	230.7	230.7	240.8	240.8	240.8	255.0	255.0	255.0	230.7	230.7	230.7
TOP CONSERVATION POOL (ACRES)				14038.0	19686.0	28988.0	14038.0	19686.0	28988.0	14038.0	14038.0	14038.0	19686.0	19686.0	19686.0	28988.0	28988.0	28988.0	14038.0	14038.0	14038.0
TOP CONSERVATION POOL (AC-FT)				181626.0	355314.0	700000.0	181626.0	355314.0	700000.0	181626.0	181626.0	181626.0	355314.0	355314.0	355314.0	700000.0	700000.0	700000.0	181626.0	181626.0	181626.0
50-YEAR FLOOD LEVEL (ELEV.)	240.7	243.0	243.6	235.8	245.2	258.7	235.8	245.2	258.7	247.6	249.8	251.2	254.2	256.5	257.2	265.5	266.5	267.0	247.6	249.8	251.2

LEGEND
WS180 — WATER SUPPLY PURPOSE WITH 180cfs YIELD
R180 — RECREATION PURPOSE BASED ON CONSERVATION POOL YIELDING 180cfs
FC5000 - FLOOD CONTROL PURPOSE WITH 5000 AC-FT FLOOD CONTROL STORAGE

PERTINENT DATA MARSHALL LAKE ALTERNATIVES

	WS125	R125 WS125	WS125 FC50000	R125 WS125 FC50000	WS125 FC100000	R125 WS125 FC100000	WS125 FC270000	R125 WS125 FC270000	WS125 FC360000	R125 WS125 FC360000	WS125 FC415000	R125 WS125 FC415000	FC50000	FC100000	WS180 FC50000	R180 WS180 FC50000	WS180 FC100000	R180 WS180 FC100000
TOP OF DAM (ELEV.)	245.5	245.5	249.8	249.8	257.6	257.6	261.0	261.0	263.8	263.8	265.5	265.5	247.8	249.6	254.8	254.8	257.7	257.7
MAXIMUM DESIGN WATER SURFACE (ELEV.)	241.0	241.0	245.3	245.3	253.1	253.1	256.5	256.5	259.3	259.3	261.0	261.0	243.3	245.1	250.3	250.3	253.2	253.2
FEE ACQUISITION LINE (ELEV.)	229.8	229.8	234.1	234.1	237.6	237.6	247.0	247.0	251.2	251.2	253.5	253.5	222.8	228.8	239.0	239.0	242.0	242.0
FEE ACQUISITION LINE (ACRES)	13423.0	13423.0	16512.0	16512.0	18257.0	18257.0	23600.0	23600.0	26786.0	26786.0	28117.0	28117.0	9341.0	12785.0	18838.0	18838.0	20334.0	20334.0
TOP FLOOD CONTROL POOL (ELEV.)			229.1	229.1	232.6	232.6	242.0	242.0	246.2	246.2	248.5	248.5	217.8	223.8	234.0	234.0	237.0	237.0
TOP FLOOD CONTROL POOL (ACRES)			12974.0	12974.0	15396.0	15396.0	20334.0	20334.0	17684.0	17684.0	24839.0	24839.0	6321.0	9860.0	16435.0	16435.0	18010.0	18010.0
TOP FLOOD CONTROL POOL (AC-FT)			160000.0	160000.0	210000.0	210000.0	380000.0	380000.0	470000.0	470000.0	525000.0	525000.0	50000.0	100000.0	231626.0	231626.0	281626.0	281626.0
TOP CONSERVATION POOL (ELEV.)	224.8	224.8	224.8	224.8	224.8	224.8	224.8	224.8	224.8	224.8	224.8	224.8			230.7	230.7	230.7	230.7
TOP CONSERVATION POOL (ACRES)	10393.0	10393.0	10393.0	10393.0	10393.0	10393.0	10393.0	10393.0	10393.0	10393.0	10393.0	10393.0			14038.0	14038.0	14038.0	14038.0
TOP CONSERVATION POOL (AC-FT)	110000.0	110000.0	110000.0	110000.0	110000.0	110000.0	110000.0	110000.0	110000.0	110000.0	110000.0	110000.0			181626.0	181626.0	181626.0	181626.0
50-YEAR FLOOD LEVEL (ELEV.)	227.7	227.7	233.0	233.0	236.0	236.0	242.8	242.8	246.6	246.6	248.5	248.5	226.5	230.8	239.2	239.2	241.7	241.7

TABLE 31(cont)

PERTINENT DATA MARSHALL LAKE ALTERNATIVES

	R250 WS250 FC271000	R250 WS250 FC360000	R250 WS250 FC413000	R360 WS360 FC271000	R360 WS360 FC360000	R360 WS360 FC413000	WS250 FC50000	R250 WS250 FC50000	WS250 FC100000	R250 WS250 FC100000	WS360 FC50000	R360 WS360 FC50000	WS360 FC100000	R360 WS360 FC100000
TOP OF DAM (ELEV.)	270.3	272.7	273.9	279.4	281.0	282.0	261.9	261.9	264.4	264.4	274.3	274.3	275.6	275.6
MAXIMUM DESIGN WATER SURFACE (ELEV.)	265.8	268.2	269.4	274.9	276.5	277.5	257.4	257.4	259.9	259.9	269.8	269.8	271.1	271.1
FEE ACQUISITION LINE (ELEV.)	257.4	260.5	262.2	268.1	270.4	272.0	248.3	248.3	250.6	250.6	261.7	261.7	263.2	263.2
FEE ACQUISITION LINE (ACRES)	31390.0	35205.0	36661.0	41827.0	43977.0	45713.0	24672.0	24672.0	26445.0	26445.0	36230.0	36230.0	37532.0	37532.0
TOP FLOOD CONTROL POOL (ELEV.)	252.4	255.5	257.2	263.1	265.4	267.0	243.3	243.3	245.6	245.6	256.7	256.7	258.2	258.2
TOP FLOOD CONTROL POOL (ACRES)	27477.0	29492.0	31187.0	37444.0	39470.0	40832.0	21049.0	21049.0	22476.0	22476.0	30684.0	30684.0	32275.0	32275.0
TOP FLOOD CONTROL POOL (AC-FT)	626794.0	715642.0	768293.0	970766.0	1059282.0	1122242.0	405314.0	405314.0	455314.0	455314.0	750000.0	750000.0	800000.0	800000.0
TOP CONSERVATION POOL (ELEV.)	240.8	240.8	240.8	254.2	254.2	254.2	240.8	240.8	240.8	240.8	255.0	255.0	255.0	255.0
TOP CONSERVATION POOL (ACRES)	19686.0	19686.0	19686.0	28527.0	28527.0	28527.0	19686.0	19686.0	19686.0	19686.0	28988.0	28988.0	28988.0	28988.0
TOP CONSERVATION POOL (AC-FT)	355314.0	355314.0	355314.0	677618.0	677618.0	677618.0	355314.0	355314.0	355314.0	355314.0	700000.0	700000.0	700000.0	700000.0
50-YEAR FLOOD LEVEL (ELEV.)	254.2	256.5	257.2	265.5	266.5	267.0	247.2	247.2	249.0	249.0	261.0	261.0	262.6	262.6

LEGEND
WS180 — WATER SUPPLY PURPOSE WITH 180cfs YIELD
R180 — RECREATION PURPOSE BASED ON CONSERVATION POOL YIELDING 180cfs
FC5000 - FLOOD CONTROL PURPOSE WITH 5000 AC-FT FLOOD CONTROL STORAGE

TABLE 33

ECONOMIC ANALYSIS OF MARSHALL LAKE ALTERNATIVES

(JULY 84 PRICES,8-3/8% INTEREST, 100-YEAR PERIOD OF ANALYSIS)

LEGEND
WS180 — WATER SUPPLY PURPOSE WITH 180cfs YIELD
R180 — RECREATION PURPOSE BASED ON CONSERVATION POOL YIELDING 180cfs
FC5000 - FLOOD CONTROL PURPOSE WITH 5000 AC-FT FLOOD CONTROL STORAGE

ALTERNATIVES	WS125	WS125	WS125	WS125	WS125	WS125	WS125	WS125	WS125	WS125	WS125	WS125	FC50000	FC100000	WS180	WS180	WS180	WS180
		R125	FC50000	FC50000	FC100000	FC100000	FC270000	FC270000	FC360000	FC360000	FC415000	FC415000			FC50000	FC50000	FC100000	FC100000
				R125		R125		R125		R125		R125				R180		R180
ITEM								(COST IN $1,000's)										
01 LANDS(PROJECT)	13423.0	13423.0	17305.0	17305.0	19444.0	19444.0	26432.0	26432.0	30938.0	30938.0	32897.0	32897.0	8967.0	12785.0	20157.0	20157.0	22164.0	22164.0
(MITIGATION)	22351.0	22351.0	20962.0	20962.0	18615.0	18615.0	14113.0	14113.0	12101.0	12101.0	11000.0	11000.0	2060.0	2266.0	26023.0	26023.0	24587.0	24587.0
(RECREATION SPECIFIC)		1500.0		1572.0		1598.0		1680.0		1733.0		1755.0				1605.0		1635.0
02 RELOCATIONS (TOTAL)	21200.0	21200.0	32200.0	32200.0	38200.0	38200.0	55200.0	55200.0	62200.0	62200.0	66200.0	66200.0	20000.0	28000.0	45280.0	45280.0	50280.0	50280.0
REPLACEMENT ABOVE-IN-KIND	10000.0	10000.0	14000.0	14000.0	17000.0	17000.0	20000.0	20000.0	26200.0	26200.0	28200.0	28200.0	8000.0	12800.0	20000.0	20000.0	22000.0	22000.0
03 RESERVOIRS	3740.0	3740.0	3750.0	3750.0	3780.0	3780.0	3800.0	3800.0	3850.0	3850.0	3860.0	3860.0	2730.0	2740.0	4070.0	4070.0	4080.0	4080.0
04 DAMS	22250.0	22250.0	23700.0	23700.0	26300.0	26300.0	27500.0	27500.0	28500.0	28500.0	29200.0	29200.0	22800.0	23500.0	25400.0	25400.0	26400.0	26400.0
07 POWER PLANT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08 ROADS,RAILROADS,BRIDGES	455.0	455.0	472.0	472.0	495.0	495.0	510.0	510.0	520.0	520.0	530.0	530.0	465.0	472.0	485.0	485.0	497.0	497.0
14 RECREATION FACILITIES	0.0	22707.4	0.0	22707.4	0.0	22707.4	0.0	22707.4	0.0	22707.4	0.0	22707.4	0.0	0.0	0.0	22707.4	0.0	22707.4
18 CULTURAL RESOURCE PRESER	482.4	709.5	607.2	834.3	693.8	920.9	876.2	1103.3	956.8	1183.9	1004.1	1231.1	465.9	553.1	758.4	985.5	818.6	1045.7
19 BUILDINGS,GROUNDS,UTILIT	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0
20 PERMANENT OPERATING EQP.	217.0	217.0	221.0	221.0	228.0	228.0	233.0	233.0	235.0	235.0	238.0	238.0	218.0	220.0	226.0	226.0	229.0	229.0
30 ENGINEERING & DESIGN	3859.2	5675.8	4857.7	6674.3	5550.5	7367.1	7009.7	8826.3	7654.6	9471.2	8032.5	9849.1	3727.3	4424.8	6067.1	7883.7	6549.1	8365.7
31 SUPERVISION & ADMINISTRA	3713.8	5379.8	4644.5	6331.0	5283.1	6969.6	6636.9	8323.4	7238.5	8925.0	7589.1	9275.6	3485.6	4145.4	5792.9	7479.4	6239.2	7923.2
TOTAL FINANCIAL COSTS------	92069.4	119986.4	109097.4	137106.9	118967.4	147003.0	142688.8	170806.3	154572.0	182742.6	160928.6	189121.2	65296.8	79484.3	134637.4	162680.0	142221.9	170292.0
TOTAL ECONOMIC COSTS-------	80047.0	107737.0	92334.2	120116.7	98655.6	126464.1	118732.6	146623.1	123380.4	151323.9	127381.8	155347.3	55598.9	64160.0	110799.0	138614.5	116015.3	143858.3
INTEREST RATE--------------	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375
CONSTRUCTION PERIOD (YEARS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
INTEREST DURING CONSTRUCT.-	10091.9	15096.6	12697.6	17718.8	14504.3	19530.1	18311.1	23351.6	19994.3	25044.3	20980.0	26034.0	9728.8	11550.8	15857.6	20884.7	17114.9	22146.9
TOTAL FINANCIAL INVESTMENT-	102161.3	135083.0	121795.0	154825.8	133471.7	166533.1	160999.9	194158.0	174566.3	207786.9	181908.6	215155.2	75025.6	91035.1	150495.0	183564.7	159336.8	192439.0
TOTAL ECONOMIC INVESTMENT--	90138.9	122833.5	105031.8	137835.5	113159.9	145994.3	137043.7	169974.7	143374.6	176368.2	148361.8	181381.3	65327.7	75710.8	126656.6	159499.2	133130.1	166005.2
ANNUAL FINANCIAL CHARGES---	8558.8	11316.8	10203.6	12970.8	11181.8	13951.6	13488.1	16266.0	14624.6	17407.7	15239.7	18025.0	6285.4	7626.6	12608.0	15378.5	13348.7	16121.9
ANNUAL ECONOMIC CHARGES----	7551.6	10290.6	8799.2	11547.4	9480.2	12231.0	11481.1	14240.0	12011.5	14775.6	12429.3	15195.6	5473.0	6342.8	10610.9	13362.4	11153.2	13907.4
PROJECT O&M----------------	270.0	800.0	420.0	940.0	420.0	940.0	420.0	940.0	420.0	940.0	420.0	940.0	140.0	195.0	540.0	1150.0	550.0	1150.0
MITIGATION O&M-------------	108.0	108.0	102.0	102.0	90.0	90.0	69.0	69.0	59.0	59.0	53.0	53.0	10.0	11.0	126.0	126.0	119.0	119.0
TOTAL O&M------------------	378.0	908.0	522.0	1042.0	510.0	1030.0	489.0	1009.0	479.0	999.0	473.0	993.0	150.0	206.0	666.0	1276.0	669.0	1269.0
TOTAL ANN. FINANCIAL CHARGE	8936.8	12224.8	10725.6	14012.8	11691.8	14981.6	13977.1	17275.0	15103.6	18406.7	15712.7	19018.0	6435.4	7832.6	13274.0	16654.5	14017.7	17390.9
TOTAL ANN. ECONOMIC CHARGES	7929.6	11198.6	9321.2	12589.4	9990.2	13261.0	11970.1	15249.0	12490.5	15774.6	12902.3	16188.6	5623.0	6548.8	11276.9	14638.4	11822.2	15176.4
FLOOD CONTROL BENEFITS-----	140.0	140.0	225.0	225.0	300.0	300.0	470.0	470.0	480.0	480.0	505.0	505.0	95.0	190.0	280.0	280.0	350.0	350.0
WATER SUPPLY BENEFITS------	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0			12800.0	12800.0	12800.0	12800.0
RECREATION BENEFITS--------		3300.0		3300.0	0.0	3300.0		3300.0		3300.0		3300.0				4340.0	0.0	4340.0
HYDROPOWER BENEFITS--------																		
TOTAL BENEFITS-------------	8940.0	12240.0	9025.0	12325.0	9100.0	12400.0	9270.0	12570.0	9280.0	12580.0	9305.0	12605.0	95.0	190.0	13080.0	17420.0	13150.0	17490.0
NET BENEFITS---------------	1010.4	1041.4	-296.2	-264.4	-890.2	-861.0	-2700.1	-2679.0	-3210.5	-3194.6	-3597.3	-3583.6	-5528.0	-6358.8	1803.1	2781.6	1327.8	2313.6
BENEFIT-COST RATIO---------																		
YIELD (MGD)----------------	80.8	80.8	80.8	80.8	80.8	80.8	80.8	80.8	80.8	80.8	80.8	80.8			278.5	278.5	278.5	278.5

TABLE 33(cont)

ECONOMIC ANALYSIS OF MARSHALL LAKE ALTERNATIVES
(JULY 84 PRICES,8-3/8% INTEREST, 100-YEAR PERIOD OF ANALYSIS)

LEGEND
WS180 — WATER SUPPLY PURPOSE WITH 180cfs YIELD
R180 — RECREATION PURPOSE BASED ON CONSERVATION POOL YIELDING 180cfs
FC5000 - FLOOD CONTROL PURPOSE WITH 5000 AC-FT FLOOD CONTROL STORAGE

ALTERNATIVES

(COST IN $1,000's)

ITEM	FC271000	FC360000	FC413000	WS180	WS250	WS360	WS180 R180	WS250 R250	WS360 R360	WS180 FC271000	WS180 FC360000	WS180 FC413000	WS250 FC271000	WS250 FC360000	WS250 FC413000	WS360 FC271000	WS360 FC360000	WS360 FC413000	WS180 R180 FC271000	WS180 R180 FC360000	WS180 R180 FC413000
01 LANDS(PROJECT)	23397.0	25504.5	28361.2	18442.5	25169.0	42779.4	18792.1	25576.4	43301.1	30464.6	33490.7	35919.0	37668.0	43478.2	45826.3	53873.2	57390.0	60249.7	30940.7	33947.1	36371.7
(MITIGATION)	3193.0	3708.0	3914.0	26677.0	34299.0	46041.0	26677.0	34299.0	46041.0	19541.2	17816.9	16859.0	28743.2	27259.0	26444.2	42162.0	41059.9	40293.6	19541.2	17816.9	16859.0
(RECREATION SPECIFIC)	0.0	0.0	0.0	0.0	0.0	0.0	1612.5	1695.0	1867.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1755.0	1785.0	1807.5
02 RELOCATIONS (TOTAL)	49310.0	54490.0	56040.0	38450.0	59040.0	94900.0	38450.0	59040.0	94900.0	65390.0	71020.0	74800.0	82060.0	88520.0	90620.0	115440.0	118750.0	120910.0	65390.0	71020.0	74800.0
REPLACEMENT ABOVE-IN-KIND	21000.0	23000.0	23500.0	17000.0	25000.0	39900.0	17000.0	25000.0	39900.0	27500.0	30000.0	31500.0	34500.0	37000.0	38000.0	49500.0	51000.0	52000.0	27500.0	30000.0	31500.0
03 RESERVOIRS	2810.0	2820.0	2830.0	4050.0	4620.0	5500.0	4050.0	4620.0	5500.0	4130.0	4170.0	4180.0	4700.0	4710.0	4730.0	5650.0	5660.0	5680.0	4130.0	4170.0	4180.0
04 DAMS	25600.0	26700.0	27600.0	24200.0	26600.0	32600.0	24200.0	26600.0	32600.0	28900.0	30200.0	30800.0	31900.0	32700.0	33200.0	35800.0	36700.0	37400.0	28900.0	30200.0	30800.0
07 POWER PLANT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08 ROADS,RAILROADS,BRIDGES	490.0	500.0	511.0	475.0	499.0	575.0	475.0	499.0	575.0	525.0	540.0	549.0	558.0	575.0	585.0	640.0	667.0	685.0	525.0	540.0	549.0
14 RECREATION FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	22707.4	22707.4	22707.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22707.4	22707.4	22707.4
18 CULTURAL RESOURCE PRESER	788.2	851.2	875.9	677.8	913.7	1342.0	904.8	1140.7	1569.1	995.6	1065.5	1109.5	1198.4	1271.3	1297.6	1581.6	1624.1	1653.1	1222.7	1292.6	1336.6
19 BUILDINGS,GROUNDS,UTILIT	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0
20 PERMANENT OPERATING EQP.	228.0	230.0	234.0	222.0	230.0	245.0	222.0	230.0	245.0	236.0	240.0	241.0	242.0	245.0	247.0	254.0	257.0	258.0	236.0	240.0	241.0
30 ENGINEERING & DESIGN	6305.3	6809.4	7007.4	5422.0	7309.4	10735.8	7238.6	9126.0	12552.4	7964.7	8523.8	8875.8	9587.0	10170.2	10380.8	12653.0	12993.0	13224.9	9781.3	10340.4	10692.4
31 SUPERVISION & ADMINISTRA	5932.3	6407.3	6599.6	5193.2	6990.5	10256.5	6879.7	8677.0	11943.0	7553.6	8072.4	8401.0	9111.1	9660.3	9857.8	12043.3	12362.2	12580.8	9240.1	9758.9	10087.5
TOTAL FINANCIAL COSTS------	118431.7	128398.4	134351.2	124187.5	166048.5	245352.7	152587.1	194588.5	274179.5	166078.7	175517.4	182112.3	206145.7	218967.0	223566.7	280475.1	287841.2	293313.1	194747.3	204196.3	210810.1
TOTAL ECONOMIC COSTS-------	93409.6	101005.2	106356.3	103891.7	136284.8	197966.2	132064.3	164597.7	226565.8	133348.1	139831.9	144651.9	165134.4	174997.8	178417.1	221770.5	227363.1	231652.0	161789.7	168283.8	173122.5
INTEREST RATE--------------	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375
CONSTRUCTION PERIOD (YEARS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.0	5.0	5.0	4.0	4.0	4.0
INTEREST DURING CONSTRUCT.-	16464.3	17780.8	18298.9	14174.3	19106.4	28061.2	19202.8	24149.7	33135.4	20808.1	22266.8	23185.5	25049.9	26572.8	27122.5	42537.7	43679.6	44458.8	25862.1	27326.2	28248.9
TOTAL FINANCIAL INVESTMENT-	134896.0	146179.2	152650.1	138361.8	185155.0	273413.9	171789.9	218738.2	307314.9	186886.8	197784.1	205297.8	231195.6	245539.9	250689.2	323012.8	331520.9	337772.0	220609.5	231522.5	239059.0
TOTAL ECONOMIC INVESTMENT--	109873.8	118786.0	124655.2	118066.0	155391.3	226027.3	151267.1	188747.4	259701.2	154156.2	162098.7	167837.3	190184.3	201570.6	205539.6	264308.2	271042.7	276110.8	187651.8	195610.0	201371.4
ANNUAL FINANCIAL CHARGES---	11301.2	12246.4	12788.6	11591.5	15511.7	22905.8	14392.0	18325.2	25745.9	15656.8	16569.7	17199.2	19368.9	20570.6	21002.0	27061.0	27773.8	28297.5	18482.0	19396.2	20027.6
ANNUAL ECONOMIC CHARGES----	9204.9	9951.5	10443.2	9891.2	13018.2	18935.9	12672.7	15812.7	21757.0	12914.7	13580.1	14060.9	15933.1	16887.0	17219.5	22142.9	22707.1	23131.7	15720.9	16387.6	16870.3
PROJECT O&M---------------	360.0	420.0	460.0	380.0	545.0	870.0	910.0	1070.0	1310.0	530.0	530.0	530.0	695.0	695.0	695.0	1020.0	1020.0	1020.0	1150.0	1150.0	1150.0
MITIGATION O&M------------	15.5	18.0	19.0	129.5	166.5	223.5	129.5	166.5	223.5	94.9	86.5	81.8	139.5	132.3	128.4	204.7	199.3	195.6	94.9	86.5	81.8
TOTAL O&M-----------------	375.5	438.0	479.0	509.5	711.5	1093.5	1039.5	1236.5	1533.5	624.9	616.5	611.8	834.5	827.3	823.4	1224.7	1219.3	1215.6	1244.9	1236.5	1231.8
TOTAL ANN. FINANCIAL CHARGE	11676.7	12684.4	13267.6	12101.0	16223.2	23999.3	15431.5	19561.7	27279.4	16281.7	17186.2	17811.0	20203.4	21397.9	21825.4	28285.7	28993.1	29513.1	19726.9	20632.7	21259.4
TOTAL ANN. ECONOMIC CHARGES	9580.4	10389.5	10922.2	10400.7	13729.7	20029.4	13712.2	17049.2	23290.5	13539.6	14196.6	14672.7	16767.6	17714.3	18042.9	23367.6	23926.4	24347.3	16965.8	17624.1	18102.1
FLOOD CONTROL BENEFITS-----	420.0	457.0	488.0	202.0	281.0	416.0	202.0	281.0	416.0	489.6	492.2	515.5	500.0	510.0	525.0	510.0	522.0	535.0	489.6	492.2	515.5
WATER SUPPLY BENEFITS------	0.0	0.0	0.0	12850.0	23200.0	40800.0	12850.0	23200.0	40800.0	12850.0	12850.0	12850.0	23200.0	23200.0	23200.0	40800.0	40800.0	40800.0	12850.0	12850.0	12850.0
RECREATION BENEFITS--------	0.0	0.0	0.0	0.0	0.0	0.0	4302.5	5222.9	5452.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4302.5	4302.5	4302.5
HYDROPOWER BENEFITS--------	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL BENEFITS-------------	420.0	457.0	488.0	13052.0	23481.0	41216.0	17354.5	28703.9	46668.8	13339.6	13342.2	13365.5	23700.0	23710.0	23725.0	41310.0	41322.0	41335.0	17642.1	17644.7	17668.0
NET BENEFITS---------------	-9160.4	-9932.5	-10434.2	2651.3	9751.3	21186.6	3642.3	11654.7	23378.3	-200.0	-854.4	-1307.2	6932.4	5995.7	5682.1	17942.4	17395.6	16987.7	676.3	20.6	-434.1
BENEFIT-COST RATIO---------				1.3	1.7	2.1	1.3	1.7	2.0	1.0	0.9	0.9	1.4	1.3	1.3	1.8	1.7	1.7	1.0	1.0	1.0
YIELD (MGD)----------------	NA	NA	NA	116.4	161.6	232.7	116.4	161.4	232.7	116.4	116.4	116.4	161.6	161.6	161.6	232.7	232.7	232.7	116.4	116.4	116.4

TABLE 33
ECONOMIC ANALYSIS OF MARSHALL LAKE ALTERNATIVES
(JULY 84 PRICES,8-3/8% INTEREST, 100-YEAR PERIOD OF ANALYSIS)

LEGEND
WS180 — WATER SUPPLY PURPOSE WITH 180cfs YIELD
R180 — RECREATION PURPOSE BASED ON CONSERVATION POOL YIELDING 180cfs
FC5000 - FLOOD CONTROL PURPOSE WITH 5000 AC-FT FLOOD CONTROL STORAGE

ALTERNATIVES	WS125	WS125 R125	WS125 FC50000	WS125 FC50000 R125	WS125 FC100000	WS125 FC100000 R125	WS125 FC270000	WS125 FC270000 R125	WS125 FC360000	WS125 FC360000 R125	WS125 FC415000	WS125 FC415000 R125	FC50000	FC100000	WS180 FC50000	WS180 FC50000 R180	WS180 FC100000	WS180 FC100000 R180
ITEM								(COST IN $1,000's)										
01 LANDS(PROJECT)	13423.0	13423.0	17305.0	17305.0	19444.0	19444.0	26432.0	26432.0	30938.0	30938.0	32897.0	32897.0	8967.0	12785.0	20157.0	20157.0	22164.0	22164.0
(MITIGATION)	22351.0	22351.0	20962.0	20962.0	18615.0	18615.0	14113.0	14113.0	12101.0	12101.0	11000.0	11000.0	2060.0	2266.0	26023.0	26023.0	24587.0	24587.0
(RECREATION SPECIFIC)		1500.0		1572.0		1598.0		1680.0		1733.0		1755.0				1605.0		1635.0
02 RELOCATIONS (TOTAL)	21200.0	21200.0	32200.0	32200.0	38200.0	38200.0	55200.0	55200.0	62200.0	62200.0	66200.0	66200.0	20000.0	28000.0	45280.0	45280.0	50280.0	50280.0
REPLACEMENT ABOVE-IN-KIND	10000.0	10000.0	14000.0	14000.0	17000.0	17000.0	20000.0	20000.0	26200.0	26200.0	28200.0	28200.0	8000.0	12800.0	20000.0	20000.0	22000.0	22000.0
03 RESERVOIRS	3740.0	3740.0	3750.0	3750.0	3780.0	3780.0	3800.0	3800.0	3850.0	3850.0	3860.0	3860.0	2730.0	2740.0	4070.0	4070.0	4080.0	4080.0
04 DAMS	22250.0	22250.0	23700.0	23700.0	26300.0	26300.0	27500.0	27500.0	28500.0	28500.0	29200.0	29200.0	22800.0	23500.0	25400.0	25400.0	26400.0	26400.0
07 POWER PLANT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08 ROADS,RAILROADS,BRIDGES	455.0	455.0	472.0	472.0	495.0	495.0	510.0	510.0	520.0	520.0	530.0	530.0	465.0	472.0	485.0	485.0	497.0	497.0
14 RECREATION FACILITIES	0.0	22707.4	0.0	22707.4	0.0	22707.4	0.0	22707.4	0.0	22707.4	0.0	22707.4	0.0	0.0	0.0	22707.4	0.0	22707.4
18 CULTURAL RESOURCE PRESER	482.4	709.5	607.2	834.3	693.8	920.9	876.2	1103.3	956.8	1183.9	1004.1	1231.1	465.9	553.1	758.4	985.5	818.6	1045.7
19 BUILDINGS,GROUNDS,UTILIT	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0
20 PERMANENT OPERATING EQP.	217.0	217.0	221.0	221.0	228.0	228.0	233.0	233.0	235.0	235.0	238.0	238.0	218.0	220.0	226.0	226.0	229.0	229.0
30 ENGINEERING & DESIGN	3859.2	5675.8	4857.7	6674.3	5550.5	7367.1	7009.7	8826.3	7654.6	9471.2	8032.5	9849.1	3727.3	4424.8	6067.1	7883.7	6549.1	8365.7
31 SUPERVISION & ADMINISTRA	3713.8	5379.8	4644.5	6331.0	5283.1	6969.6	6636.9	8323.4	7238.5	8925.0	7589.1	9275.6	3485.6	4145.4	5792.9	7479.4	6239.2	7923.2
TOTAL FINANCIAL COSTS------	92069.4	119986.4	109097.4	137106.9	118967.4	147003.0	142688.8	170806.3	154572.0	182742.6	160928.6	189121.2	65296.8	79484.3	134637.4	162680.0	142221.9	170292.0
TOTAL ECONOMIC COSTS-------	80047.0	107737.0	92334.2	120116.7	98655.6	126464.1	118732.6	146623.1	123380.4	151323.9	127381.8	155347.3	55598.9	64160.0	110799.0	138614.5	116015.3	143858.3
INTEREST RATE--------------	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375
CONSTRUCTION PERIOD (YEARS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
INTEREST DURING CONSTRUCT.-	10091.9	15096.6	12697.6	17718.8	14504.3	19530.1	18311.1	23351.6	19994.3	25044.3	20980.0	26034.0	9728.8	11550.8	15857.6	20884.7	17114.9	22146.9
TOTAL FINANCIAL INVESTMENT-	102161.3	135083.0	121795.0	154825.8	133471.7	166533.1	160999.9	194158.0	174566.3	207786.9	181908.6	215155.2	75025.6	91035.1	150495.0	183564.7	159336.8	192439.0
TOTAL ECONOMIC INVESTMENT--	90138.9	122833.5	105031.8	137835.5	113159.9	145994.3	137043.7	169974.7	143374.6	176368.2	148361.8	181381.3	65327.7	75710.8	126656.6	159499.2	133130.1	166005.2
ANNUAL FINANCIAL CHARGES---	8558.8	11316.8	10203.6	12970.8	11181.8	13951.6	13488.1	16266.0	14624.6	17407.7	15239.7	18025.0	6285.4	7626.6	12608.0	15378.5	13348.7	16121.9
ANNUAL ECONOMIC CHARGES----	7551.6	10290.6	8799.2	11547.4	9480.2	12231.0	11481.1	14240.0	12011.5	14775.6	12429.3	15195.6	5473.0	6342.8	10610.9	13362.4	11153.2	13907.4
PROJECT O&M----------------	270.0	800.0	420.0	940.0	420.0	940.0	420.0	940.0	420.0	940.0	420.0	940.0	140.0	195.0	540.0	1150.0	550.0	1150.0
MITIGATION O&M-------------	108.0	108.0	102.0	102.0	90.0	90.0	69.0	69.0	59.0	59.0	53.0	53.0	10.0	11.0	126.0	126.0	119.0	119.0
TOTAL O&M------------------	378.0	908.0	522.0	1042.0	510.0	1030.0	489.0	1009.0	479.0	999.0	473.0	993.0	150.0	206.0	666.0	1276.0	669.0	1269.0
TOTAL ANN. FINANCIAL CHARGE	8936.8	12224.8	10725.6	14012.8	11691.8	14981.6	13977.1	17275.0	15103.6	18406.7	15712.7	19018.0	6435.4	7832.6	13274.0	16654.5	14017.7	17390.9
TOTAL ANN. ECONOMIC CHARGES	7929.6	11198.6	9321.2	12589.4	9990.2	13261.0	11970.1	15249.0	12490.5	15774.6	12902.3	16188.6	5623.0	6548.8	11276.9	14638.4	11822.2	15176.4
FLOOD CONTROL BENEFITS-----	140.0	140.0	225.0	225.0	300.0	300.0	470.0	470.0	480.0	480.0	505.0	505.0	95.0	190.0	280.0	280.0	350.0	350.0
WATER SUPPLY BENEFITS------	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0	8800.0			12800.0	12800.0	12800.0	12800.0
RECREATION BENEFITS--------		3300.0		3300.0	0.0	3300.0		3300.0		3300.0		3300.0				4340.0	0.0	4340.0
HYDROPOWER BENEFITS--------																		
TOTAL BENEFITS-------------	8940.0	12240.0	9025.0	12325.0	9100.0	12400.0	9270.0	12570.0	9280.0	12580.0	9305.0	12605.0	95.0	190.0	13080.0	17420.0	13150.0	17490.0
NET BENEFITS---------------	1010.4	1041.4	-296.2	-264.4	-890.2	-861.0	-2700.1	-2679.0	-3210.5	-3194.6	-3597.3	-3583.6	-5528.0	-6358.8	1803.1	2781.6	1327.8	2313.6
BENEFIT-COST RATIO---------																		
YIELD (MGD)----------------	80.8	80.8	80.8	80.8	80.8	80.8	80.8	80.8	80.8	80.8	80.8	80.8			278.5	278.5	278.5	278.5

TABLE 33(cont)

ECONOMIC ANALYSIS OF MARSHALL LAKE ALTERNATIVES

(JULY 84 PRICES,8-3/8% INTEREST, 100-YEAR PERIOD OF ANALYSIS)

LEGEND
WS180 — WATER SUPPLY PURPOSE WITH 180cfs YIELD
R180 — RECREATION PURPOSE BASED ON CONSERVATION POOL YIELDING 180cfs
FC5000 - FLOOD CONTROL PURPOSE WITH 5000 AC-FT FLOOD CONTROL STORAGE

(COST IN $1,000's)

ALTERNATIVES	WS250 FC50000	WS250 FC50000 R250	WS250 FC100000	WS250 FC100000 R250	WS360 FC50000	WS360 FC50000 R360 ·	WS360 FC100000	WS360 FC100000 R360	R250 WS250 FC271000	R250 WS250 FC360000	R250 WS250 FC413000	R360 WS360 FC271000	R360 WS360 FC360000	R360 WS360 FC413000
ITEM														
01 LANDS(PROJECT)	27879.0	27879.0	30412.0	30412.0	44925.0	44925.0	47103.0	47103.0	38138.9	44006.3	46192.9	54375.1	57829.8	60569.7
(MITIGATION)	33102.0	33102.0	32000.0	32000.0	45536.0	45536.0	44817.0	44817.0	28743.2	27259.0	26444.2	42162.0	41059.9	40293.6
(RECREATION SPECIFIC)		1695.0		1725.0		1860.0		1883.0	1822.5	1875.0	1890.0	1950.0	1972.5	1987.5
02 RELOCATIONS (TOTAL)	62340.0	62340.0	64840.0	64840.0	95650.0	95650.0	99850.0	99850.0	82060.0	88520.0	90620.0	115440.0	118750.0	120910.0
REPLACEMENT ABOVE-IN-KIND	23500.0	23500.0	24500.0	24500.0	42000.0	42000.0	43500.0	43500.0	34500.0	37000.0	38000.0	49500.0	51000.0	52000.0
03 RESERVOIRS	4630.0	4630.0	4660.0	4660.0	5540.0	5540.0	5560.0	5560.0	4700.0	4710.0	4730.0	5650.0	5660.0	5680.0
04 DAMS	27500.0	27500.0	28800.0	28800.0	33400.0	33400.0	33900.0	33900.0	31900.0	32700.0	33200.0	35800.0	36700.0	37400.0
07 POWER PLANT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08 ROADS,RAILROADS,BRIDGES	508.0	508.0	523.0	523.0	590.0	590.0	600.0	600.0	558.0	575.0	585.0	640.0	667.0	685.0
14 RECREATION FACILITIES	0.0	22707.4	0.0	22707.4	0.0	22707.4	0.0	22707.4	22707.4	22707.4	22707.4	22707.4	22707.4	22707.4
18 CULTURAL RESOURCE PRESER	955.9	1183.0	994.4	1221.4	1358.1	1585.1	1405.4	1632.5	1409.9	1498.4	1524.7	1808.7	1851.2	1880.2
19 BUILDINGS,GROUNDS,UTILIT	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0
20 PERMANENT OPERATING EQP.	232.0	.232.0	236.0	236.0	248.0	248.0	250.0	250.0	242.0	245.0	247.0	254.0	257.0	258.0
30 ENGINEERING & DESIGN	7647.0	9463.6	7955.0	9771.6	10864.5	12681.1	11243.0	13059.6	11278.8	11986.8	12197.4	14469.6	14809.6	15041.5
31 SUPERVISION & ADMINISTRA	7306.4	8992.9	7594.1	9280.6	10379.4	12065.9	10732.1	12418.6	10682.2	11346.8	11544.3	13729.8	14048.7	14267.3
TOTAL FINANCIAL COSTS------	172478.4	200610.9	178392.5	206555.0	248869.0	277166.6	255838.5	284159.1	234620.9	247807.7	252260.9	309364.6	316691.1	322058.2
TOTAL ECONOMIC COSTS-------	144403.5	172309.0	149125.1	177060.6	199042.9	227113.4	204234.1	232327.6	193398.0	203611.3	206884.2	250432.9	255985.9	260170.0
INTEREST RATE--------------	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375
CONSTRUCTION PERIOD (YEARS)	4.0	4.0	4.0	4.0	4.0	5.0	4.0	5.0	4.0	4.0	4.0	5.0	5.0	5.0
INTEREST DURING CONSTRUCT.-	19987.9	25031.1	20791.6	25840.2	28397.4	43060.2	29385.3	44336.4	30070.1	31648.3	32200.7	49084.8	50231.9	51014.6
TOTAL FINANCIAL INVESTMENT-	192466.2	225642.0	199184.0	232395.2	277266.4	320226.8	285223.8	328495.5	264691.0	279456.1	284461.6	358449.3	366923.0	373072.7
TOTAL ECONOMIC INVESTMENT--	164391.3	197340.1	169916.7	202900.8	227440.4	270173.6	233619.4	276664.0	223468.1	235259.7	239084.9	299517.6	306217.8	311184.6
ANNUAL FINANCIAL CHARGES---	16124.2	18903.6	16687.0	19469.4	23228.5	26827.6	23895.2	27520.3	22175.0	23412.0	23831.3	30029.8	30739.7	31254.9
ANNUAL ECONOMIC CHARGES----	13772.2	16532.5	14235.1	16998.4	19054.3	22634.3	19571.9	23178.1	18721.5	19709.3	20029.8	25092.7	25654.0	26070.1
PROJECT O&M----------------	720.0	1400.0	720.0	1400.0	1020.0	1685.0	1020.0	1685.0	360.0	1400.0	1400.0	1690.0	1690.0	1690.0
MITIGATION O&M-------------	161.0	161.0	155.0	155.0	221.0	221.0	218.0	218.0	15.5	132.3	128.4	204.7	199.3	195.6
TOTAL O&M------------------	881.0	1561.0	875.0	1555.0	1241.0	1906.0	1238.0	1903.0	375.5	1532.3	1528.4	1894.7	1889.3	1885.6
TOTAL ANN. FINANCIAL CHARGE	17005.2	20464.6	17562.0	21024.4	24469.5	28733.6	25133.2	29423.3	22550.5	24944.3	25359.7	31924.5	32629.0	33140.5
TOTAL ANN. ECONOMIC CHARGES	14653.2	18093.5	15110.1	18553.4	20295.3	24540.3	20809.9	25081.1	19097.0	21241.6	21558.2	26987.4	27543.3	27955.7
FLOOD CONTROL BENEFITS-----	340.0	340.0	390.0	390.0	438.0	438:0	460.0	460.0	500.0	510.0	525.0	510.0	522.0	535.0
WATER SUPPLY BENEFITS------	23200.0	23200.0	23200.0	23200.0	40800.0	40800.0	40800.0	40800.0	23200.0	23200.0	23200.0	40800.0	40800.0	40800.0
RECREATION BENEFITS--------	0.0	5200.0	0.0	5200.0	0.0	5452.8	0.0	5452.8	5222.9	5222.9	5222.9	5452.8	5452.8	5452.8
HYDROPOWER BENEFITS--------									0.0	0.0	0.0	0.0	0.0	0.0
TOTAL BENEFITS-------------	23540.0	28740.0	23590.0	28790.0	41238.0	46690.8	41260.0	46712.8	28922.9	28932.9	28947.9	46762.8	46774.8	46787.8
NET BENEFITS---------------	8886.8	10646.5	8479.9	10236.6	20942.7	22150.5	20450.1	21631.7	9825.9	7691.3	7389.7	19775.4	19231.5	18832.1
BENEFIT-COST RATIO---------									1.5	1.4	1.3	1.7	1.7	1.7
YIELD (MGD)----------------	162.3	162.3	162.3	162.3	233.8	233.8	233.8	233.8	NA	161.6	161.6	232.7	232.7	232.7

TABLE 34

ECONOMIC ANALYSIS OF BLACK CYPRESS LAKE ALTERNATIVES

(JULY 84 PRICES,8-3/8% INTEREST, 100-YEAR PERIOD OF ANALYSIS)

LEGEND
WS180 — WATER SUPPLY PURPOSE WITH 180cfs YIELD
R180 — RECREATION PURPOSE BASED ON CONSERVATION POOL YIELDING 180cfs
FC5000 - FLOOD CONTROL PURPOSE WITH 5000 AC-FT FLOOD CONTROL STORAGE

ALTERNATIVES	FC150000	FC200000	FC230000	WS125	WS180	WS244	R125 WS125	R180 WS180	R244 WS244	WS125 FC150000	WS125 FC200000	WS125 FC230000	WS180 FC150000	WS180 FC200000	WS180 FC230000	WS244 FC150000	WS244 FC200000	WS244 FC230000	R125 WS125 FC150000	R125 WS125 FC200000	R125 WS125 FC230000
ITEM							(COST IN $1,000's)														
01 LANDS(PROJECT)	11617.7	14004.0	15873.7	9073.9	16454.2	25611.3	9180.5	16722.5	26128.7	16083.4	18848.0	20327.9	23411.2	25657.6	26985.3	32337.4	34083.8	35234.4	16258.3	19047.5	20455.1
(MITIGATION)	2060.0	2472.0	2781.0	17922.0	31312.0	44393.0	17922.0	31312.0	44393.0	16467.6	16125.7	15938.2	30364.4	30111.0	29956.5	43698.8	43511.3	43401.1	16467.6	16125.7	15938.2
(RECREATION SPECIFIC)	0.0	0.0	0.0	0.0	0.0	0.0	946.0	1028.5	1111.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1023.0	1050.5	1061.5
02 RELOCATIONS (TOTAL)	25500.0	31500.0	32500.0	18000.0	41000.0	71500.0	18000.0	41000.0	71500.0	44000.0	44500.0	47000.0	61500.0	66500.0	69000.0	91500.0	95000.0	95500.0	44000.0	44500.0	47000.0
REPLACEMENT ABOVE-IN-KIND	12500.0	15500.0	16000.0	8500.0	20000.0	31500.0	8500.0	20000.0	31500.0	20500.0	21000.0	22000.0	27000.0	29500.0	30500.0	42500.0	44500.0	45000.0	20500.0	21000.0	22000.0
03 RESERVOIRS	1360.0	1390.0	1400.0	2090.0	2690.0	3540.0	2090.0	2690.0	3540.0	2150.0	2180.0	2190.0	2750.0	2780.0	2790.0	3560.0	3590.0	3600.0	2150.0	2180.0	2190.0
04 DAMS	17500.0	18600.0	19200.0	17400.0	19400.0	22000.0	17400.0	19400.0	22000.0	19500.0	20200.0	20400.0	21400.0	21900.0	22200.0	23400.0	23700.0	23900.0	19500.0	20200.0	20400.0
07 POWER PLANT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08 ROADS,RAILROADS,BRIDGES	471.0	472.0	473.0	470.0	474.0	481.0	470.0	474.0	481.0	475.0	476.0	478.0	480.0	481.0	482.0	485.0	486.0	487.0	475.0	476.0	478.0
14 RECREATION FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	11439.8	11439.8	11439.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11439.8	11439.8	11439.8
18 CULTURAL RESOURCE PRESER	453.7	525.1	541.2	385.0	641.2	980.9	499.4	755.6	1095.3	666.8	679.1	706.3	867.0	922.3	950.4	1195.2	1233.6	1240.7	781.2	793.5	820.7
19 BUILDINGS,GROUNDS,UTILIT	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0
20 PERMANENT OPERATING EQP.	163.0	170.0	173.0	162.0	175.0	192.0	162.0	175.0	192.0	176.0	179.0	181.0	188.0	191.0	192.0	200.0	202.0	203.0	176.0	179.0	181.0
30 ENGINEERING & DESIGN	3629.8	4200.8	4329.9	3080.0	5129.4	7847.3	3995.2	6044.5	8762.5	5334.3	5433.0	5650.2	6935.7	7378.4	7603.4	9561.8	9868.5	9925.4	6249.5	6348.2	6565.3
31 SUPERVISION & ADMINISTRA	3419.9	3959.4	4087.0	2964.1	4942.6	7541.5	3815.2	5793.7	8392.6	5071.5	5171.5	5376.7	6634.3	7050.3	7262.4	9145.9	9434.4	9490.1	5922.5	6022.6	6227.8
TOTAL FINANCIAL COSTS------	66553.1	77671.3	81736.8	71925.0	122596.4	184465.0	86298.0	137213.6	199413.8	110302.6	114170.4	118626.3	154908.6	163349.6	167800.0	215462.2	221487.5	223359.7	124820.9	128740.8	133135.4
TOTAL ECONOMIC COSTS-------	51674.4	59259.2	62731.6	61731.0	98875.2	147133.1	75989.6	113378.0	161967.5	85978.8	89257.3	92532.0	122883.6	128384.3	131652.6	165221.9	168901.0	170189.0	100382.7	103713.3	106926.7
INTEREST RATE--------------	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375
CONSTRUCTION PERIOD (YEARS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
INTEREST DURING CONSTRUCT.-	9478.9	10970.3	11308.6	8054.3	13414.6	20519.1	10611.8	15986.9	23106.2	13938.3	14197.4	14764.5	18129.9	19285.8	19873.3	24994.6	25795.3	25944.4	16509.7	16773.7	17342.7
TOTAL FINANCIAL INVESTMENT-	76031.9	88641.6	93045.4	79979.3	136011.0	204984.1	96909.9	153200.5	222520.0	124240.9	128367.8	133390.8	173038.4	182635.4	187673.3	240456.7	247282.8	249304.1	141330.6	145514.5	150478.2
TOTAL ECONOMIC INVESTMENT--	61153.2	70229.5	74040.2	69785.3	112289.8	167652.2	86601.5	129365.0	185073.7	99917.1	103454.7	107296.5	141013.5	147670.1	151525.9	190216.5	194696.2	196133.4	116892.4	120487.0	124269.5
ANNUAL FINANCIAL CHARGES	6369.7	7426.1	7795.1	6700.4	11394.6	17172.9	8118.8	12834.7	18642.0	10408.5	10754.3	11175.1	14496.6	15300.6	15722.7	20144.7	20716.6	20885.9	11840.2	12190.8	12606.6
ANNUAL ECONOMIC CHARGES----	5123.2	5883.6	6202.9	5846.4	9407.3	14045.4	7255.2	10837.8	15504.9	8370.8	8667.1	8989.0	11813.7	12371.3	12694.4	15935.8	16311.1	16431.5	9792.9	10094.0	10410.9
PROJECT O&M----------------	215.0	250.0	275.0	225.0	390.0	625.0	730.0	920.0	1130.0	375.0	375.0	375.0	540.0	540.0	540.0	775.0	775.0	775.0	840.0	840.0	840.0
MITIGATION O&M-------------	10.0	12.0	13.5	87.0	152.0	215.5	87.0	152.0	215.5	79.9	78.3	77.4	147.4	146.2	145.4	212.1	211.2	210.7	79.9	78.3	77.4
TOTAL O&M------------------	225.0	262.0	288.5	312.0	542.0	840.5	817.0	1072.0	1345.5	454.9	453.3	452.4	687.4	686.2	685.4	987.1	986.2	985.7	919.9	918.3	917.4
TOTAL ANN. FINANCIAL CHARGE	6594.7	7688.1	8083.6	7012.4	11936.6	18013.4	8935.8	13906.7	19987.5	10863.4	11207.6	11627.5	15184.0	15986.8	16408.1	21131.8	21702.8	21871.6	12760.1	13109.1	13524.0
TOTAL ANN. ECONOMIC CHARGES	5348.2	6145.6	6491.4	6158.4	9949.3	14885.9	8072.2	11909.8	16850.4	8825.7	9120.4	9441.4	12501.1	13057.5	13379.8	16922.9	17297.3	17417.2	10712.8	11012.3	11328.3
FLOOD CONTROL BENEFITS-----	225.0	260.0	270.0	87.0	148.0	225.0	87.0	148.0	225.0	245.0	275.0	285.0	261.6	293.6	301.1	291.0	310.0	320.0	245.0	275.0	285.0
WATER SUPPLY BENEFITS------	0.0	0.0	0.0	6950.0	9550.0	13400.0	6950.0	9550.0	13400.0	6950.0	6950.0	6950.0	9550.0	9550.0	9550.0	13400.0	13400.0	13400.0	6950.0	6950.0	6950.0
RECREATION BENEFITS--------	0.0	0.0	0.0	0.0	0.0	0.0	2473.4	3029.8	3029.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2473.4	2473.4	2473.4
HYDROPOWER BENEFITS--------	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL BENEFITS-------------	225.0	260.0	270.0	7037.0	9698.0	13625.0	9510.4	12727.8	16654.8	7195.0	7225.0	7235.0	9811.6	9843.6	9851.1	13691.0	13710.0	13720.0	9668.4	9698.4	9708.4
NET BENEFITS---------------	-5123.2	-5885.6	-6221.4	878.6	-251.3	-1260.9	1438.2	818.0	-195.6	-1630.7	-1895.4	-2206.4	-2689.5	-3213.9	-3528.7	-3231.9	-3587.3	-3697.2	-1044.4	-1313.9	-1619.9
BENEFIT-COST RATIO---------	0.0	0.0	0.0	1.1	1.0	0.9	1.2	1.1	1.0	0.8	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.9	0.9	0.9
YIELD (MGD)----------------	NA	NA	NA	80.8	116.4	157.7	80.8	116.4	157.7	80.8	80.8	80.8	116.4	116.4	116.4	157.7	157.7	157.7	80.8	80.8	80.8

TABLE 34(cont)

ECONOMIC ANALYSIS OF BLACK CYPRESS LAKE ALTERNATIVES

(JULY 84 PRICES,8-3/8% INTEREST, 100-YEAR PERIOD OF ANALYSIS)

LEGEND
WS180 — WATER SUPPLY PURPOSE WITH 180cfs YIELD
R180 — RECREATION PURPOSE BASED ON CONSERVATION POOL YIELDING 180cfs
FC5000 - FLOOD CONTROL PURPOSE WITH 5000 AC-FT FLOOD CONTROL STORAGE

(COST IN $1,000's)

ALTERNATIVES	R180 WS180 FC150000	R180 WS180 FC200000	R180 WS180 FC230000	R244 WS244 FC150000	R244 WS244 FC200000	R244 WS244 FC230000	FC50000	FC100000	WS125 FC50000	WS125 FC50000 R125	WS125 FC100000	WS125 FC100000 R125	WS180 FC50000	WS180 FC50000 R180	WS180 FC100000	WS180 FC100000 R180	WS250 FC50000	WS250 FC50000 R250	WS250 FC100000	WS250 FC100000 R250
ITEM																				
01 LANDS(PROJECT)	23650.1	25837.6	27253.8	32585.7	34342.9	35566.8	6063.0	9074.0	11092.0	11092.0	14072.0	14072.0	18612.0	18612.0	21000.0	21000.0	27950.0	27950.0	30167.0	30167.0
(MITIGATION)	30364.4	30111.0	29956.5	43698.8	43511.3	43401.1	1133.0	1751.0	17246.0	17246.0	16773.0	16773.0	30650.0	30650.0	30342.0	30342.0	44048.0	44048.0	43827.0	43827.0
(RECREATION SPECIFIC)	1089.0	1105.5	1116.5	1155.0	1166.0	1177.0				957.0		990.0		1034.0		1056.0		1111.0		1133.0
02 RELOCATIONS (TOTAL)	61500.0	66500.0	69000.0	91500.0	95000.0	95500.0	13000.0	18000.0	26000.0	26000.0	36000.0	36000.0	48000.0	48000.0	54000.0	54000.0	82000.0	82000.0	85000.0	85000.0
REPLACEMENT ABOVE-IN-KIND	27000.0	29500.0	30500.0	42500.0	44500.0	45000.0	7000.0	11000.0	17300.0	17300.0	18000.0	18000.0	22000.0	22000.0	23200.0	23200.0	36200.0	36200.0	40000.0	40000.0
03 RESERVOIRS	2750.0	2780.0	2790.0	3560.0	3590.0	3600.0	1270.0	1320.0	2120.0	2120.0	2150.0	2150.0	2700.0	2700.0	2710.0	2710.0	3520.0	3520.0	3540.0	3540.0
04 DAMS	21400.0	21900.0	22200.0	23400.0	23700.0	23900.0	14900.0	16300.0	18000.0	18000.0	18800.0	18800.0	20300.0	20300.0	20800.0	20800.0	22500.0	22500.0	23000.0	23000.0
07 POWER PLANT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08 ROADS,RAILROADS,BRIDGES	480.0	481.0	482.0	485.0	486.0	487.0	462.0	465.0	470.0	470.0	472.0	472.0	477.0	477.0	479.0	479.0	282.0	282.0	284.0	284.0
14 RECREATION FACILITIES	11439.8	11439.8	11439.8	11439.8	11439.8	11439.8	0.0	0.0	0.0	11439.0	0.0	11439.0	0.0	11439.0	0.0	11439.0	0.0	11439.0	0.0	11439.0
18 CULTURAL RESOURCE PRESER	981.4	1036.7	1064.8	1309.6	1348.0	1355.1	301.6	366.2	471.4	585.7	579.7	694.1	720.4	834.7	785.5	899.9	1088.8	1203.1	1124.0	1238.4
19 BUILDINGS,GROUNDS,UTILIT	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0	378.0
20 PERMANENT OPERATING EQP.	188.0	191.0	192.0	200.0	202.0	203.0	148.0	156.0	167.0	167.0	172.0	172.0	180.0	180.0	184.0	184.0	195.0	195.0	198.0	198.0
30 ENGINEERING & DESIGN	7850.9	8293.6	8518.5	10477.0	10783.7	10840.6	2412.6	2929.5	3770.8	4685.9	4637.8	5552.9	5762.8	6677.9	6284.1	7199.2	8710.0	9625.1	8992.0	9907.1
31 SUPERVISION & ADMINISTRA	7485.4	7901.3	8113.5	9996.9	10285.4	10341.1	2266.5	2760.5	3608.9	4459.9	4420.8	5271.8	5533.8	6384.8	6023.2	6874.2	8345.5	9196.5	8612.1	9463.1
TOTAL FINANCIAL COSTS------	169556.9	177955.5	182505.5	230185.9	236233.1	238189.5	42334.7	53500.3	83324.1	97600.6	98455.3	112764.8	133313.9	147667.4	142985.8	157361.3	199017.3	213447.8	205122.1	219574.6
TOTAL ECONOMIC COSTS-------	137417.5	142875.8	146243.6	179831.3	183532.1	184904.5	33955.2	40440.1	62888.5	77050.6	77103.6	91298.7	107205.6	121444.7	115427.5	129688.6	156153.7	170469.9	157838.1	172176.3
INTEREST RATE--------------	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375
CONSTRUCTION PERIOD (YEARS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
INTEREST DURING CONSTRUCT.-	20713.0	21871.9	22461.4	27589.5	28392.2	28543.3	6299.2	7650.3	9857.2	12416.5	12120.3	14685.6	15067.8	17640.9	16428.8	19005.8	22770.5	25357.4	23507.0	26097.9
TOTAL FINANCIAL INVESTMENT-	190269.9	199827.4	204966.8	257775.4	264625.3	266732.8	48634.0	61150.5	93181.3	110017.1	110575.6	127450.4	148381.7	165308.3	159414.6	176367.2	221787.8	238805.2	228629.2	245672.6
TOTAL ECONOMIC INVESTMENT--	158130.6	164747.7	168705.0	207420.8	211924.3	213447.8	40254.4	48090.4	72745.7	89467.2	89223.9	105984.2	122273.4	139085.6	131856.3	148694.5	178924.2	195827.2	181345.2	198274.2
ANNUAL FINANCIAL CHARGES---	15940.2	16740.9	17171.5	21595.6	22169.5	22346.1	4074.4	5123.0	7806.4	9216.9	9263.7	10677.4	12431.0	13849.0	13355.3	14775.5	18580.7	20006.4	19153.9	20581.7
ANNUAL ECONOMIC CHARGES----	13247.7	13802.1	14133.6	17377.1	17754.4	17882.0	3372.4	4028.9	6094.4	7495.3	7474.9	8879.0	10243.7	11652.2	11046.5	12457.2	14989.7	16405.8	15192.5	16610.8
PROJECT O&M----------------	1170.0	1170.0	1170.0	1485.0	1485.0	1485.0	173.0	218.0	490.0	1080.0	600.0	1240.0	732.0	1412.0	795.0	1490.0	978.0	1658.0	1030.0	1700.0
MITIGATION O&M-------------	147.4	146.2	145.4	212.1	211.2	210.7	6.0	9.0	84.0	84.0	81.0	81.0	149.0	149.0	147.0	147.0	213.0	213.0	213.0	213.0
TOTAL O&M------------------	1317.4	1316.2	1315.4	1697.1	1696.2	1695.7	179.0	227.0	574.0	1164.0	681.0	1321.0	881.0	1561.0	942.0	1637.0	1191.0	1871.0	1243.0	1913.0
TOTAL ANN. FINANCIAL CHARGE	17257.6	18057.1	18486.9	23292.7	23865.7	24041.8	4253.4	5350.0	8380.4	10380.9	9944.7	11998.4	13312.0	15410.0	14297.3	16412.5	19771.7	21877.4	20396.9	22494.7
TOTAL ANN. ECONOMIC CHARGES	14565.1	15118.3	15449.0	19074.2	19450.6	19577.7	3551.4	4255.9	6668.4	8659.3	8155.9	10200.0	11124.7	13213.2	11988.5	14094.2	16180.7	18276.8	16435.5	18523.8
FLOOD CONTROL BENEFITS-----	261.6	293.6	301.1	292.0	310.0	320.0	104.0	176.0	154.0	154.0	205.0	205.0	187.0	187.0	225.0	225.0	247.0	247.0	270.0	270.0
WATER SUPPLY BENEFITS------	9550.0	9550.0	9550.0	13400.0	13400.0	13400.0			7000.0	7000.0	7000.0	7000.0	9500.0	9500.0	9500.0	9500.0	13400.0	13400.0	13400.0	13400.0
RECREATION BENEFITS--------	3029.8	3029.8	3029.8	3029.8	3029.8	3029.8				2500.0		2500.0		3000.0		3000.0		3010.0		3010.0
HYDROPOWER BENEFITS--------	0.0	0.0	0.0	0.0	0.0	0.0														
TOTAL BENEFITS-------------	12841.4	12873.4	12880.9	16721.8	16739.8	16749.8	104.0	176.0	7154.0	9654.0	7205.0	9705.0	9687.0	12687.0	9725.0	12725.0	13647.0	16657.0	13670.0	16680.0
NET BENEFITS---------------	-1723.7	-2244.9	-2568.1	-2352.4	-2710.8	-2827.9	-3447.4	-4079.9	485.6	994.7	-950.9	-495.0	-1437.7	-526.2	-2263.5	-1369.2	-2533.7	-1619.8	-2765.5	-1843.8
BENEFIT-COST RATIO---------	0.9	0.9	0.8	0.9	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
YIELD (MGD)----------------	116.4	116.4	116.4	157.7	157.7	157.7			80.8	80.8	80.8	80.8	116.9	116.9	116.9	116.9	161.6	161.6	161.6	161.6

TABLE 35

HYDROPOWER ANALYSIS
DEDICATED STORAGE
MARSHALL LAKE

Top of Conservation Pool Elevation (feet NGVD)	Reservoir Yield (cfs)	Water Supply Yield (cfs)	Unit Size (MW)	Plant Factor (%)	Weekly Load (days/week)	Annual Firm Energy (MWH)	Average Annual Secondary Energy (MWH)	Average Annual Benefits (1,000)
230.7	180	0	2.0	13.7	7	2,400	3,575	800.6
			5.9	5.0	5	1,847	5,299	1,931.0
255.0	360	0	7.0	13.7	7	8,400	4,906	1,858.5
			25.3	5.0	5	7,919	6,480	4,289.2
255.0	360	250	2.9	13.7	7	3,480	2,516	829.9
			9.7	5.0	5	3,037	4,564	2,155.7
266.4	405	250	4.9	13.7	7	5,880	2,363	1,068.0
			16.8	5.0	5	5,258	4,123	2,803.9

TABLE 36

HYDROPOWER ANALYSIS
DEDICATED STORAGE
BLACK CYPRESS LAKE

Top of Conservation Pool Elevation (feet NGVD)	Reservoir Yield (cfs)	Water Supply Yield (cfs)	Unit Size (MW)	Plant Factor (%)	Weekly Load (days/week)	Annual Firm Energy (MWH)	Average Annual Secondary Energy (MWH)	Average Annual Benefits (1,000)
229.0	125	0	1.6	13.7	7	1,920	2,676	617.6
			5.1	5.0	5	1,596	3,610	1,430.6
253.0	244	0	5.4	13.7	7	6,480	2,923	1,326.8
			18.4	5.0	5	5,759	3,774	2,888.8
262.0	270	250	3.0	13.7	7	3,600	1,266	692.7
			9.5	5.0	5	2,974	2,237	1,562.5

TABLE 37

MARSHALL LAKE HYDROPOWER ALTERNATIVES
PERTINENT DATA

	HD180 MW2.0 & MW5.9	HD360 MW7.0 & MW25.3	WS250	WS250 HD110 MW2.9 & MW9.7	WS250 HD155 MW4.9 & MW16.8
TOP OF DAM (ELEV.)	251.2	272.8	258.5	272.8	280.8
MAXIMUM DESIGN WATER SURFACE (ELEV.)	246.7	268.3	254.0	268.3	276.3
FEE ACQUISITION LINE (ELEV.)	235.7	260.0	245.8	260.0	275.3
FEE ACQUISITION LINE (ACRES)	17481.0	34780.0	22634.0	34780.0	49511.0
TOP POWER POOL (ELEV.)	230.7	255.0	-	255.0	271.0
TOP POWER POOL (ACRES)	14038.0	28988.0	-	28988.0	44653.0
TOP POWER POOL (AC-FT)	181626.0	700000.0	-	700000.0	1294081.0
TOP CONSERVATION POOL (ELEV.)	-	-	240.8	240.8	240.8
TOP CONSERVATION POOL (ACRES)	-	-	19686.0	19686.0	19686.0
TOP CONSERVATION POOL (AC-FT)	-	-	355314.0	355314.0	355314.0
STREAMBED ELEVATION (ELEV.)	198.0	198.0	198.0	198.0	198.0
50-YEAR FLOOD LEVEL (ELEV.)	235.8	258.7	245.2	258.7	274.0

TABLE 38

BLACK CYPRESS LAKE HYDROPOWER ALTERNATIVES
PERTINENT DATA

	HD125 MW1.6 & MW5.1	HD244 MW5.4 & MW18.4	WS244	WS244 HD20 MW3.0 & MW9.5
TOP OF DAM (ELEV.)	251.3	267.7	267.7	270.1
MAXIMUM DESIGN WATER SURFACE (ELEV.)	247.6	264.0	264.0	266.4
FEE ACQUISITION LINE (ELEV.)	234.0	258.0	258.0	258.0
FEE ACQUISITION LINE (ACRES)	10675.0	25870.0	25870.0	27513.0
TOP POWER POOL (ELEV.)	229.7	253.0	-	255.6
TOP POWER POOL (ACRES)	8536.0	21951.0	-	23966.0
TOP POWER POOL (AC-FT)	99584.0	447262.0	-	507037.0
TOP CONSERVATION POOL (ELEV.)	-	-	253.0	253.0
TOP CONSERVATION POOL (ACRES)	-	-	21951.0	21951.0
TOP CONSERVATION POOL (AC-FT)	-	-	447262.0	447262.0
STREAMBED ELEVATION (ELEV.)	190.0	190.0	190.0	190.0
50-YEAR FLOOD LEVEL (ELEV.)	232.0	255.0	255.0	257.4

TABLE 39

HYDROPOWER ANALYSIS
MARSHALL LAKE ALTERNATIVES

(JULY 84 PRICES, 8 3/8 % INTEREST, 100-YEAR PERIOD OF ANALYSIS)

($1000)

ALTERNATIVES ITEM	HD180 MW2.0	HD180 MW5.9	HD360 MW7.0	HD360 MW25.3	WS250	WS250 HD110 MW2.9	WS250 HD110 MW9.7	WS250 HD155 MW4.9	WS250 HD155 MW16.8
01 LANDS(PROJECT)	18442.5	18442.5	42779.4	42779.4	25169.0	42779.4	42779.4	66344.7	66344.7
(MITIGATION)	26677.0	26677.0	46041.0	46041.0	34299.0	46041.0	46041.0	59225.0	59225.0
(RECREATION SPECIFIC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02 RELOCATIONS (TOTAL)	38450.0	38450.0	94900.0	94900.0	59040.0	94900.0	94900.0	152500.0	152500.0
REPLACEMENT ABOVE-IN-KIND	17000.0	17000.0	39900.0	39900.0	25000.0	39900.0	39900.0	73000.0	73000.0
03 RESERVOIRS	4050.0	4050.0	5500.0	500.0	4620.0	5500.0	5500.0	7000.0	7000.0
04 DAMS	24200.0	24200.0	32600.0	32600.0	26600.0	32600.0	32600.0	36600.0	36600.0
07 POWER PLANT	6982.5	9642.5	8844.5	49543.5	0.0	5985.0	13965.0	6982.5	38459.2
08 ROADS,RAILROADS,BRIDGES	475.0	475.0	575.0	575.0	499.0	575.0	575.0	662.0	662.0
14 RECREATION FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18 CULTURAL RESOURCE PRESER	747.6	774.2	1430.4	1787.4	913.7	1402.8	1481.6	2043.8	2358.6
19 BUILDINGS,GROUNDS,UTILIT	378.0	378.0	378.0	378.0	378.0	478.0	378.0	378.0	378.0
20 PERMANENT OPERATING EQP.	222.0	222.0	245.0	245.0	230.0	245.0	245.0	256.0	256.0
30 ENGINEERING & DESIGN	5980.6	6193.4	11443.4	14299.3	7309.4	11222.6	11853.0	16350.3	18868.4
31 SUPERVISION & ADMINISTRA	5709.9	5906.8	10911.0	13552.7	6990.5	10706.8	11289.9	15562.8	17892.0
TOTAL FINANCIAL COSTS------	132315.1	135411.3	255647.7	297201.4	166048.5	252435.7	261608.0	363905.0	400543.9
TOTAL ECONOMIC COSTS-------	111949.5	115019.2	208172.7	249369.4	136284.8	204988.3	214081.8	277619.2	313943.3
INTEREST RATE--------------	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375
CONSTRUCTION PERIOD (YEARS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0	5.0	5.0
INTEREST DURING CONSTRUCT.-	15631.4	16186.4	29906.8	37356.0	19106.4	29330.9	30975.2	54967.7	63417.8
TOTAL FINANCIAL INVESTMENT-	147946.4	151597.7	285554.5	334557.3	185155.0	281766.6	292583.2	418872.7	463961.7
TOTAL ECONOMIC INVESTMENT--	127580.9	131205.6	238079.5	286725.3	155391.3	234319.2	245057.0	332586.9	377361.1
ANNUAL FINANCIAL CHARGES---	12394.5	12700.4	23922.9	28028.2	15511.7	23605.5	24511.7	35091.9	38869.3
ANNUAL ECONOMIC CHARGES----	10688.3	10992.0	19945.6	24021.0	13018.2	19630.5	20530.1	27863.1	31614.2
PROJECT O&M----------------	446.7	491.5	979.4	1414.1	545.0	931.4	1036.9	1391.3	1726.3
MITIGATION O&M-------------	129.5	129.5	223.5	223.5	166.5	223.5	223.5	287.5	287.5
TOTAL O&M------------------	576.2	621.0	1202.9	1637.6	711.5	1154.9	1260.4	1678.8	2013.8
TOTAL ANN. FINANCIAL CHARGE	12970.7	13321.4	25125.8	29665.8	16223.2	24760.4	25772.1	36770.7	40883.1
TOTAL ANN. ECONOMIC CHARGES	11264.5	11613.0	21148.5	25658.6	13729.7	20785.4	21790.5	29541.9	33628.0
FLOOD CONTROL BENEFITS-----	202.0	202.0	416.0	416.0	281.0	416.0	416.0	500.0	500.0
WATER SUPPLY BENEFITS------	0.0	0.0	0.0	0.0	23200.0	23200.0	23200.0	23200.0	23200.0
RECREATION BENEFITS--------	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROPOWER BENEFITS--------	800.6	1931.0	1858.5	4289.2	0.0	829.9	2155.7	1068.0	2803.9
TOTAL BENEFITS-------------	1002.6	2133.0	2274.5	4705.2	23481.0	24445.9	25771.7	24768.0	26503.9
NET BENEFITS---------------	-10261.9	-9480.0	-18874.0	-20953.4	9751.3	3660.5	3981.2	-4773.9	-7124.1
BENEFIT-COST RATIO---------	0.09	0.18	0.11	0.18	1.71	1.18	1.18	0.84	0.79

LEGEND
WS180-WATER SUPPLY PURPOSE WITH 180 CFS YIELD
HD180-HYDROPOWER AS PURPOSE WITH DEDICATED STORAGE WHICH YIELDS 180 CFS
MW2.0-HYDROPOWER UNIT SIZE IN MEGA-WATTS

TABLE 40

HYDROPOWER ANALYSIS

BLACK CYPRESS LAKE ALTERNATIVES

(JULY 84 PRICES, 8 3/8 % INTEREST, 100-YEAR PERIOD OF ANALYSIS)

($1000)

ALTERNATIVES ITEM	HD125 MW1.6	HD125 MW5.1	HD244 MW5.4	HD244 MW18.4	WS244	WS244 HD20 MW3.0	WS244 HD20 MW9.5
01 LANDS(PROJECT)	9073.9	9073.9	25611.3	25611.3	25611.3	27788.1	27788.1
(MITIGATION)	17922.0	17922.0	44393.0	44393.0	44393.0	48101.0	48101.0
(RECREATION SPECIFIC)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02 RELOCATIONS (TOTAL)	18000.0	18000.0	71500.0	71500.0	71500.0	79900.0	79900.0
REPLACEMENT ABOVE-IN-KIND	8500.0	8500.0	31500.0	31500.0	31500.0	35000.0	35000.0
03 RESERVOIRS	2090.0	2090.0	3540.0	3540.0	3540.0	3690.0	3690.0
04 DAMS	17400.0	17400.0	22000.0	22000.0	22000.0	22700.0	22700.0
07 POWER PLANT	6317.5	9310.0	7647.5	42892.5	0.0	5209.1	12967.5
08 ROADS,RAILROADS,BRIDGES	470.0	470.0	481.0	481.0	481.0	482.0	482.0
14 RECREATION FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18 CULTURAL RESOURCE PRESER	448.2	478.1	1057.4	1409.8	980.9	1125.5	1203.1
19 BUILDINGS,GROUNDS,UTILIT	378.0	378.0	378.0	378.0	378.0	378.0	378.0
20 PERMANENT OPERATING EQP.	162.0	162.0	192.0	192.0	192.0	195.0	195.0
30 ENGINEERING & DESIGN	3585.4	3824.8	8459.1	11278.7	7847.3	9004.3	9625.0
31 SUPERVISION & ADMINISTRA	3431.6	3653.0	8107.4	10715.6	7541.5	8633.3	9207.4
TOTAL FINANCIAL COSTS------	79278.6	82761.8	193366.7	234391.9	184465.0	207206.3	216237.1
TOTAL ECONOMIC COSTS-------	69021.4	72474.7	155958.3	196631.0	147133.1	165690.8	174644.0
INTEREST RATE--------------	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375	0.08375
CONSTRUCTION PERIOD (YEARS)	4.0	4.0	4.0	4.0	4.0	4.0	4.0
INTEREST DURING CONSTRUCT.-	9372.6	9997.0	22114.9	29469.4	20519.1	23540.9	25159.9
TOTAL FINANCIAL INVESTMENT-	88651.2	92758.9	215481.6	263861.3	204984.1	230747.3	241397.0
TOTAL ECONOMIC INVESTMENT--	78394.0	82471.8	178073.2	226100.4	167652.2	189231.7	199803.9
ANNUAL FINANCIAL CHARGES---	7426.9	7771.1	18052.4	22105.5	17172.9	19331.3	20223.5
ANNUAL ECONOMIC CHARGES----	6567.6	6909.2	14918.4	18942.0	14045.4	15853.3	16739.0
PROJECT O&M----------------	280.1	329.4	715.2	1092.2	625.0	746.7	847.3
MITIGATION O&M-------------	87.0	87.0	215.5	215.5	215.5	233.5	233.5
TOTAL O&M------------------	367.1	416.4	930.7	1307.7	840.5	980.2	1080.8
TOTAL ANN. FINANCIAL CHARGE	7794.0	8187.5	18983.1	23413.2	18013.4	20311.5	21304.3
TOTAL ANN. ECONOMIC CHARGES	6934.7	7325.6	15849.1	20249.7	14885.9	16833.5	17819.8
FLOOD CONTROL BENEFITS-----	87.0	87.0	225.0	225.0	225.0	235.0	235.0
WATER SUPPLY BENEFITS------	0.0	0.0	0.0	0.0	13400.0	13400.0	13400.0
RECREATION BENEFITS--------	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYDROPOWER BENEFITS--------	617.6	1430.6	1326.8	2888.8	0.0	692.7	1562.5
TOTAL BENEFITS-------------	704.6	1517.6	1551.8	3113.8	13625.0	14327.7	15197.5
NET BENEFITS---------------	-6230.1	-5808.0	-14297.3	-17135.9	-1260.9	-2505.8	-2622.3
BENEFIT-COST RATIO---------	0.10	0.21	0.10	0.15	0.92	0.85	0.85

LEGEND

WS180-WATER SUPPLY PURPOSE WITH 180 CFS YIELD

HD180-HYDROPOWER AS PURPOSE WITH DEDICATED STORAGE WHICH YIELDS 180 CFS

MW2.0-HYDROPOWER UNIT SIZE IN MEGA-WATTS

TABLE 41

INCREMENTAL ECONOMIC ANALYSIS
ADDITION OF HYDROPOWER
MARSHALL LAKE ALTERNATIVE

(July 1984 prices, 8.375 percent interest, 100-year period of analysis)
(Values in thousands of dollars)

Item	WS250	WS250 HD110 MW2.9	WS250 HD110 MW9.7
Annual Economic Costs	13,018.2	19,630.5	20,530.1
Annual Benefits	23,481.0	24,445.9	25,771.7
Incremental Costs of Hydropower	-	6,612.3	7,511.9
Incremental Benefits of Hydropower	-	829.9	2,155.7
Incremental Benefits-Incremental Costs	-	-5,782.4	-5,356.2
Incremental Benefit-to-Cost Ratio	-	0.13	0.29

TABLE 42

SUMMARY OF FIRST COSTS
SHREVEPORT, LOUISIANA, TO DAINGERFIELD, TEXAS
NAVIGATION CHANNEL
AUTHORIZED ALIGNMENT

(July 1984 prices)
(1,000)

Item	Cost
Lands and Damages	9,023
Relocations	155,055
Navigation Dam	9,691
Navigation Locks	225,260
Channels	172,985
Levees	3,146
Channel Stabilization	6,735
Pumping Facilities	9,425
Access Roads	950
Buildings, Grounds, and Utilities	2,684
Engineering and Design (7%)	41,647
Supervision and Administration (8%)	47,596
Subtotal	684,197
U.S. Coast Guard Aid to Navigation	605
Total First Cost	684,802

TABLE 43

ECONOMIC ANALYSIS
AUTHORIZED NAVIGATION CHANNEL
SHREVEPORT, LOUISIANA, TO DAIGNERFIELD, TEXAS
(July 1984 prices, 100-year period of analysis)
($1,000)

	3-1/4%	8-3/8%
First Costs	684,802	684,802
Interest During Construction (8-year construction period)	95,550	275,921
Total Investment	780,352	960,793
Interest and Amortization	26,438	80,495
Operation, Maintenance, and Replacement	4,096	4,096
Total Annual Charges	30,534	84,591
Annual Transportation Savings	20,555	18,047
Area Redevelopment Benefit	258	638
Total Annual Benefits	20,813	18,685
Net Annual Benefits	-9,721	-65,906
Benefit-Cost Ratio	0.68	0.22

TABLE 44

NAVIGATION CHANNEL
OFF-CHANNEL ALIGNMENTS

SUMMARY OF FIRST COSTS
SHREVEPORT, LOUISIANA, TO DAINGERFIELD, TEXAS

(July 1984 prices)
($1.000)

Item	North Alignment	South Alignment
Lands and Damages	8,606	8,256
Relocations	219,055	211,055
Navigation Dam	0	0
Navigation Locks	213,266	213,266
Channels	175,712	146,201
Levees	56,135	69,207
Channel Stabilization	6,735	6,735
Pumping Facilities	9,425	9,425
Access Roads	950	950
Buildings, Grounds Utilities	2,684	2,684
Engineering and Design (7%)	48,480	46,745
Supervision and Administration (8%)	55,405	53,422
Subtotal	796,453	767,946
U.S. Coast Guard Aid to Navigation	605	605
Total First Costs	796,058	768,551

TABLE 45

COMPARISON OF COSTS
EXTENSION OF SHREVEPORT-DAINGERFIELD REACH TO DALLAS-FORT WORTH
(July 1984 prices)
($1,000)

	Plan B	Plan C	Plan D
Channels	2,028,802	2,187,164	3,006,348
Locks	591,231	607,451	566,142
Dams	1,410,028	1,389,818	339,000
Totals	4,030,061	4,184,433	3,911,490

TABLE 46

ECONOMIC ANALYSIS
DALLAS-FORT WORTH NAVIGATION CHANNEL EXTENSION
(July 1984 prices, 8-3/8% interest, 100-year period of analysis)
($1,000)

First Cost	3,226,688
Interest During Construction (10-year construction period)	1,726,994
Total Investment Cost	4,953,682
Interest and Amortization	415,019
Operation and Maintenance	4,100
Total Annual Cost	419,119
Annual Transportation Benefit	2,225
Net Annual Benefits	-416,894
Benefit-Cost Ratio	0.01

TABLE 47

SCREENING OF PRELIMINARY ALTERNATIVES

ALTERNATIVE	PRELIMINARY[1] FEASIBILITY	PASSED[1] SCREENING	ALTERNATIVES CONSIDERED FOR DETAILED[1] STUDIES
NONSTRUCTURAL			
° Water Conservation	NC	A	
° Change Operating Procedure of Lake O' The Pines	Y	I	
° Raising Existing Structures	Y	Y	Y
° Evacuate Flood Plain	N	N	
[2] ° Storage Reallocation at Lake O' The Pines	NC	–	Y
STRUCTURAL			
° Ground Water	N	N	
Utilization	N	N	
° Levees	N	N	
° Enlarge Channel	N	N	
° Diversion Channel			
° Lakes			
- Marshall Site	Y	Y	Y
- Black Cypress Site	Y	N	
° Addition of Hydro-power to Lakes	Y	N	
° Navigation Channel	N	N	

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[1] Y = Yes
N = No
NC = Not Computed
I = Alternative is already implemented
A = Assumed in effect

[2] ADDED AT REQUEST OF LOCAL INTERESTS

TABLE 48

DETAILED ECONOMIC ANALYSIS OF RAISING STRUCTURES ALTERNATIVE

(January 1986 price levels; based on 50-year project life and 8.625 percent interest)

Reach	Number of Structures To Be Raised	Total First Cost ($)	Annual Cost ($)	O&M ($)	Total Annual Cost ($)	Annual Benefits ($)	Net Benefits ($)
Big Cypress							
1	5	74,500	6,530	300	6,830	5,900	-(930)
2	30	538,800	47,225	2,220	49,445	22,000	-(27,445)
3	5	74,500	6,530	300	6,830	4,500	-(2,330)
4	47	791,800	69,400	3,240	72,640	69,000	-(3,640)
5	69	1,241,600	108,825	5,120	113,945	76,700	-(37,245)
6	45	670,500	58,770	2,900	61,670	17,900	-(43,770)
Caddo							
1	79	1,284,200	112,560	5,240	117,800	87,100	-(30,700)
2	6	89,400	7,835	360	8,195	3,100	-(5,095)
3	7	104,300	9,140	420	9,560	9,000	-(560)
6	50	867,000	75,990	3,560	79,550	55,600	-(23,950)
TOTALS	343	$5,736,600	$502,805	$23,660	$526,465	$350,800	-($175,665)

TABLE 49
MARSHALL LAKE
PERTINENT DATA (600 FT. SPILLWAY)
(RM 21.3 LITTLE CYPRESS BAYOU, 617 SQUARE MILE DRAINAGE AREA)

RESERVOIR

Top of Dam, Elevation	253.4
Maximum Design Water Surface Elevation	248.9
Fee Acquisition, Line Elevation	241.0
Fee Acquisition Line, Acres	19793
Top of Flood Control Pool, Elevation	---
Top of Flood Control Pool, Acres	---
Top of Flood Control Pool, Acre-feet	---
Top of Conservation Pool - Spillway Crest, Elevation	233.1
Top of Conservation Pool, Acres	15763
Top of Conservation Pool, Acre-feet	217324
Sediment Storage, Acre-feet	10,800

FEATURES OF DAM

Type	Earth Fill
Height, Feet	55
Length, Feet	7,000
Spillway Section -	
Type	Ogee Weir
Crest Length, Feet	600
Outlet Works	
Types and Size Conduit	1-10' dia
Control, Number and Size Gates	2- 4.5'X10'
Invert, Elevation	203.0'

TABLE 50
MARSHALL LAKE
PERTINENT DATA (200, 400, and 1,000 FT. SPILLWAYS)
(RM 21.3 LITTLE CYPRESS BAYOU, 617 SQUARE MILE DRAINAGE AREA)

RESERVOIR			
Top of Dam, Elevation	261	256.5	249.9
Maximum Design Water Surface Elevation	256.5	252.0	245.4
Fee Acquisition, Line Elevation	244.0	241.7	240.1
Fee Acquisition Line, Acres	21437	20172	19312
Top of Flood Control Pool, Elevation	---	---	---
Top of Flood Control Pool, Acres	---	---	---
Top of Flood Control Pool, Acre-feet	---	---	---
Top of Conservation Pool – Spillway Crest, Elevation	233.1	233.1	233.1
Top of Conservation Pool, Acres	15763	15763	15763
Top of Conservation Pool, Acre-feet	217324	217324	217324
Sediment Storage, Acre-feet	10,800	10,800	10,800
FEATURES OF DAM			
Type	Earth Fill	Earth Fill	Earth Fill
Height, Feet	63	58	51
Length, Feet	7,000	7,000	7,000
Spillway Section –			
Type	Ogee Weir	Ogee Weir	Ogee Weir
Crest Length, Feet	200	400	1,000
Outlet Works			
Types and Size Conduit	1-10' dia	1-10' dia	1-10' dia
Control, Number and Size Gates	2-4.5'X10'	2-4.5'X10'	2-4.5'X10'
Invert, Elevation	203.0'	203.0'	203.0'

TABLE 51

MARSHALL LAKE SPILLWAY OPTIMIZATION

(YIELD = 200 cfs)
(JANUARY 1986 PRICE LEVELS ; 8.625-PERCENT INTEREST ; 100-YEAR PERIOD OF ANALYSIS)

	COST CURVE PRICE LEVEL	ENR INDEX =	4,166		JULY 1984	
	UPDATE PRICES TO	ENR INDEX =	4,205		JANUARY 1986	
	PRICE LEVEL UPDATE FACTOR		1.0094			
	GUIDE ACQUISTION LINE EL.	241.7	241.0	240.1		244
	TOP OF DAM EL.	256.5	253.4	249.9		261
	SPILLWAY LENGTH (FT)	400	600	1,000		200
		COST	IN	JANUARY 1986	DOLLARS	
COST ACCOUNT NO.						
01	LANDS : Project	27,284,000	26,671,000	25,925,000		28,995,000
	Mitigation	37,195,000	37,056,000	36,917,000		37,245,000
	Recreation Specific	2,029,000	2,021,000	2,014,000		2,029,000
02	RELOCATIONS : Total	45,169,000	43,049,000	41,485,000		50,266,000
	Above in kind replace	20,692,000	20,187,000	18,168,000		21,197,000
03	RESERVOIRS	3,230,000	3,230,000	3,230,000		4,138,000
04	DAMS	22,509,000	24,982,000	31,088,000		19,683,000
08	ROADS,RAILROADS,BRIDGES	500,000	484,000	474,000		515,000
14	RECREATION FACILITIES	22,920,000	22,920,000	22,920,000		22,920,000
18	CULTURAL RESOURCE PRESERVATION	1,133,000	1,104,000	1,079,000		1,203,000
19	BUILDINGS,GROUNDS,UTILITIES	382,000	382,000	382,000		382,000
20	OPERATING EQUIPMENT	229,000	227,000	222,000		232,000
	PERCENT E&D	8.00%	8.00%	8.00%		8.00%
	E&D	7,686,000	7,710,000	8,070,000		7,947,000
	PERCENT S&A	7.00%	7.00%	7.00%		7.00%
	S&A	7,263,000	7,286,000	7,627,000		7,510,000
	TOTAL FINANCIAL COST	177,529,000	177,122,000	181,433,000		183,065,000
	Minus above in kind replace	(23,912,000)	(23,328,000)	(20,995,000)		(24,495,000)
	TOTAL ECONOMIC COST	153,617,000	153,794,000	160,438,000		158,570,000
	INTEREST RATE	8.62500%	8.62500%	8.62500%		8.62500%
	CONSTRUCTION PERIOD (months)	48	48	48		48
	ITEREST DURING CONSTRUCTION	16,475,000	16,652,000	18,077,000		17,078,000
	TOTAL FINANCIAL INVESTMENT	194,004,000	193,774,000	199,510,000		200,143,000
	TOTAL ECONOMIC INVESTMENT	170,092,000	170,446,000	178,515,000		175,648,000
	PERIOD OF ANALYSIS (YEARS)	100	100	100		100
	ANNUAL FINANCIAL COST	16,737,000	16,717,000	17,212,000		17,267,000
	ANNUAL ECONOMIC COST	14,674,000	14,705,000	15,401,000		15,154,000
	PROJECT O&M	989,000	989,000	989,000		989,000
	MITIGATION O&M	138,000	138,000	138,000		138,000
	TOTAL ANNUAL O&M	1,127,000	1,127,000	1,127,000		1,127,000
	TOTAL ANNUAL FINANCIAL CHARGES	17,864,000	17,844,000	18,339,000		18,394,000
	TOTAL ANNUAL ECONOMIC CHARGES	15,801,000	15,832,000	16,528,000		16,281,000
	ANNUAL BENEFITS					
	FLOOD CONTROL	340,000	187,000	139,000		495,000
	RECREATION	4,567,000	4,567,000	4,567,000		4,567,000
	WATER SUPPLY	15,902,000	15,902,000	15,902,000		15,902,000
	NET BENEFITS	5,008,000	4,824,000	4,080,000		4,683,000
	BENEFIT TO COST RATIO	1.32	1.30	1.25		1.29

TABLE 52
ECONOMIC EVALUATION OF MARSHALL LAKE
(JAN 1986 PRICE LEVELS, 8-5/8 PERCENT INTEREST, 100-YEAR PERIOD OF ANALYSIS)

Economic First Costs	$ 153,617,000
Interest During Construction	$ 16,475,000
Total Investment Costs	$ 170,092,000
Amortized First Cost	$ 14,674,000
Operation and Maintenance	$ 1,127,000
Total Annual Cost	$ 15,801,000
Total Annual Benefits	$ 20,809,000
Benefit To Cost Ratio (BCR)	1.32
Excess Benefits	$ 5,008,000
Specific Annual Costs By Purpose	
Flood Control	$ 337,200
Water Supply	$ 10,917,600
Recreation	$ 4,546,200
Separable Benefits	
Flood Control	$ 340,000
Water Supply	$ 15,902,000
Recreation	$ 4,567,000
BCR's By Purpose	
Flood Control	1.01
Water Supply	1.46
Recreation	1.00

TABLE 53

PRELIMINARY COST ALLOCATION FOR MARSHALL LAKE

(January 1986 price levels, 100-year project life, 8.625 percent interest)

ITEM	FLOOD CONTROL ($1,000)	WATER SUPPLY ($1,000)	RECREATION ($1,000)	TOTAL ($1,000)
Allocation of Annual Charges:				
Benefits	340.0	15,902.0	4,567.0	20,809.0
Alternate Cost	8,150.0	11,020.0	15,801.0	34,971.0
Benefits Limited By Alternate Cost	340.0	11,020.0	4,567.0	15.927.0
Separable Cost	0.0	0.0	2,257.3	2,257.3
Remaining Benefits	340.0	11,020.0	2,309.7	13,669.7
% Allocation of Joint Costs	0.0249	0.8061	0.1690	1.00
Allocated Joint Use Cost	337.2	10,917.6	2,088.9	13,543.7
Total Allocation	337.2	10,917.6	4,546.2	15,801.0
% Distribution	0.0213	0.6909	0.2877	1.00
Allocation of Operation and Mantenance Costs:				
Separable Costs	0	0	524.8	524.8
% Allocation of Joint Costs	0.0249	0.8061	0.1690	1.00
Allocated Joint Costs	15.0	485.4	101.8	602.2
Total Allocation	15.0	485.4	626.6	1,127.00
% Distribution	0.0133	0.4307	0.5560	1.00
Allocation of Investment:				
Annual Investment Cost	322.2	10,432.2	3,919.6	14,674.0
Allocated Investment	3,738.7	120,920.8	45,432.5	170,092.0
Allocation of First Costs:				
Specific Investment	0	0	20,081.6	20,081.6
Joint Use Investment	3,735.3	120,923.3	25,351.8	150,010.4
% Allocation of Joint Use Investment	0.0249	0.8061	0.1690	1.00
Joint First Cost	3,204.7	103,747.5	21,750.8	128,703.0
Specific First Cost	0	0	24,914.0	24,914.0
Total First Cost	3,204.7	103,747.5	46,664.8	153,617.0
% Allocation of Total First Cost	0.0209	0.6754	0.3038	1.00

TABLE 54

ECONOMIC SUMMARY FOR MARSHALL LAKE BASED ON COST SHARING POLICIES INCLUDED IN THE WATER RESOURCES DEVELOPMENT ACT OF 1986 (PL 99-662)

(January 1986 price level)

	FEDERAL ($)	PERCENT APPORTIONMENT OF TOTAL (%)	NON-FEDERAL ($)	PERCENT APPORTIONMENT OF TOTAL (%)	TOTAL	PERCENT OF TOTAL (%)
FIRST COSTS:						
Flood Control 1/	2,403,500	1.6	801,200	0.5	3,204,700	2.1
Water Supply	----	---	103,747,500	67.5	103,747,500	67.5
Recreation 2/	23,332,400	15.2	23,332,400	15.2	46,664,800	30.4
Total	25,735,900	16.8	127,881,100	83.2	153,617,000	100.0
ANNUAL COSTS: 1/						
Flood Control	207,400	1,3	129,800	0,8	337,200	2.1
Water Supply	----	---	10,917,600	69.1	10,917,600	69.1
Recreation 2/	1,959,800	12.4	2,586,400	16.4	4,546,200	28.8
Total	2,167,200	13.7	13,633,800	86.5	15,801,000	100.0

1/ Flood control costs shared 75% Federal and 25% Non-Federal (5% of costs and lands, easements, and rights-of-way, or a minimum of 5%), O&M 100% Non-Federal responsibility.

2/ Separable recreation costs shared 50% Federal and 50% Non-Federal with recreation O&M costs 100% Non-Federal responsibility.

3/ Includes: Interest during construction; interest and amortization; operation and maintenance; and major replacement. Evaluated at 8-5/8% interest rate and 100-year project life.

TABLE 55

ECONOMIC SUMMARY FOR MARSHALL LAKE
BASED ON SUPERCEDED TRADITIONAL COST SHARING POLICIES
(January 1986 price level)

	FEDERAL ($)	PERCENT APPORTIONMENT OF TOTAL (%)	NON-FEDERAL ($)	PERCENT APPORTIONMENT OF TOTAL (%)	TOTAL	PERCENT OF TOTAL (%)
FIRST COSTS:						
Flood Control	3,204,700	2.1	-----	-----	3,204,700	2.1
Water Supply	----	---	103,747,500	67.5	103,747,500	67.5
Recreation 2/	34,207,800	22.3	12,457,000	8.1	46,664,800	30.4
Total	37,412,500	24.4	116,204,500	75.6	153,617,000	100.0
ANNUAL COSTS: 1/						
Flood Control	337,200	2.1	-----	-----	337,200	2.1
Water Supply	----	---	10,917,600	69.1	10,917,600	69.1
Recreation 2/	2,790,900	17.7	1,755,300	11.1	4,546,200	28.8
Total	3,128,100	19.8	12,672,900	80.2	15,801,000	100.0

1/ Includes: Interest during construction; interest and amortization; operation and maintenance; and major replacement. Evaluated at 8-5/8% interest rate and 100-year project life.

2/ Separable recreation costs shared 50% Federal and 50% Non-Federal, with joint recreation costs 100% Federal responsibility.

TABLE 56

ECONOMIC SUMMARY FOR MARSHALL LAKE 1/ AND NON-FEDERAL FINANCIAL ANNUAL COST

(January 1986 price level)

	FEDERAL ($)	PERCENT APPORTIONMENT OF TOTAL (%)	NON-FEDERAL ($)	PERCENT APPORTIONMENT OF TOTAL (%)	TOTAL	PERCENT OF TOTAL (%)
FIRST COSTS:						
Flood Control	3,204,700	2.1	----	---	3,204,700	2.1
Water Supply	----	---	103,747,500	67.5	103,747,500	67.5
Recreation 4/	34,207,800	22.3	12,457,000	8.1	46,664,800	30.4
Total	37,412,500	24.4	116,204,500	75.6	153,617,000	100.0
NON-FEDERAL: 3/						
Annual Costs						
Flood Control			-----	-----		
Water Supply	----	---	14,927,700		14,927,700	
Recreation			2,170,400		2,170,400	
Total			17,098,100		17,098,100	100.0

Non-Federal Cost of Water per 1,000 Gallons = $0.32
(Does Not Include Transmission Costs)

1/ Traditional cost sharing policies

2/ Interest rate determined by the Department of the Treasury in accord with provisions of the Water Supply Act of 1958, Section 301 (b).

3/ Includes: Interest during construction; interest and amortization; operation and maintenance; and major replacement. Evaluated at 11.070% interest rate and 50-year repayment schedule.

4/ Separable recreation costs shared 50% Federal and 50% Non-Federal joint recreation costs 100% Federal

TABLE 57

LAKE O' THE PINES PERTINENT DATA

Drainage Area (sq mi)	850
Elevations (feet NGVD)	
Minimum Pool	201.0
Water Supply Pool	228.5
Flood Control Pool	249.5
Spillway Crest	249.5
Top of Dam	277.0
Areas (acres)	
Minimum Pool	1,100
Water Supply Pool	18,700
Flood Control Pool	38,200
Storage Capacities (acre-feet)	
Minimum Pool	3,800
Water Supply Pool	251,100
Flood Control Pool	587,200
Dimensions (feet)	
Dam, length at crest	10,600
Dam, height above mean valley floor	77
Dam, maximum above streambed	97
Spillway width	200
Structural Data	
Dam	Earthfill
Conduits, two, each	10 ft diameter
Gates, two, each	8 ft x 12 ft-6 in

TABLE 58

YIELD CAPACITY - LAKE O' THE PINES

Elevation (ft-msl)	Capacity	Increased Capacity(AF)	Yield(AF/YR)	Increased Yield(AF/YR)
228.5	254,900	-	146,900	-
229.5	274,000	19,100	153,200	6,300
230.5	293,800	38,900	159,700	12,800
231.5	314,300	59,400	165,500	18,600
232.5	335,600	80,700	171,100	24,200
233.5	357,800	102,900	176,600	29,700
234.5	380,900	126,000	181,800	34,900
235.5	404,900	150,000	187,100	40,200
236.5	429,800	174,900	192,700	45,800
237.5	455,600	200,700	198,600	51,700
238.5	482,300	227,400	204,500	57,600
239.5	509,900	255,000	210,700	63,800
240.5	538,600	283,700	217,200	70,300
241.5	568,300	313,400	224,000	77,100
242.5	599,100	344,200	231,000	84,100
243.5	630,800	375,900	238,200	91,300
244.5	663,700	408,300	245,700	98,800
245.5	697,500	442,600	253,400	106,500
246.5	732,200	477,300	261,400	114,500
247.5	767,900	513,000	269,700	122,800
248.5	804,500	549,600	277,700	130,800
249.5	842,100	587,200	283,300	136,400

*Estimates only, based on initial area/capacity data, no reserve, with Lake Cypress Springs releases.

Source: Freese and Nichols, Inc., May 31, 1986.

TABLE 59

LITTLE CYPRESS RESERVOIR PERTINENT DATA

Miscellaneous

Dam Location, stream mile	19.7
Drainage Area, square miles	619
Initial Water Conservation Storage, acre-feet	193,485
100-Year Sediment Storage, acre-feet	7,768

Reservoir	Elevation (feet msl)	Initial Area (acres)	Initial Capacity (acre-feet)
Streambed	186.0	-0-	-0-
Spillway Crest	210.0	3,580	17,185
Top of Conservation Storage	230.0	13,760	193,485
Maximum Reservoir Water Surface	245.0	22,520	461,735
Top of Dam	250.0	26,180	583,485

Reservoir Yield

Initial Yield	129,000 acre-feet per year	115 mgd	178 cfs
Future Yield (with 100-year Sedimentation	125,000 acre-feet per year	112 mgd	174 cfs

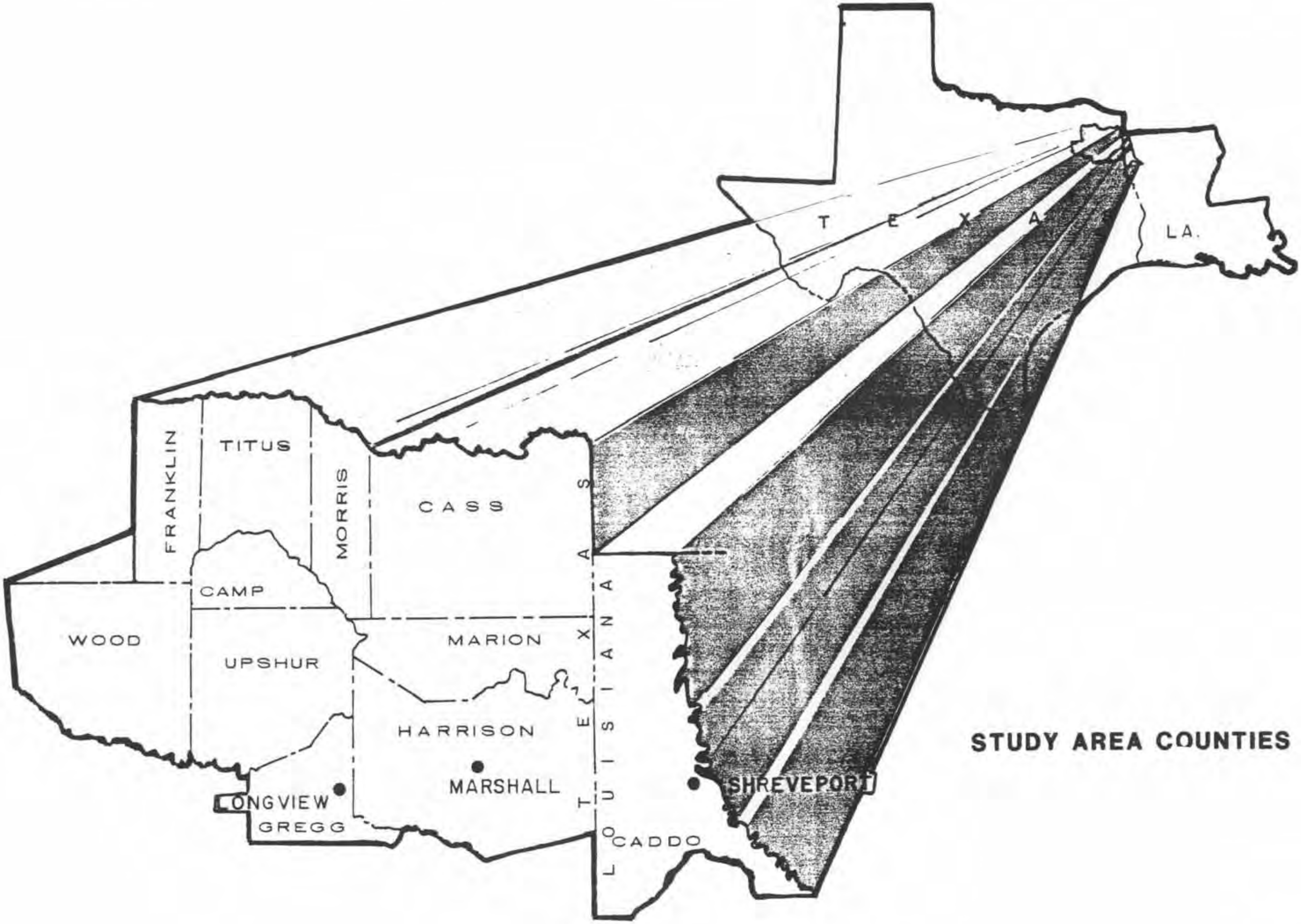
Dam	Zoned earthen embankment, 5,700 feet long, 64 feet maximum height, 20 feet crest width, 3.0:1 side slopes, 40-feet and 30-feet wide stability berms on upstream and downstream slopes, respectively, at elevation 215.0 feet msl.
Spillway	Gated ogee crest, six 40-foot wide by 22-foot high tainter gates

Source: Preliminary Engineering Report for Little Cypress Reservoir prepared by Kindle, Stone and Associates, February 21, 1986.

CYPRESS BAYOU BASIN STUDY

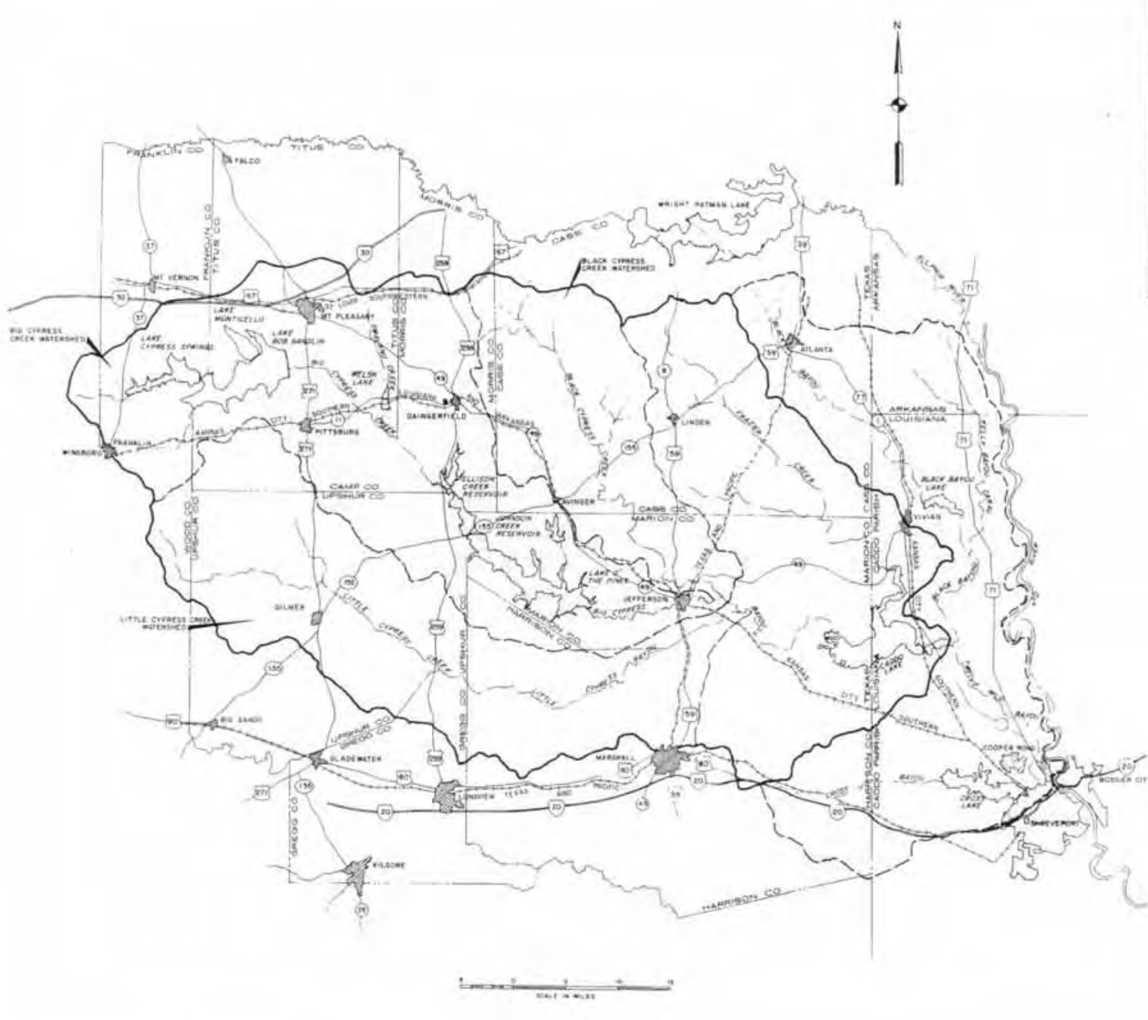
FEASIBILITY REPORT

PLATES



STUDY AREA COUNTIES

PLATE 1



VICINITY MAP
NOT TO SCALE

LEGEND

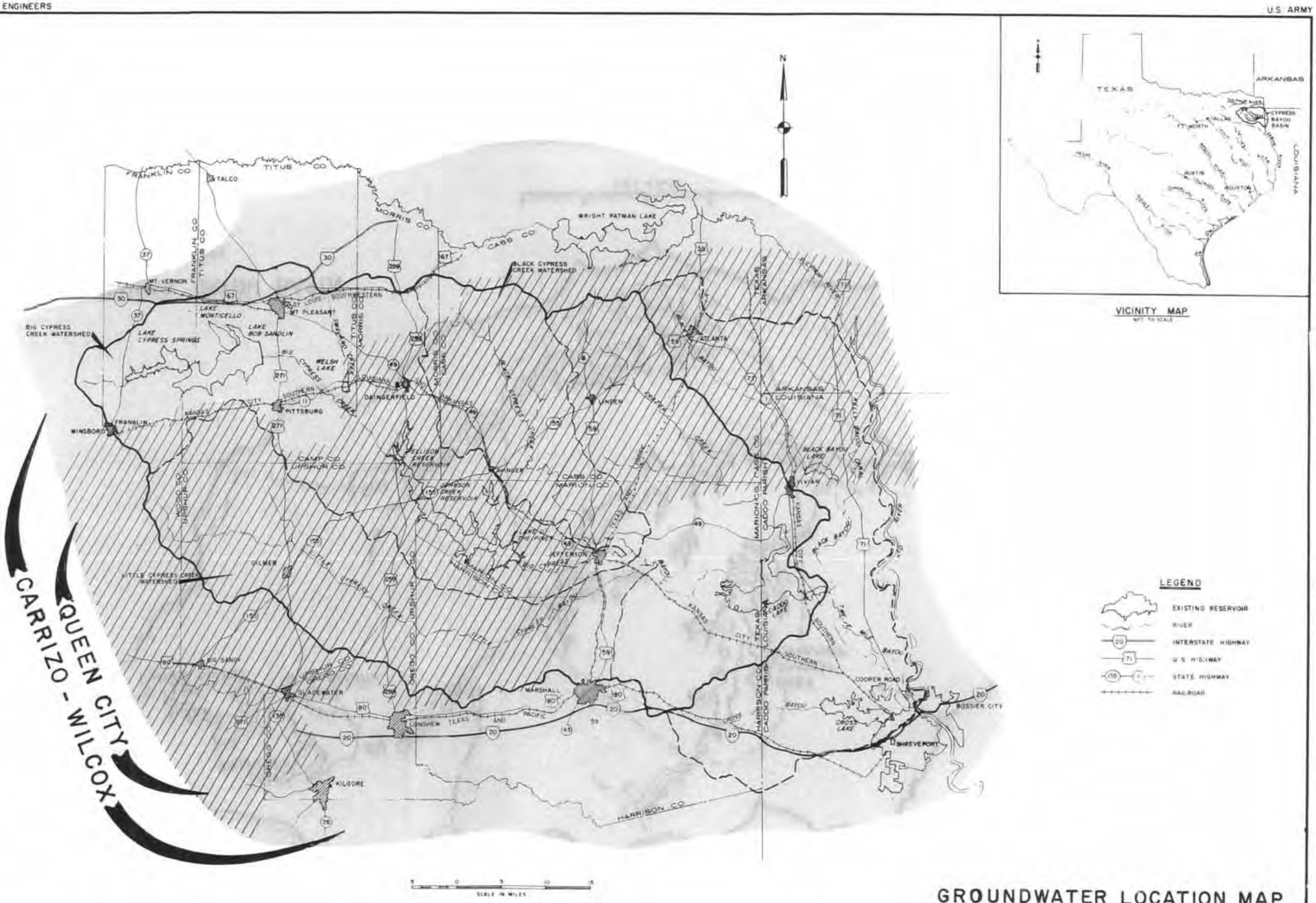
EXISTING RESERVOIR
RIVER
(20) INTERSTATE HIGHWAY
[71] U.S. HIGHWAY
(155) (1) STATE HIGHWAY
RAILROAD

CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

CYPRESS BAYOU BASIN

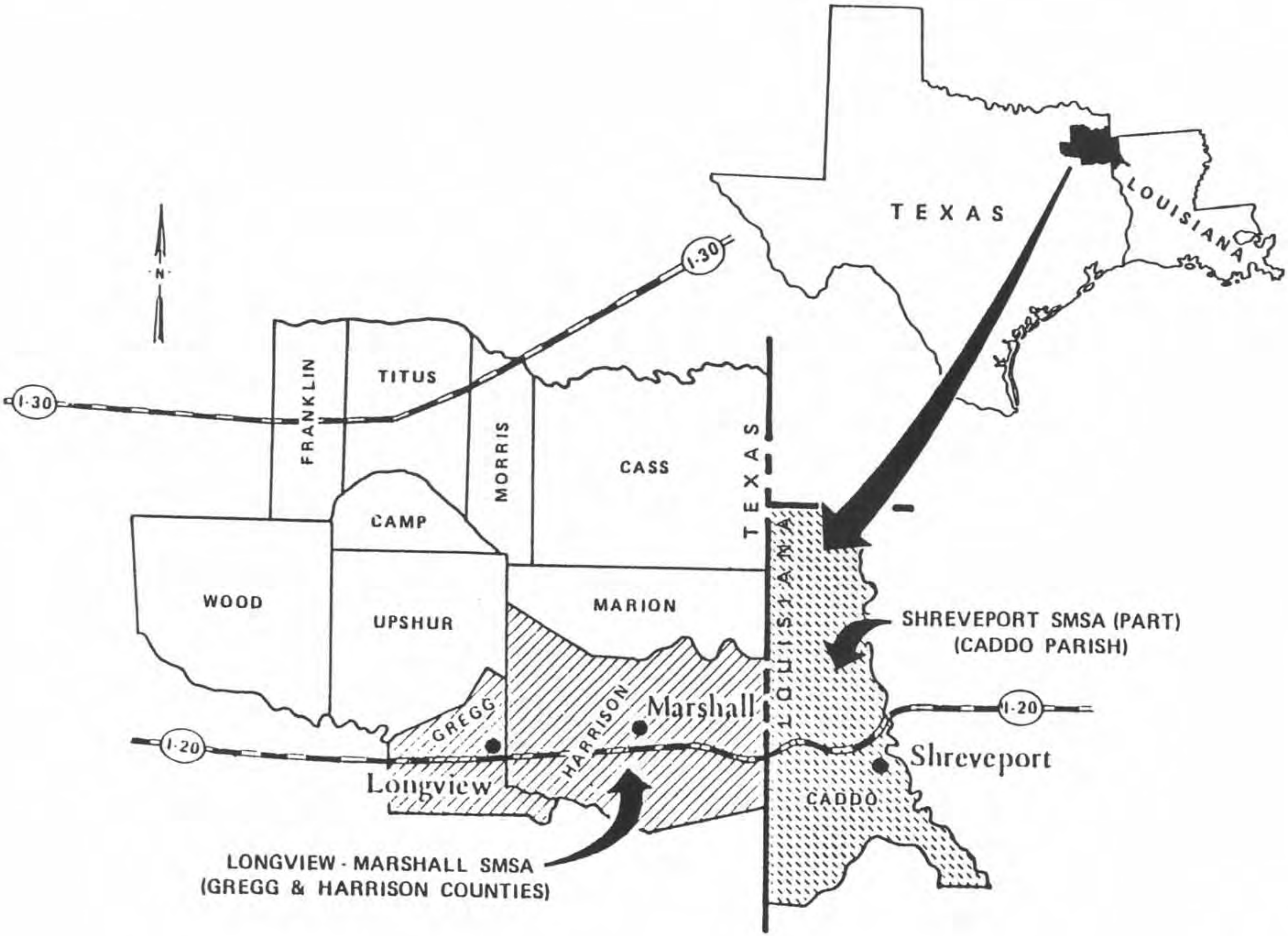
U.S. ARMY ENGINEER DISTRICT, FORT WORTH JULY 1981

FILE NO. **PLATE 2**



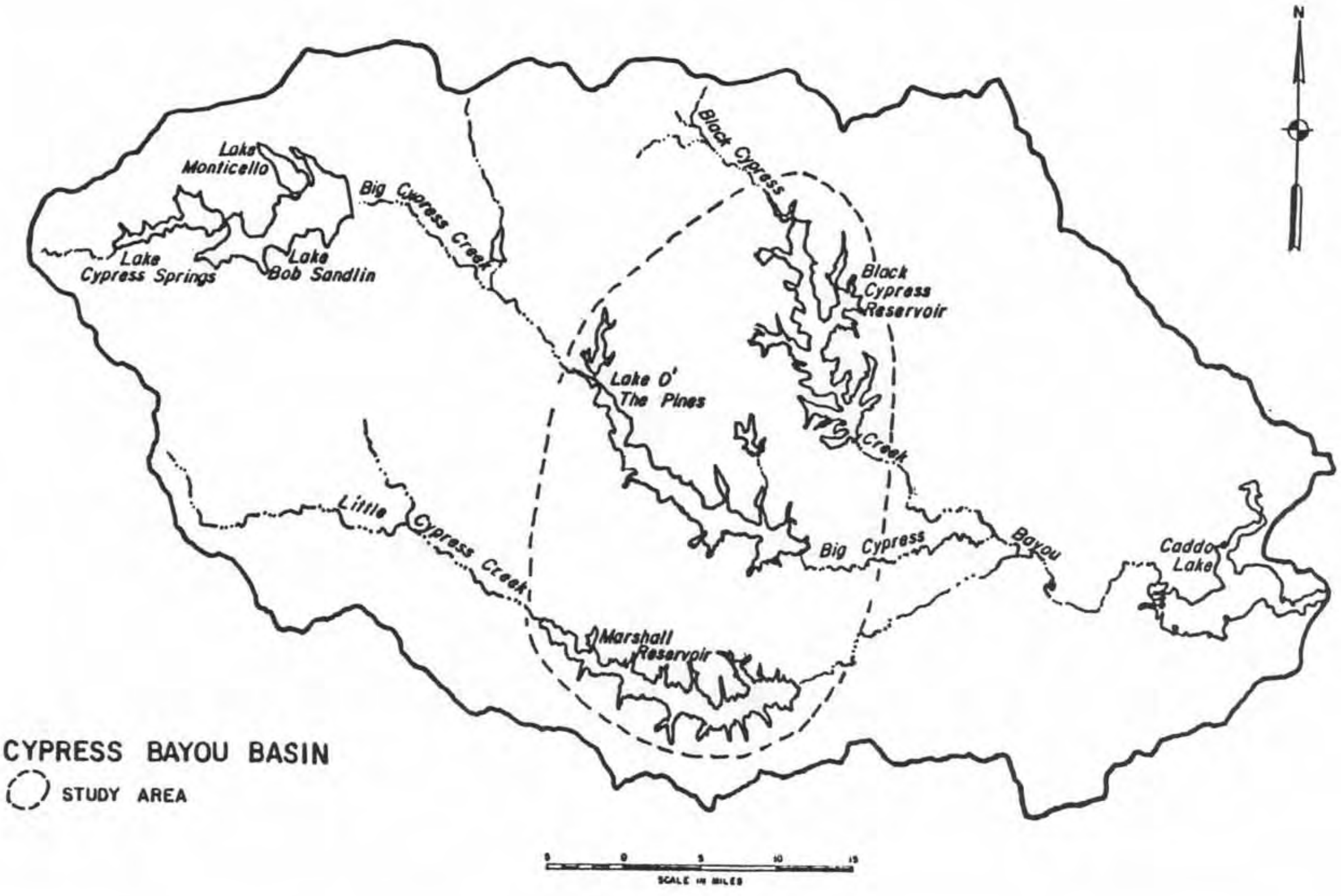
GROUNDWATER LOCATION MAP

PLATE 3



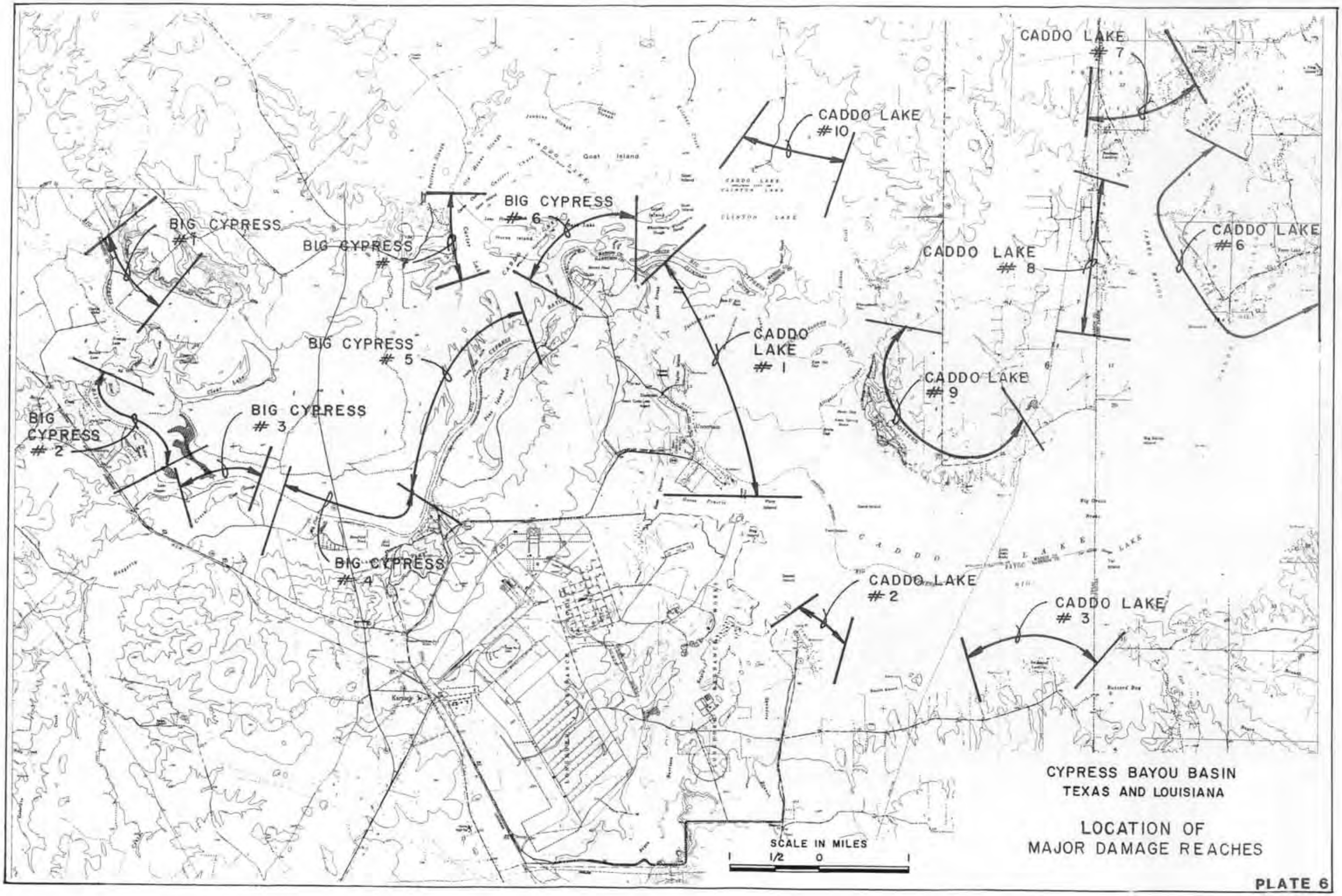
CYPRESS BAYOU BASIN WATER SUPPLY STUDY AREA

PLATE 5



Revised Study Area for the Cultural
Resources Study

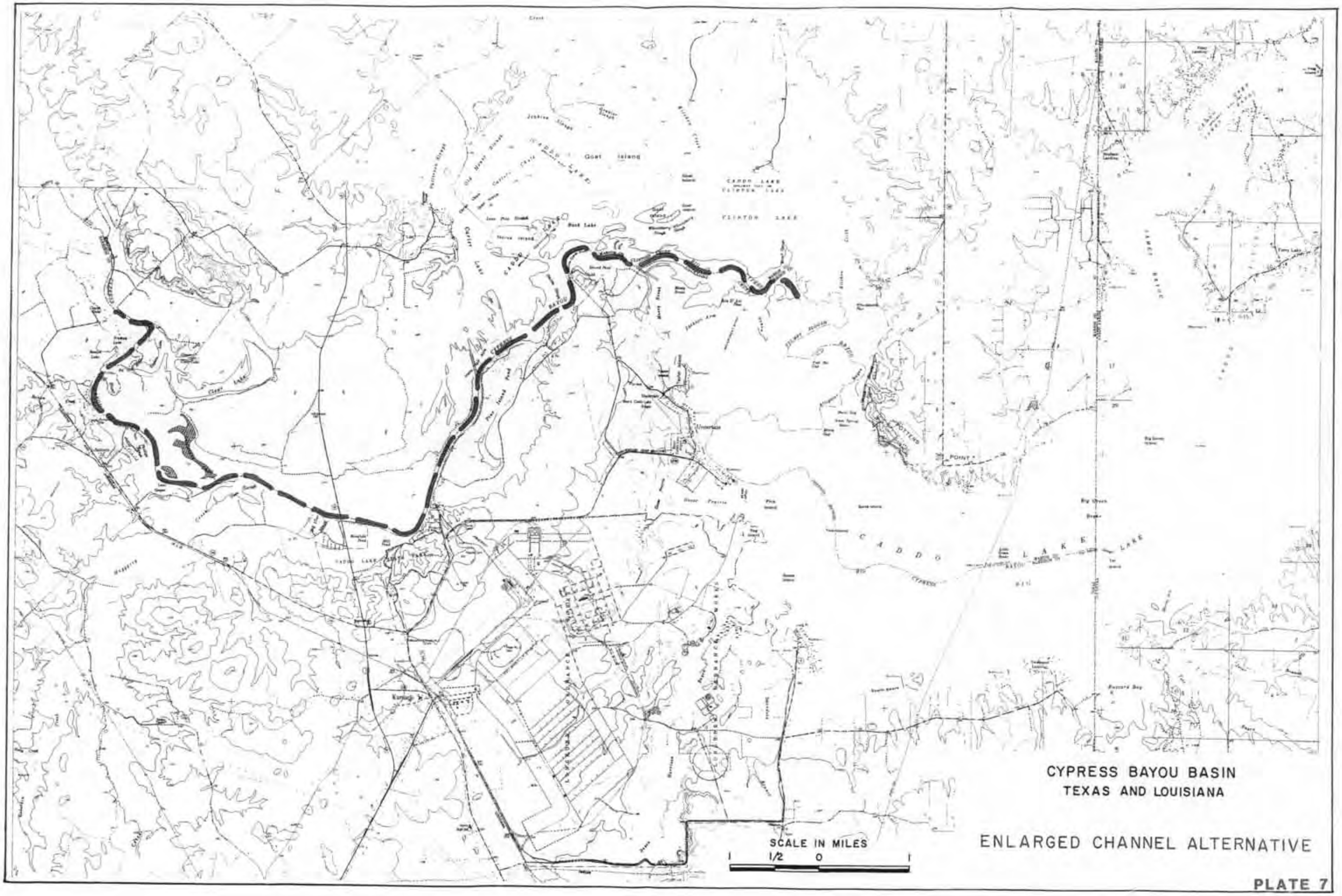
PLATE 4



CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

LOCATION OF
MAJOR DAMAGE REACHES

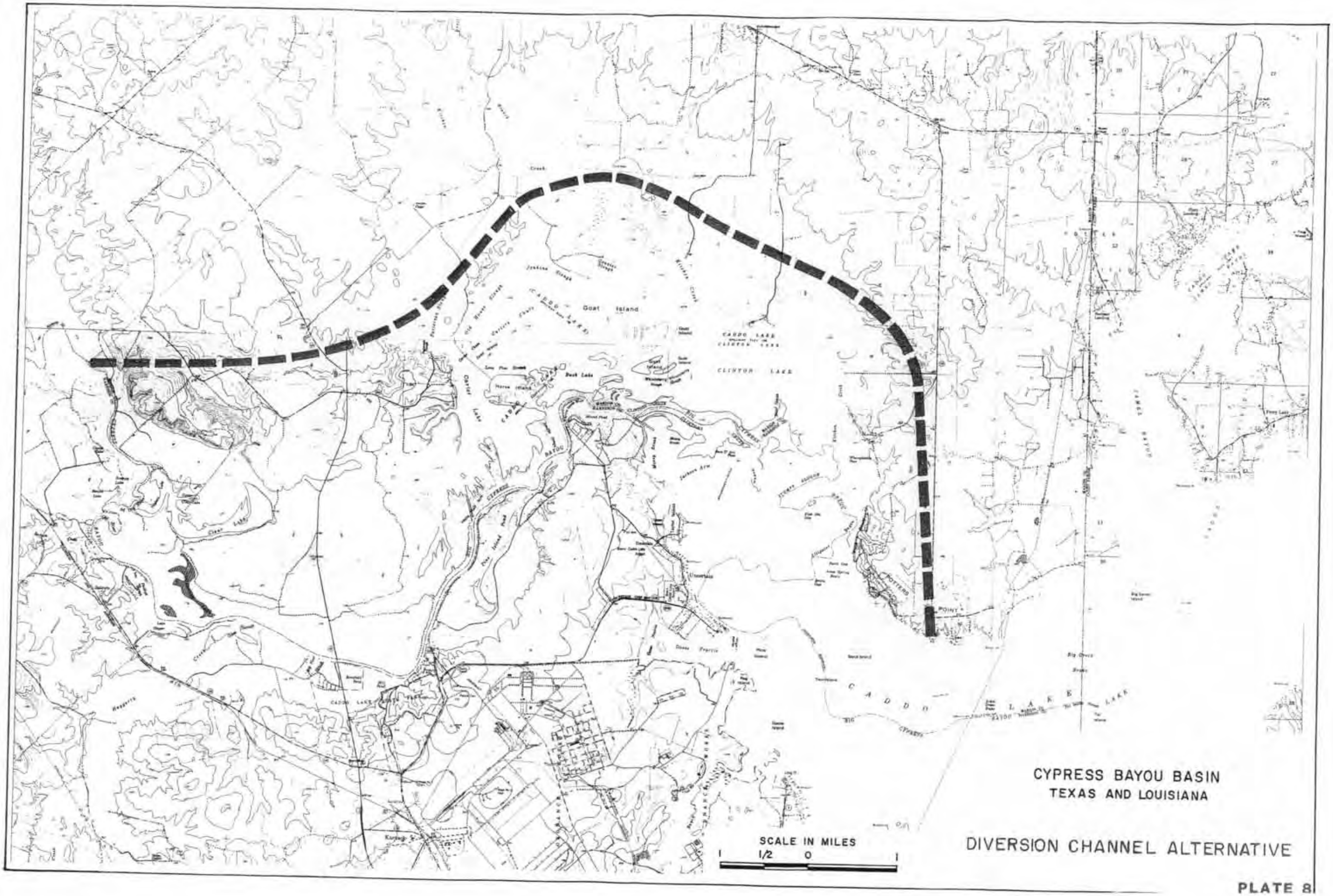
PLATE 6



CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

ENLARGED CHANNEL ALTERNATIVE

PLATE 7



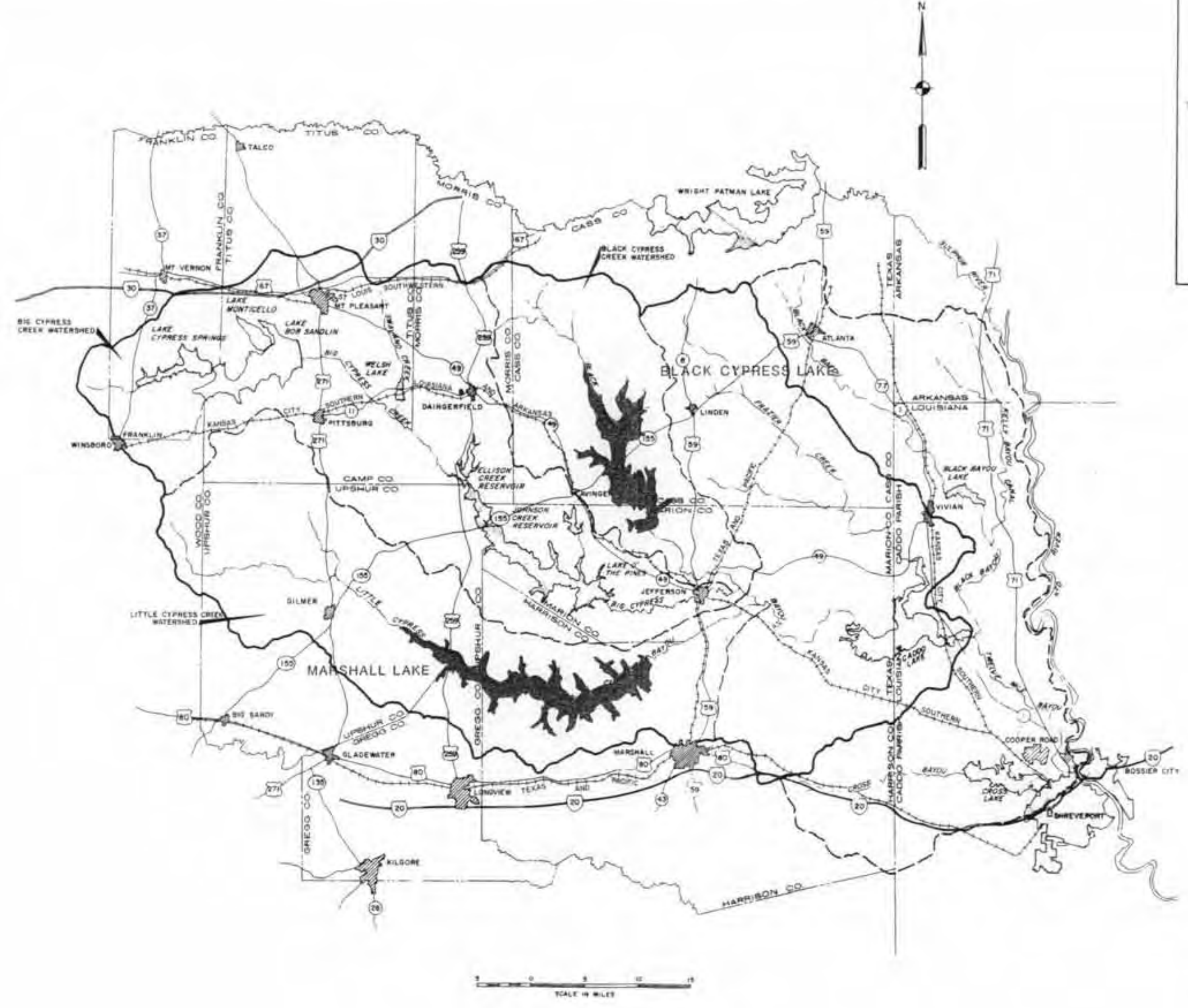
CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

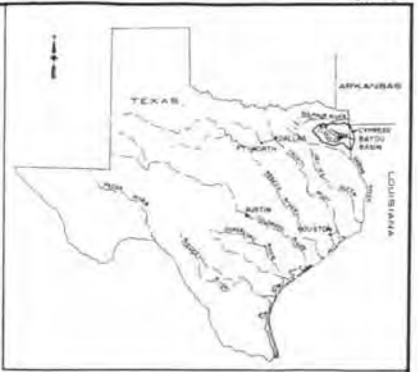
DIVERSION CHANNEL ALTERNATIVE

PLATE 8

CORPS OF ENGINEERS

U.S. ARMY





VICINITY MAP
NOT TO SCALE

LEGEND

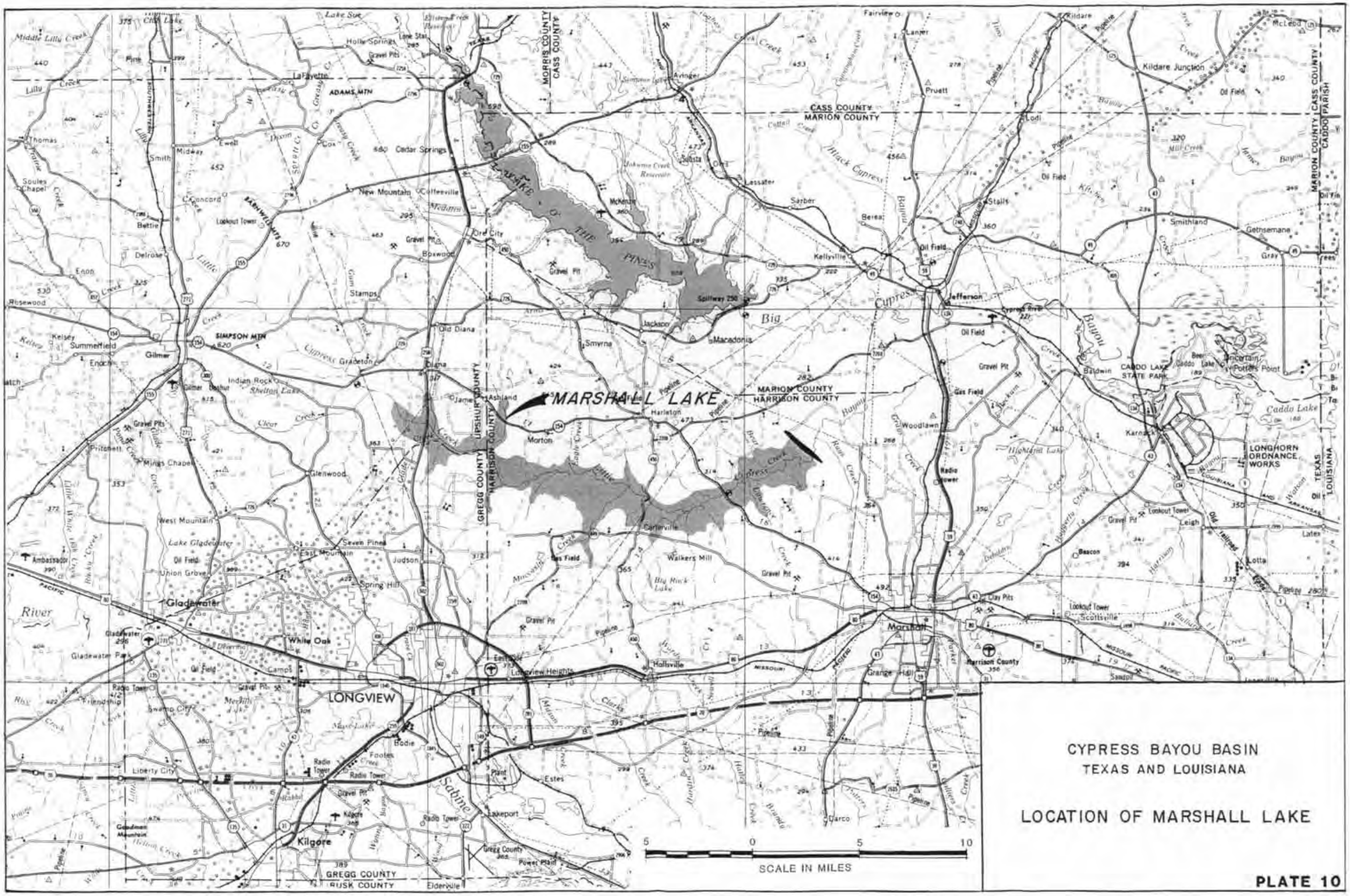
EXISTING RESERVOIR
RIVER
INTERSTATE HIGHWAY
U.S. HIGHWAY
STATE HIGHWAY
RAILROAD
PROPOSED LAKE

CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

LOCATION OF MARSHALL
AND
BLACK CYPRESS LAKES

U.S. ARMY ENGINEER DISTRICT, FORT WORTH JULY 1981

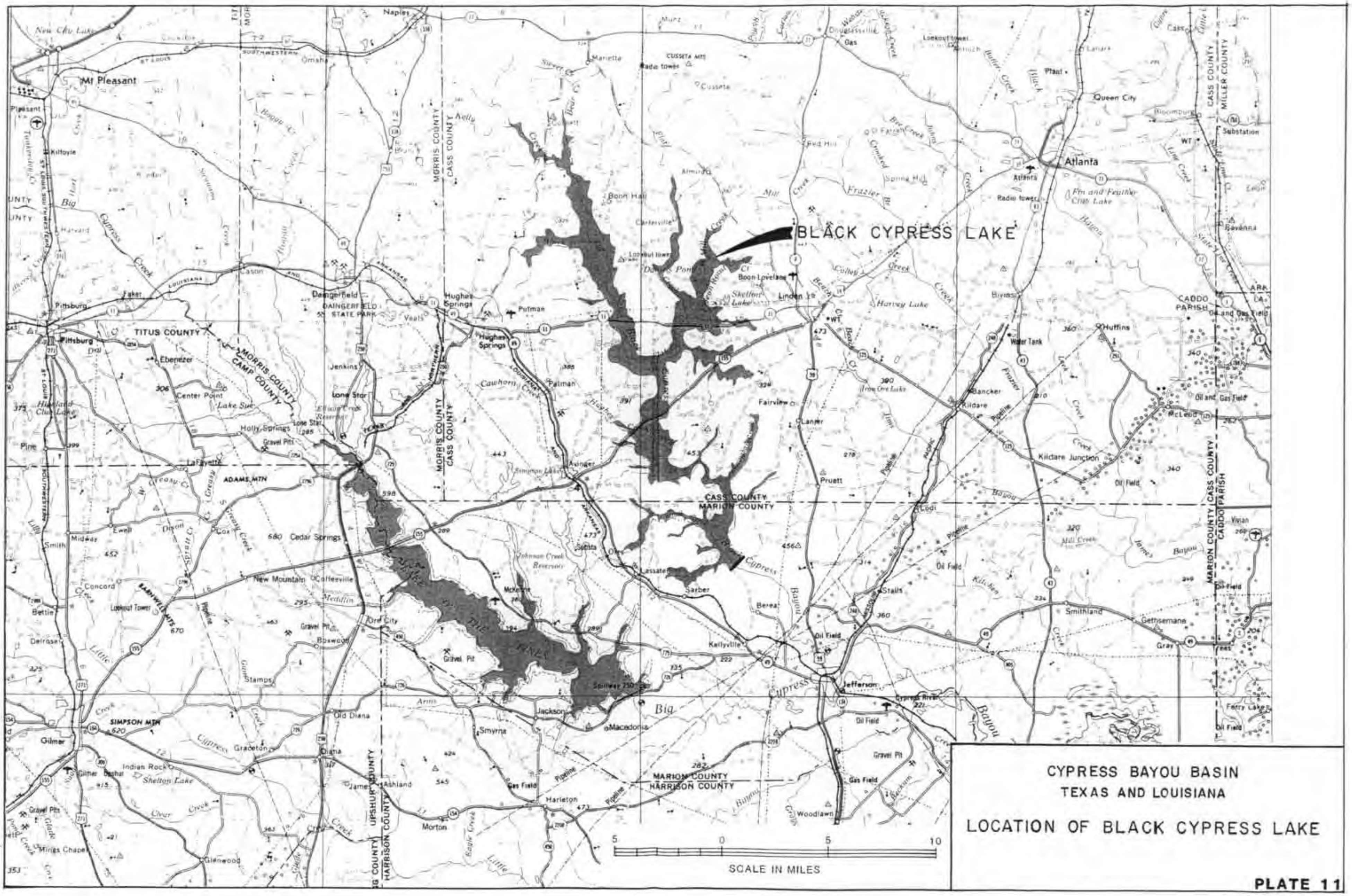
FILE NO. PLATE 9



CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

LOCATION OF MARSHALL LAKE

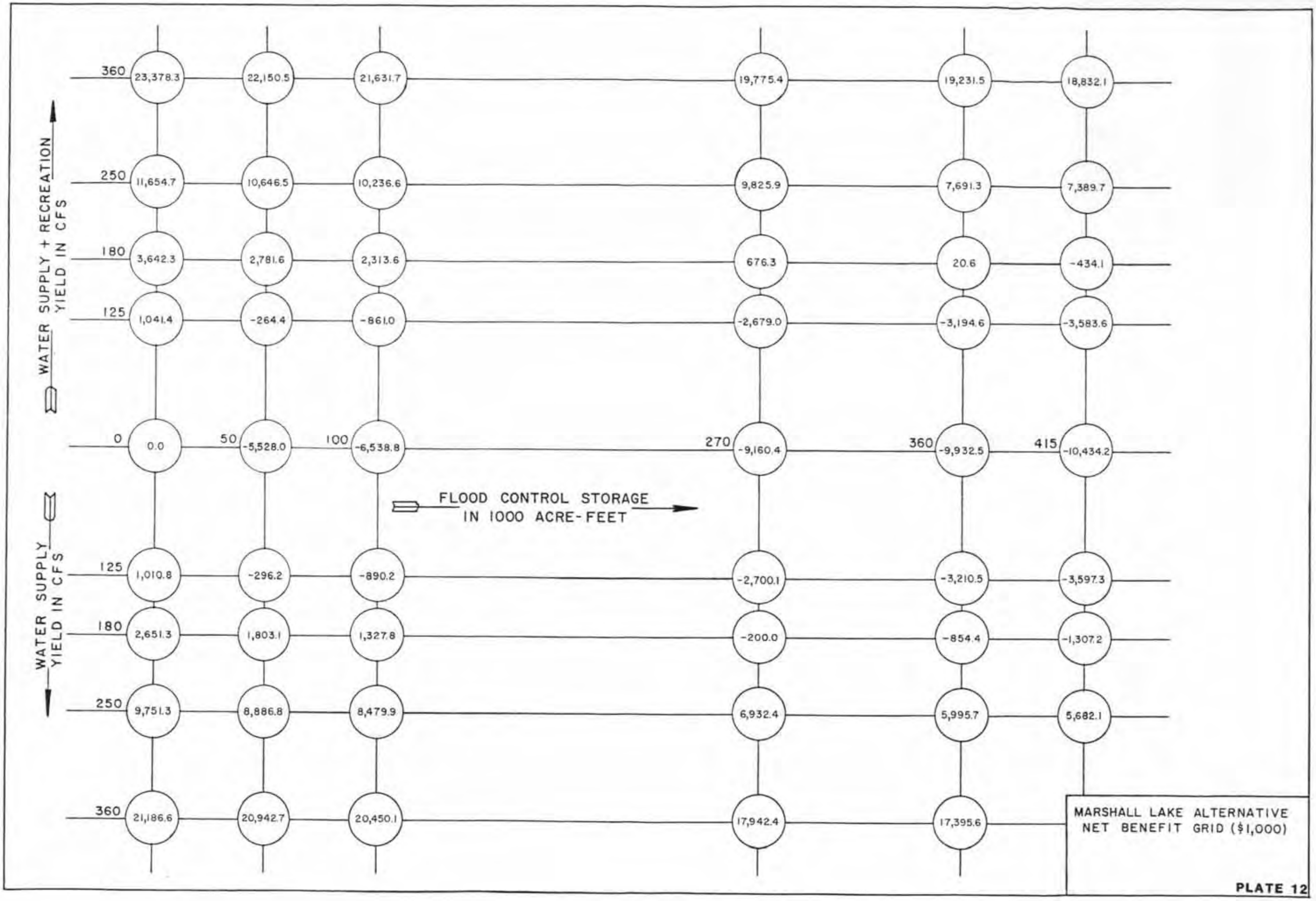
PLATE 10



CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

LOCATION OF BLACK CYPRESS LAKE

PLATE 11



WATER SUPPLY + RECREATION YIELD IN CFS

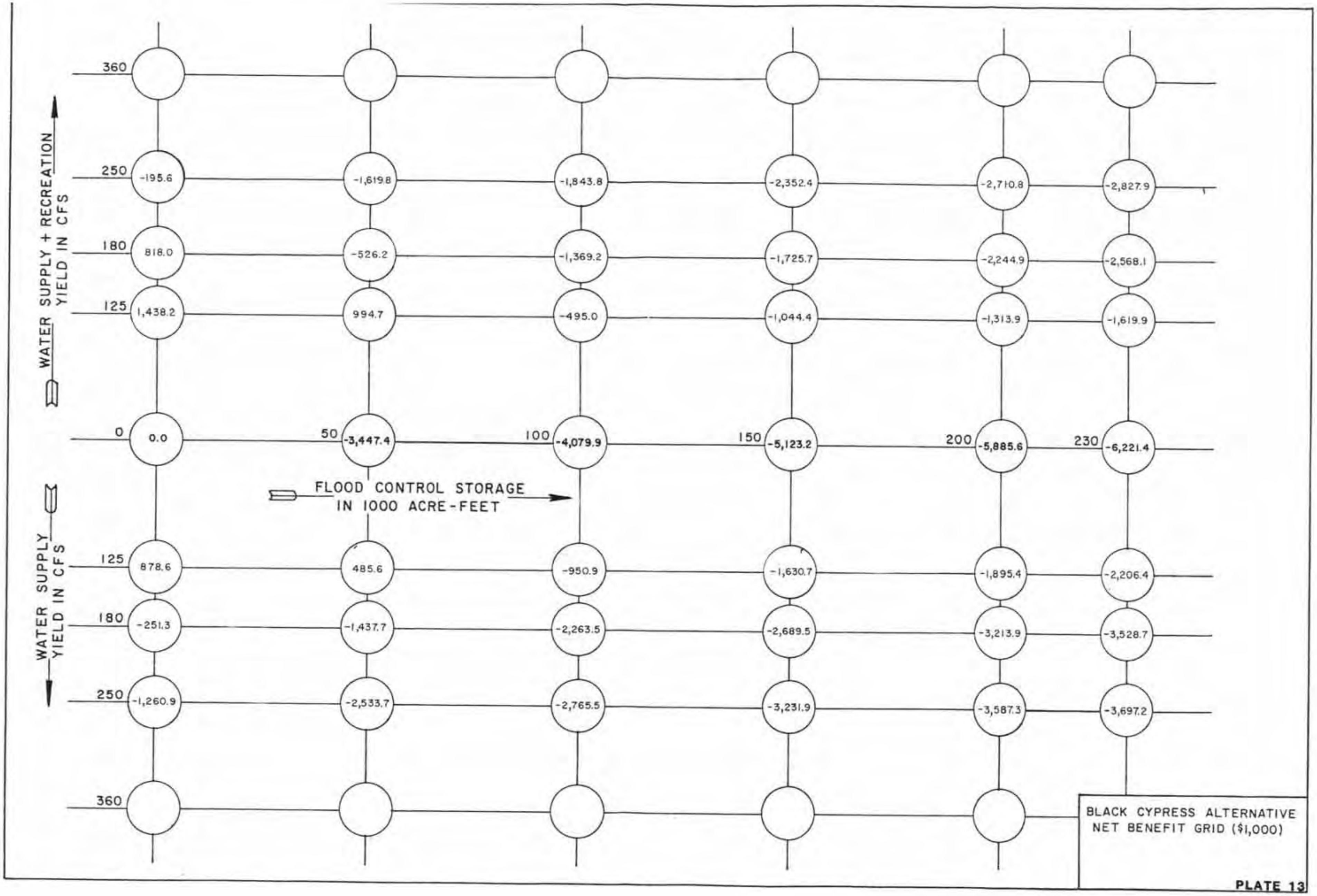
WATER SUPPLY YIELD IN CFS

FLOOD CONTROL STORAGE IN 1000 ACRE-FEET

		0	50	100	270	360	415
WATER SUPPLY + RECREATION YIELD IN CFS	360	23,378.3	22,150.5	21,631.7	19,775.4	19,231.5	18,832.1
	250	11,654.7	10,646.5	10,236.6	9,825.9	7,691.3	7,389.7
	180	3,642.3	2,781.6	2,313.6	676.3	20.6	-434.1
	125	1,041.4	-264.4	-861.0	-2,679.0	-3,194.6	-3,583.6
	0	0.0	-5,528.0	-6,538.8	-9,160.4	-9,932.5	-10,434.2
WATER SUPPLY YIELD IN CFS	125	1,010.8	-296.2	-890.2	-2,700.1	-3,210.5	-3,597.3
	180	2,651.3	1,803.1	1,327.8	-200.0	-854.4	-1,307.2
	250	9,751.3	8,886.8	8,479.9	6,932.4	5,995.7	5,682.1
	360	21,186.6	20,942.7	20,450.1	17,942.4	17,395.6	

MARSHALL LAKE ALTERNATIVE
NET BENEFIT GRID ($1,000)

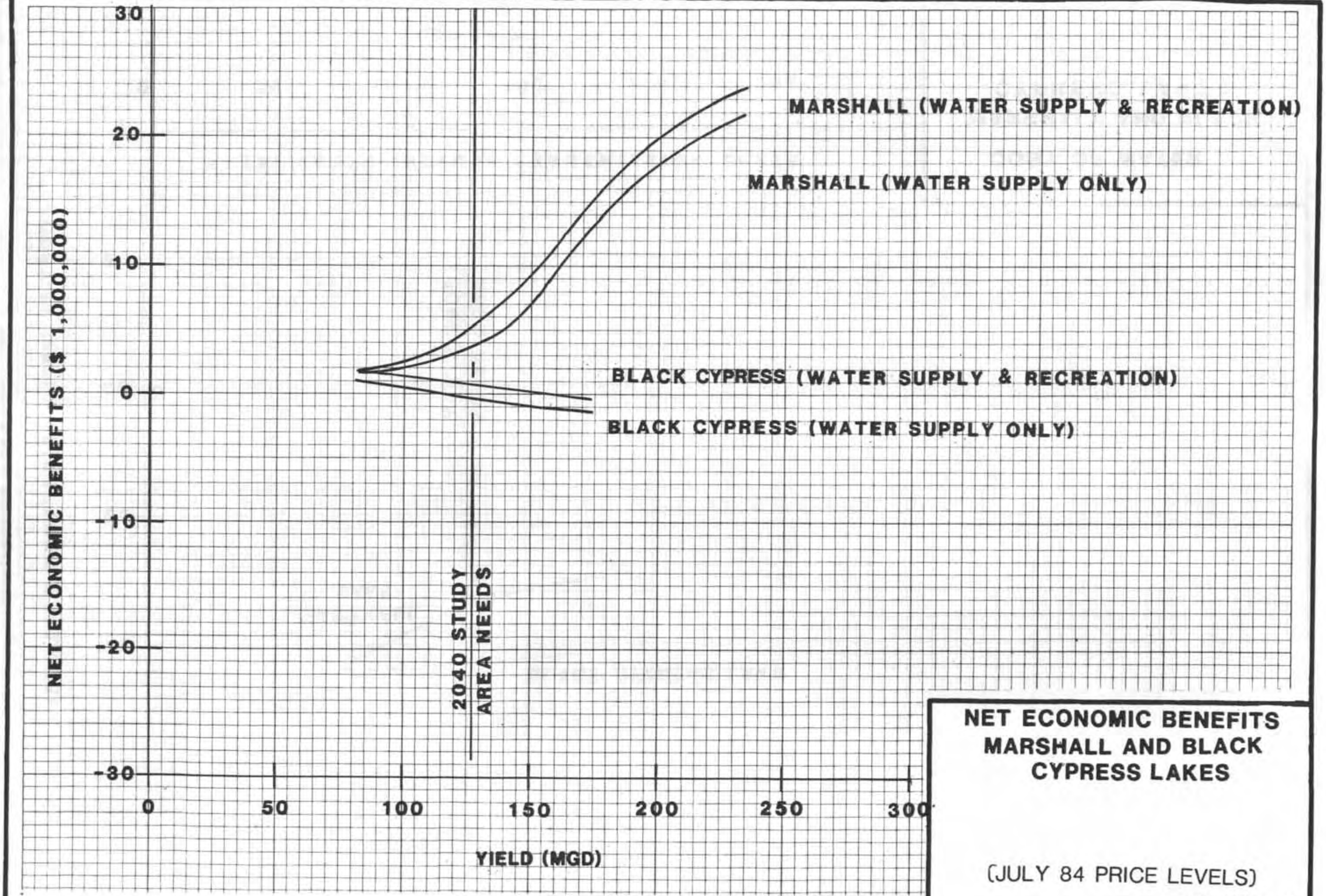
PLATE 12



	0	50	100	150	200	230
360						
250	-195.6	-1,619.8	-1,843.8	-2,352.4	-2,710.8	-2,827.9
180	818.0	-526.2	-1,369.2	-1,725.7	-2,244.9	-2,568.1
125	1,438.2	994.7	-495.0	-1,044.4	-1,313.9	-1,619.9
0	0.0	-3,447.4	-4,079.9	-5,123.2	-5,885.6	-6,221.4
125	878.6	485.6	-950.9	-1,630.7	-1,895.4	-2,206.4
180	-251.3	-1,437.7	-2,263.5	-2,689.5	-3,213.9	-3,528.7
250	-1,260.9	-2,533.7	-2,765.5	-3,231.9	-3,587.3	-3,697.2
360						

BLACK CYPRESS ALTERNATIVE
NET BENEFIT GRID ($1,000)

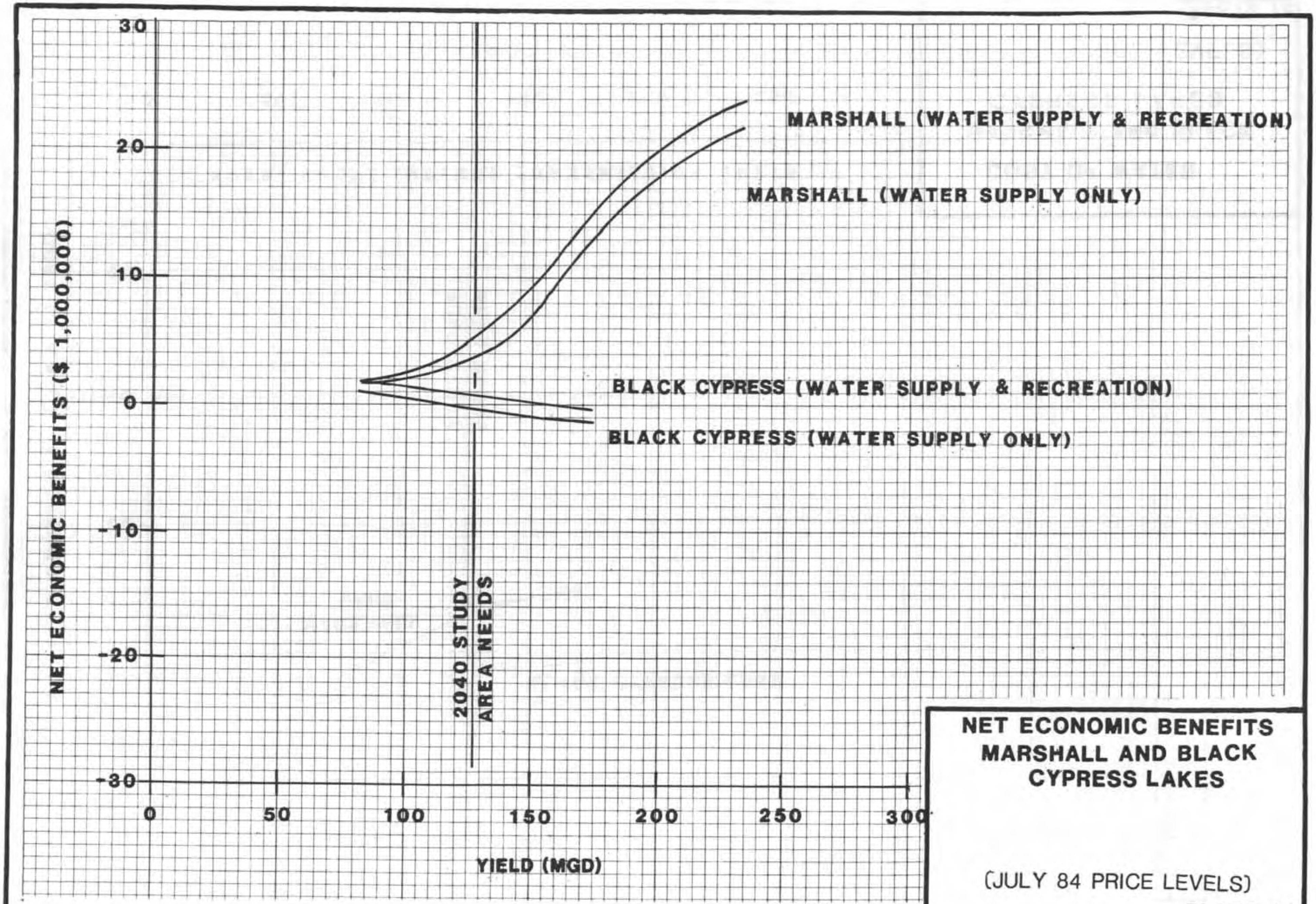
PLATE 13



NET ECONOMIC BENEFITS MARSHALL AND BLACK CYPRESS LAKES

(JULY 84 PRICE LEVELS)

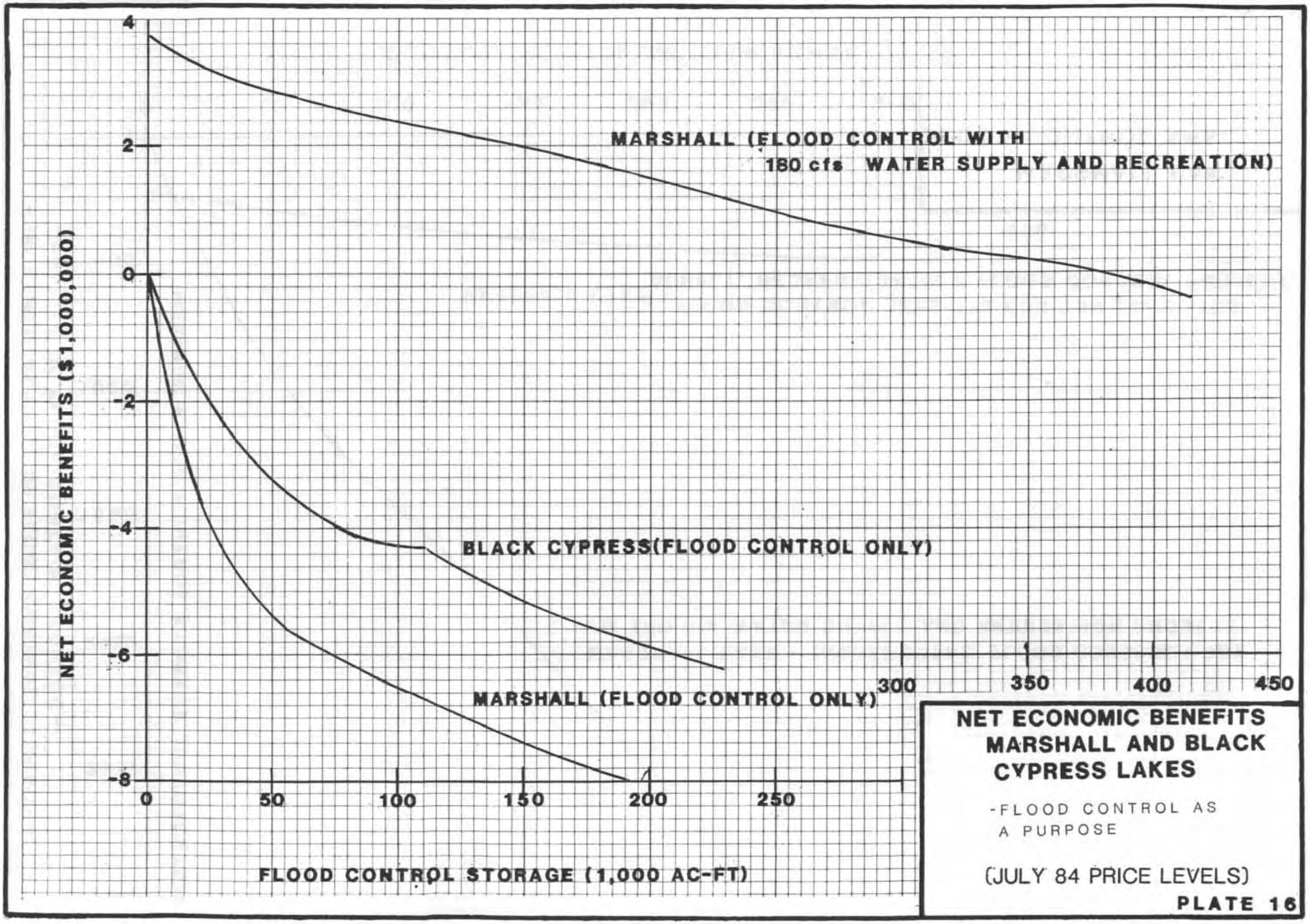
PLATE 14



NET ECONOMIC BENEFITS
MARSHALL AND BLACK
CYPRESS LAKES

(JULY 84 PRICE LEVELS)

PLATE 14

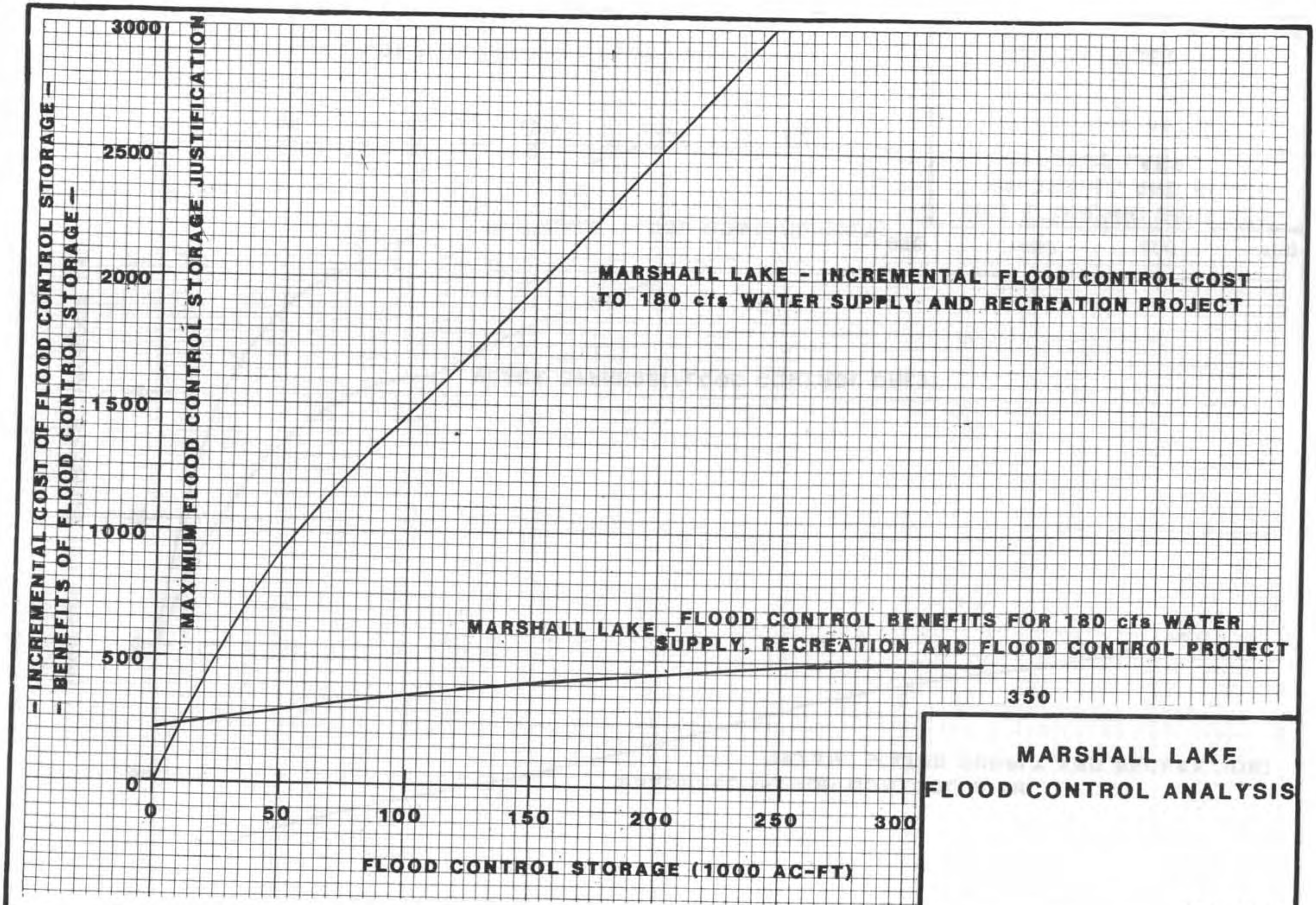


NET ECONOMIC BENEFITS MARSHALL AND BLACK CYPRESS LAKES

-FLOOD CONTROL AS A PURPOSE

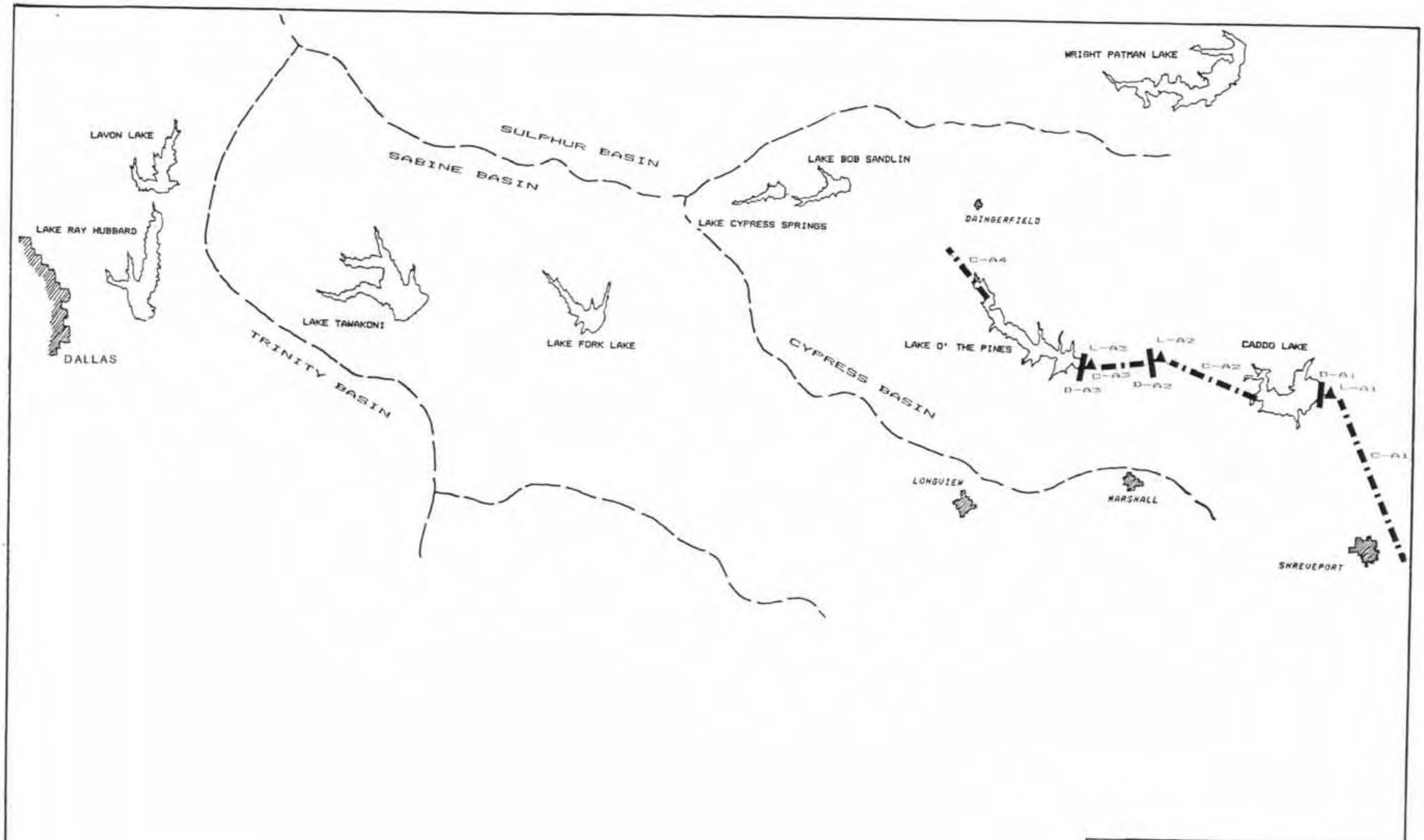
(JULY 84 PRICE LEVELS)

PLATE 16



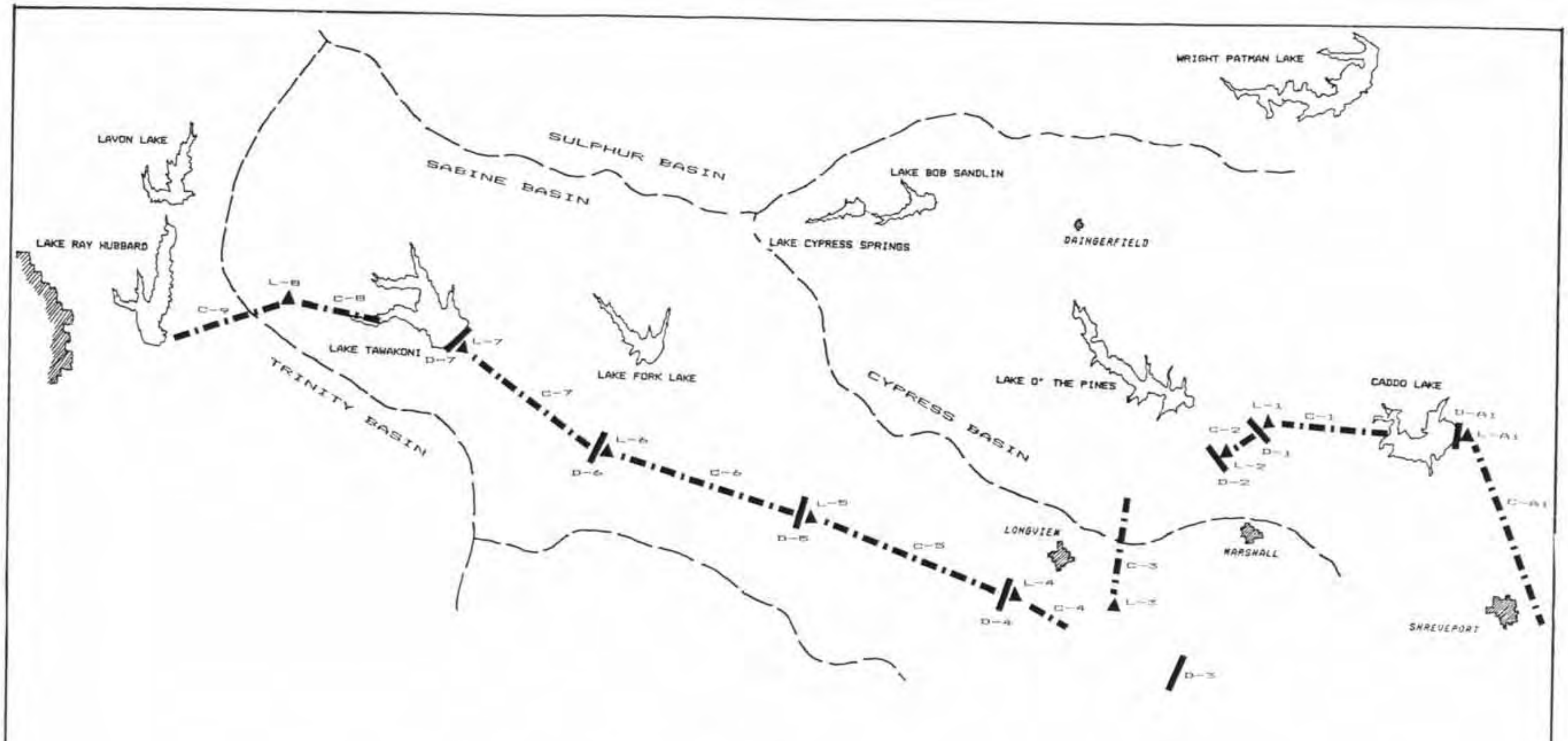
MARSHALL LAKE
FLOOD CONTROL ANALYSIS

PLATE 17



AUTHORIZED NAVIGATION
CHANNEL ALIGNMENT

PLATE 18



PLAN B - FIRST COSTS

ITEM		LENGTH (MI)	COSTS
CHANNELS	C-A1	13.8	77,280,000
	C-1	14.5	81,260,000
	C-2	16.0	61,746,000
	C-3	15.6	535,470,000
	C-4	20.0	112,388,000
	C-5	20.0	99,970,000
	C-6	21.0	94,088,000
	C-7	18.0	23,203,000
	C-8	25.0	236,953,000
	C-9	14.0	706,444,000
**TOTAL		177.9	2,028,802,000

ITEM		LIFT (FT)	COSTS
LOCKS	L-A1	18.5	49,794,000
	L-1	28.0	57,744,000
	L-2	62.0	107,220,000
	L-3	13.0	25,943,000
	L-4	35.0	63,937,000
	L-5	40.0	71,971,000
	L-6	59.0	99,588,000
	L-7	58.0	97,459,000
	L-8	1.0	17,575,000
		314.5	591,231,000

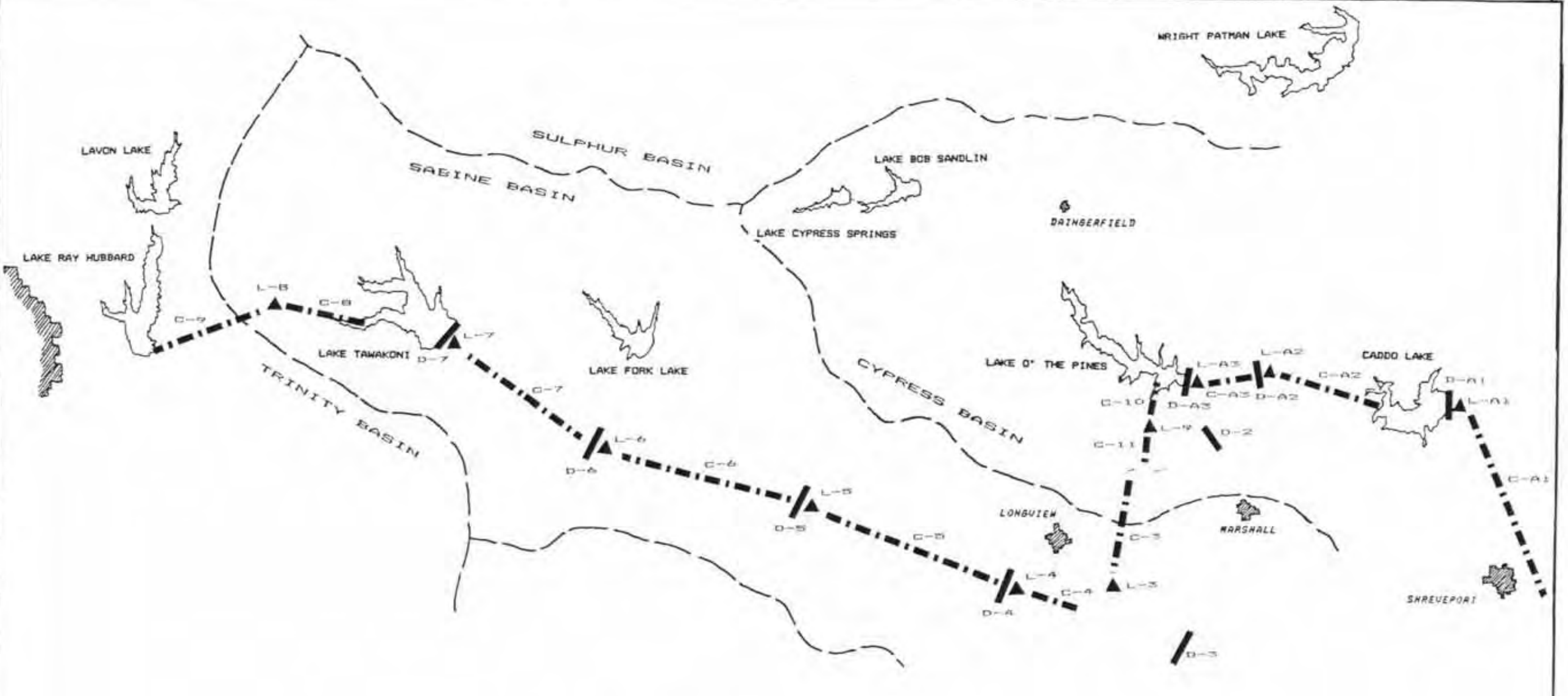
ITEM		COSTS
DAMS	D-A1	15,750,000
	D-1	117,000,000
	D-2	279,000,000
	D-3	346,448,000
	D-4	157,500,000
	D-5	180,000,000
	D-6	287,550,000
	D-7	26,780,000
		1,410,028,000
PLAN TOTAL		4,030,061,000

AUTHORIZED NAVIGATION CHANNEL

WITH EXTENSION
TO DALLAS-FORT WORTH

PLAN B

PLATE 19



PLAN C - FIRST COSTS

ITEM		LENGTH (MI)	COSTS
CHANNELS	C-A1	13.8	77,280,000
	C-A2	34.4	192,640,000
	C-A3	9.0	50,400,000
	C-10	2.3	23,905,000
	C-11	2.5	34,423,000
	C-3	15.6	535,470,000
	C-4	20.0	112,388,000
	C-5	20.0	99,970,000
	C-6	21.0	94,088,000
	C-7	18.0	23,203,000
	C-8	25.0	236,953,000
	C-9	14.0	706,444,000
**TOTAL		195.6	2,187,164,000

ITEM		LIFT (FT)	COSTS
LOCKS	L-A1	18.5	49,794,000
	L-A2	16.5	48,120,000
	L-A3	43.5	73,227,000
	L-9	30.0	59,837,000
	L-3	13.0	25,943,000
	L-4	35.0	63,937,000
	L-5	40.0	71,971,000
	L-6	59.0	99,588,000
	L-7	58.0	97,459,000
	L-8	1.0	17,575,000
		314.5	607,451,000

ITEM		COSTS
DAMS	D-A1	15,750,000
	D-A2	74,250,000
	D-A3	22,500,000
	D-2	279,000,000
	D-3	346,488,000
	D-4	157,500,000
	D-5	180,000,000
	D-6	287,550,000
	D-7	26,780,000
		1,389,818,000
PLAN TOTAL		4,184,433,000

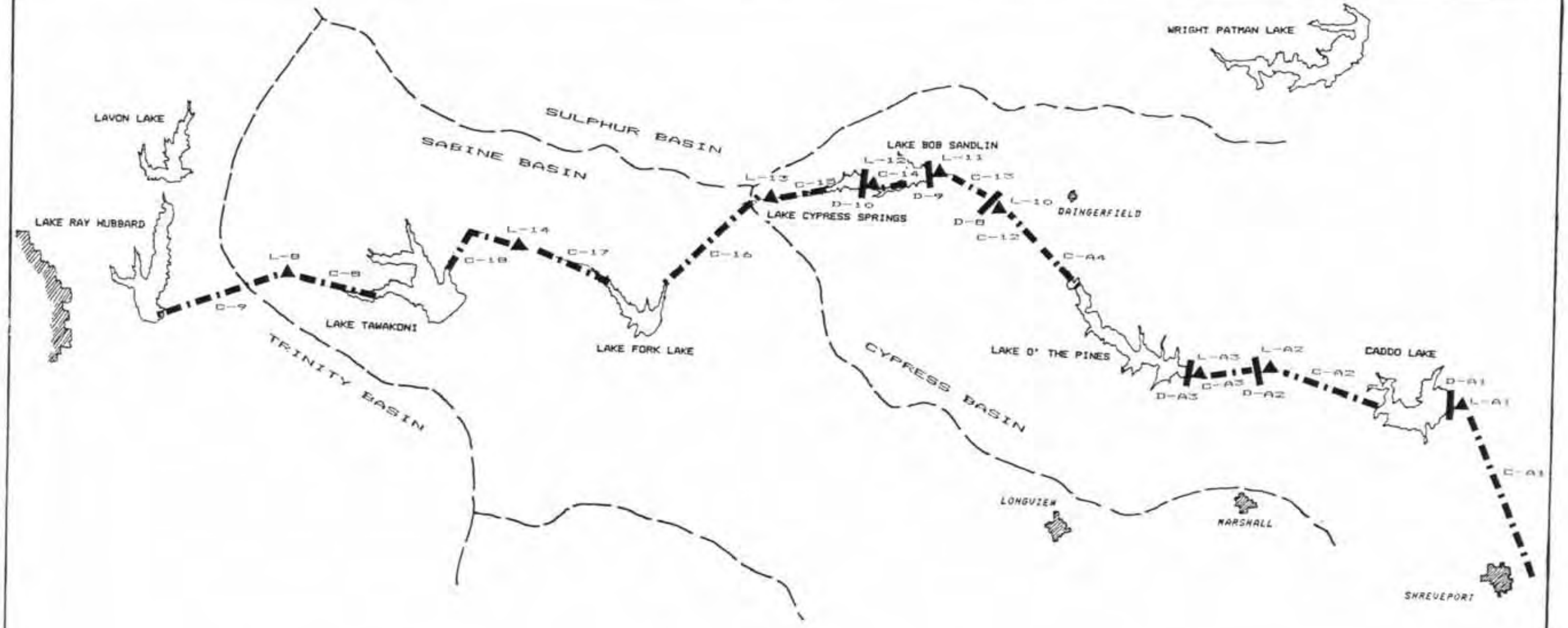
AUTHORIZED NAVIGATION CHANNEL

WITH EXTENSION

TO DALLAS-FORT WORTH

PLAN C

PLATE 20



PLAN D - FIRST COSTS

ITEM		LENGTH (MI)	COSTS
CHANNELS	C-A1	13.8	77,280,000
	C-A2	34.4	192,640,000
	C-A3	9.0	50,400,000
	C-A4	17.8	99,680,000
	C-12	9.0	63,516,000
	C-13	11.3	21,685,000
	C-14	10.1	22,506,000
	C-15	9.4	84,719,000
	C-16	21.0	849,345,000
	C-17	8.0	122,080,000
	C-18	14.0	479,100,000
	C-8	25.0	236,953,000
	C-9	14.0	706,444,000
**TOTAL		196.8	3,006,348,000

ITEM		LIFT (FT)	COSTS
LOCKS	L-A1	18.5	49,794,000
	L-A2	16.5	48,120,000
	L-A3	43.5	73,227,000
	L-10	51.5	88,290,000
	L-11	58.0	94,985,000
	L-12	40.0	73,227,000
	L-13	25.0	56,652,000
	L-14	34.5	64,272,000
	L-8	1.0	17,575,000
		288.5	566,142,000

ITEM		COSTS
DAMS	D-A1	15,750,000
	D-A2	74,250,000
	D-A3	22,500,000
	D-8	180,000,000
	D-9	24,500,000
	D-10	22,000,000
		339,000,000

PLAN TOTAL 3,911,490,000

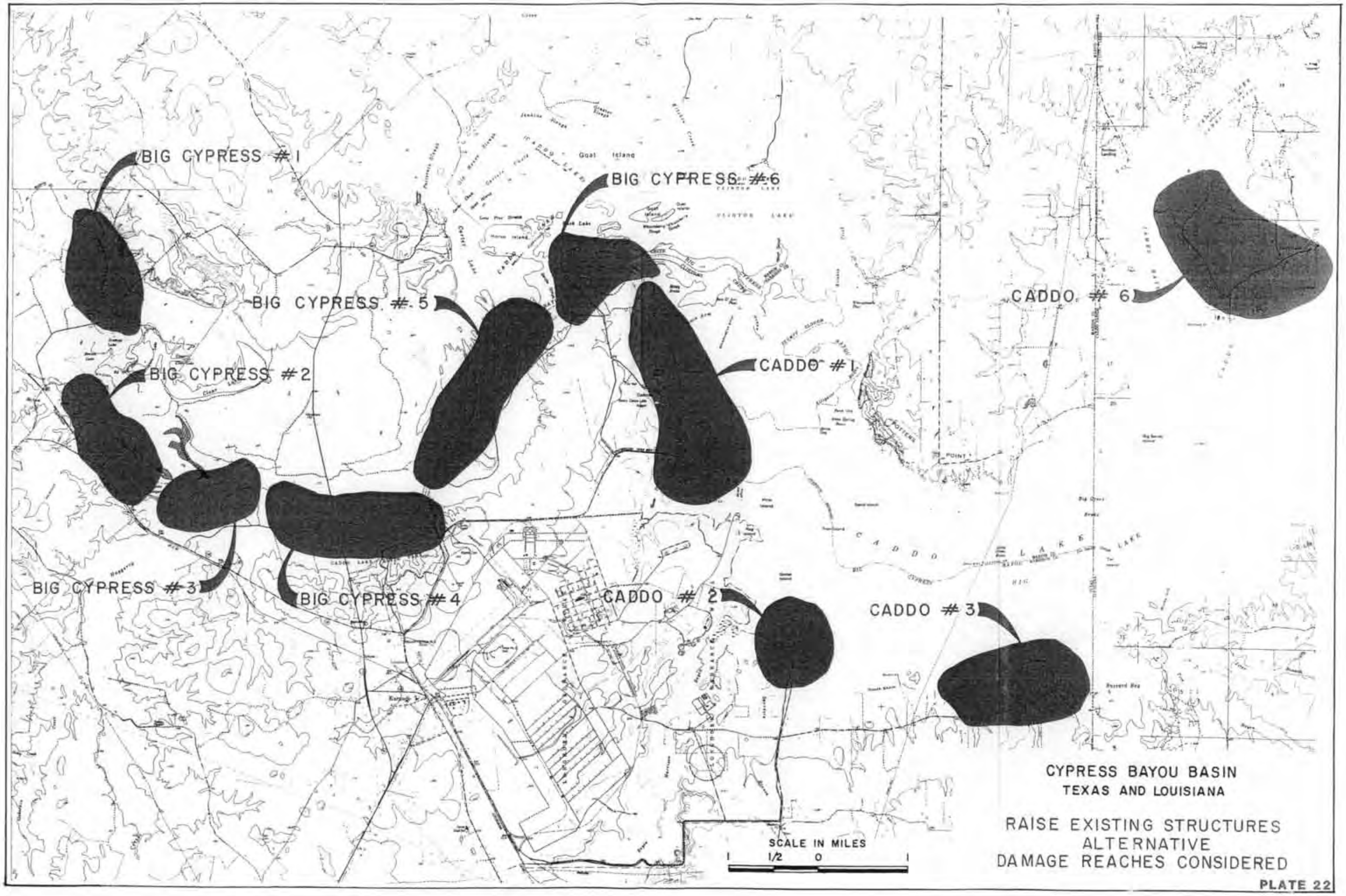
AUTHORIZED NAVIGATION CHANNEL

WITH EXTENSION

TO DALLAS-FORT WORTH

PLAN D

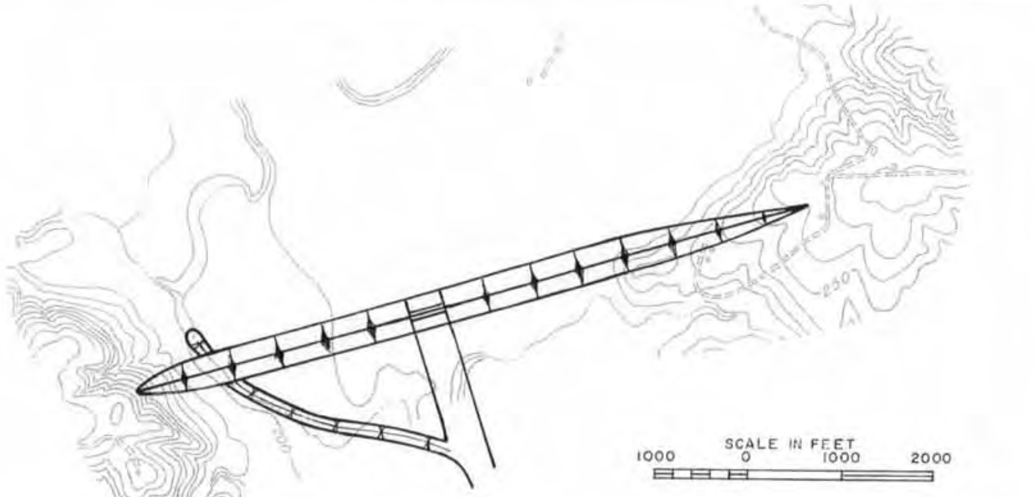
PLATE 21

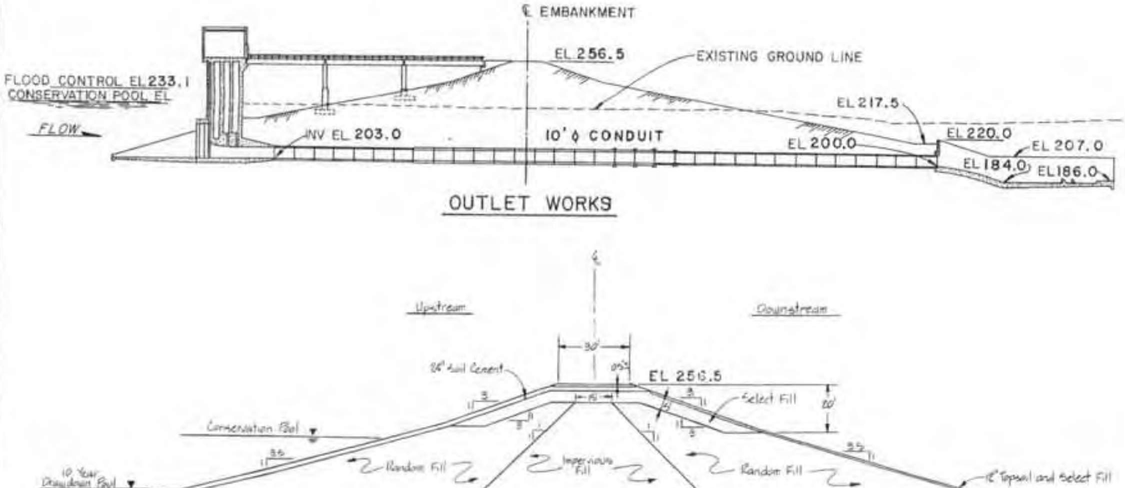


CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

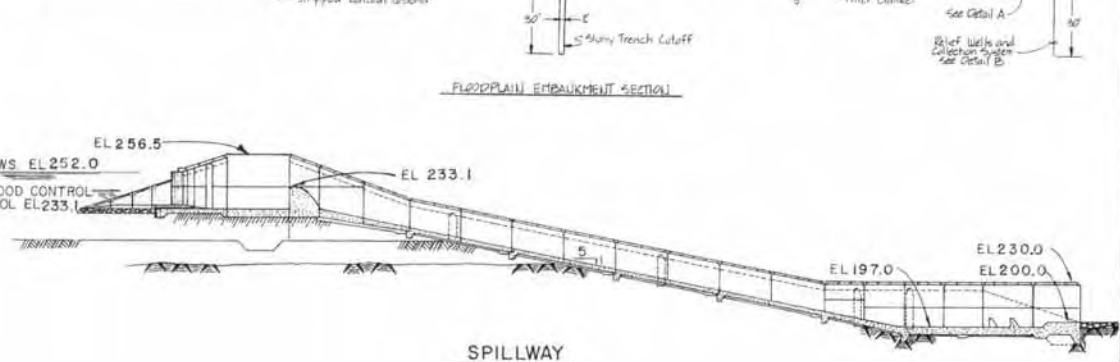
RAISE EXISTING STRUCTURES
ALTERNATIVE
DAMAGE REACHES CONSIDERED

PLATE 22

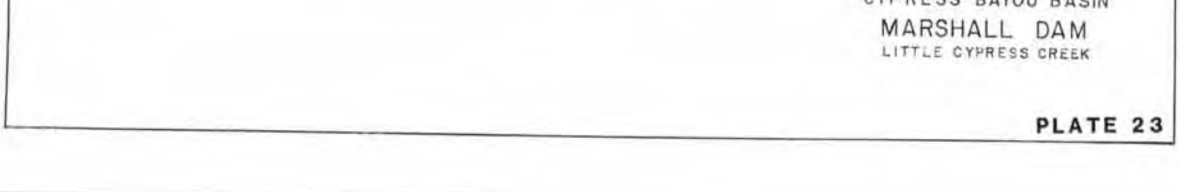




OUTLET WORKS



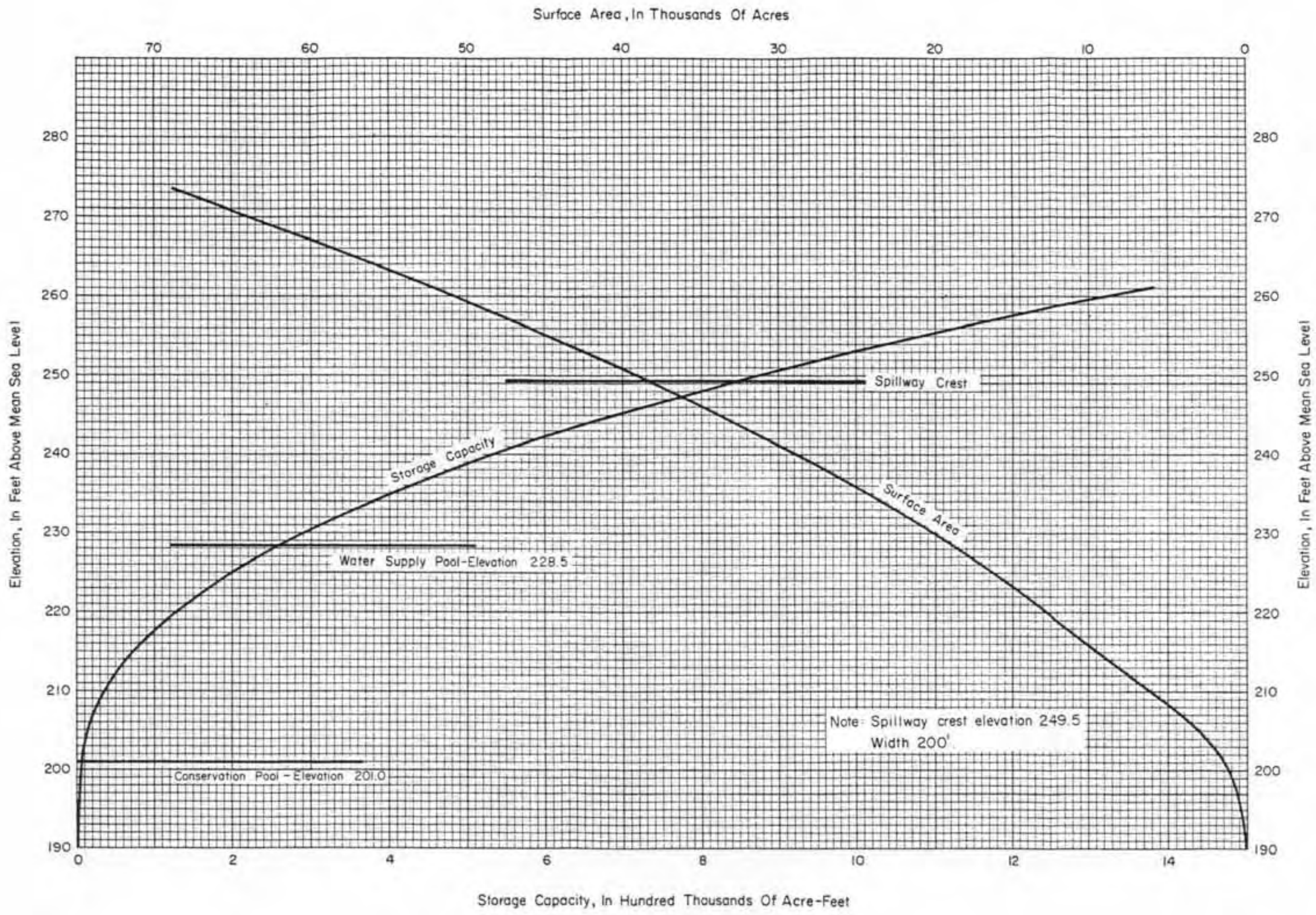
FLOODPLAIN EMBANKMENT SECTION



SPILLWAY

CYPRESS BAYOU BASIN
MARSHALL DAM
LITTLE CYPRESS CREEK

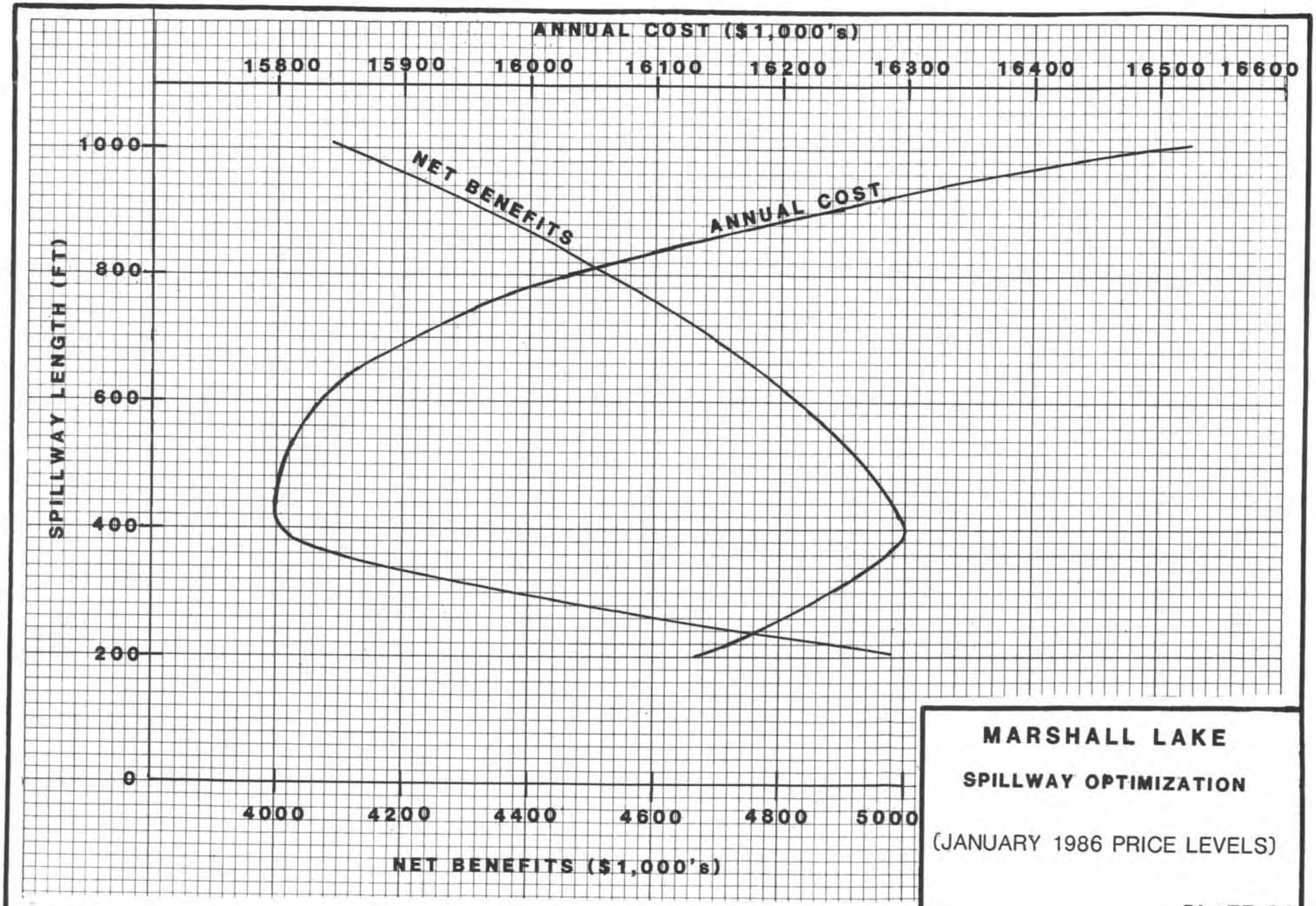
PLATE 23



AREA AND CAPACITY CURVES

LAKE O THE PINES

PLATE 25

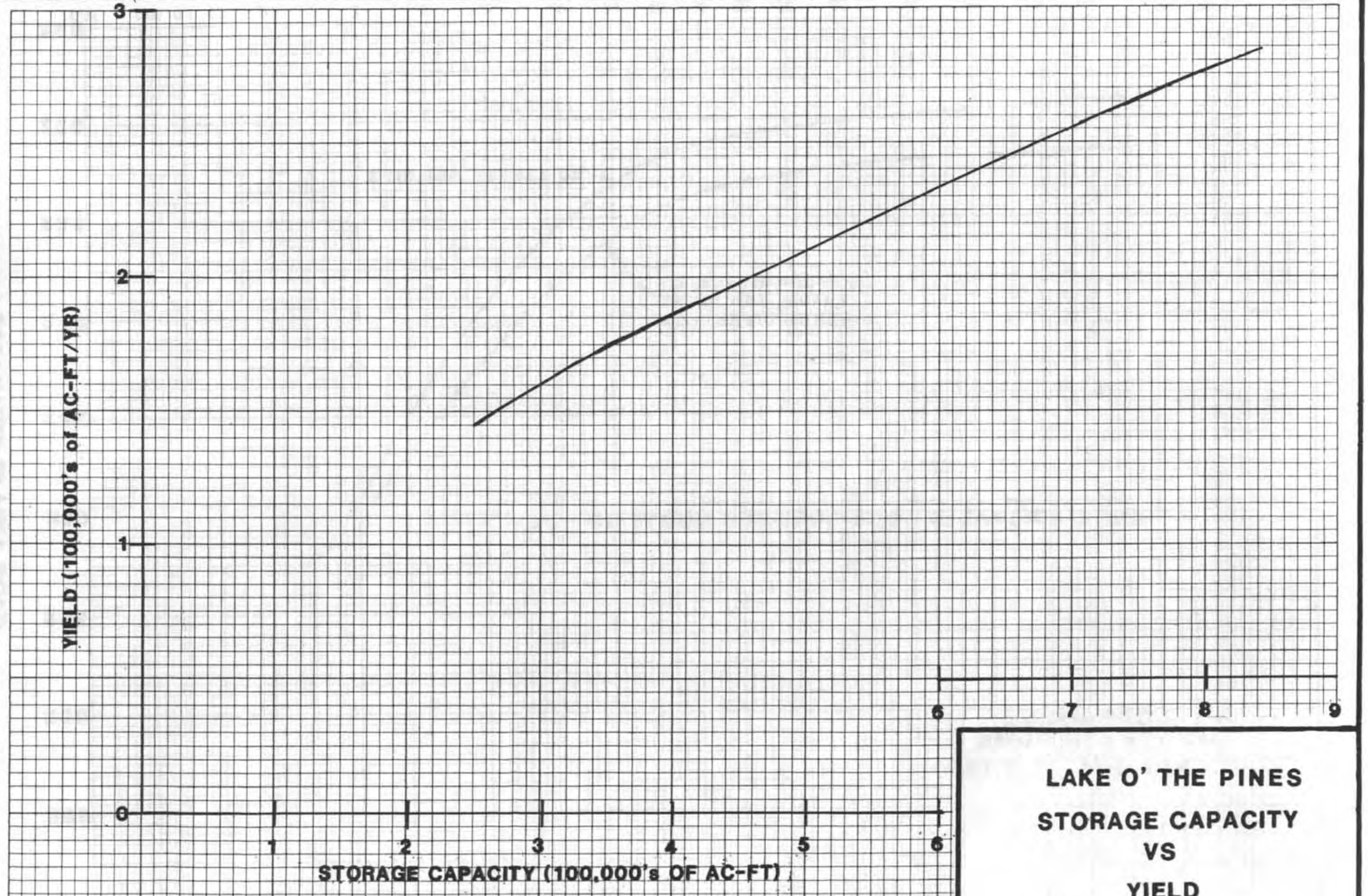


MARSHALL LAKE

SPILLWAY OPTIMIZATION

(JANUARY 1986 PRICE LEVELS)

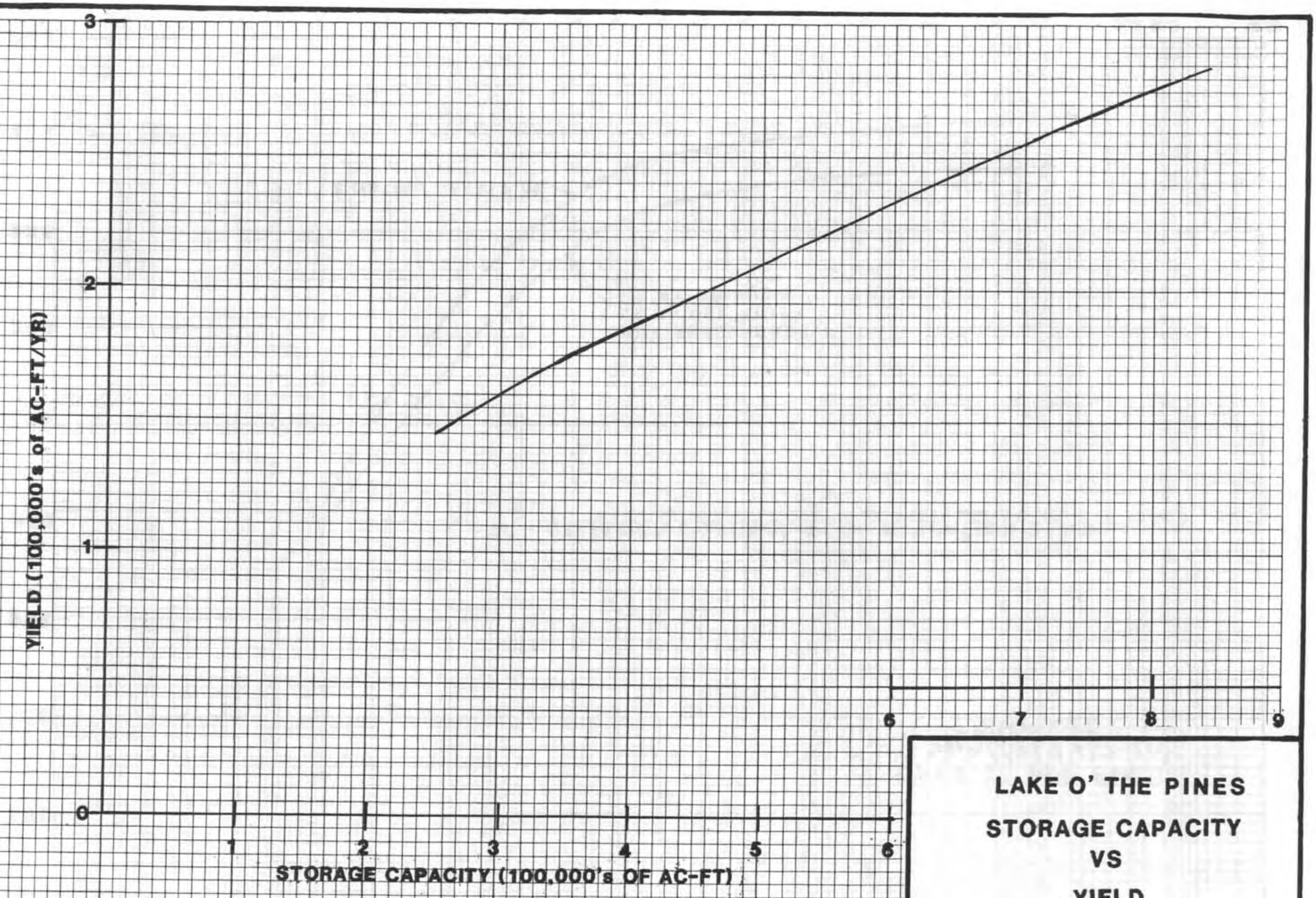
PLATE 24



SOURCE: FREESE AND NICHOLS 5-31-86

LAKE O' THE PINES
STORAGE CAPACITY
VS
YIELD

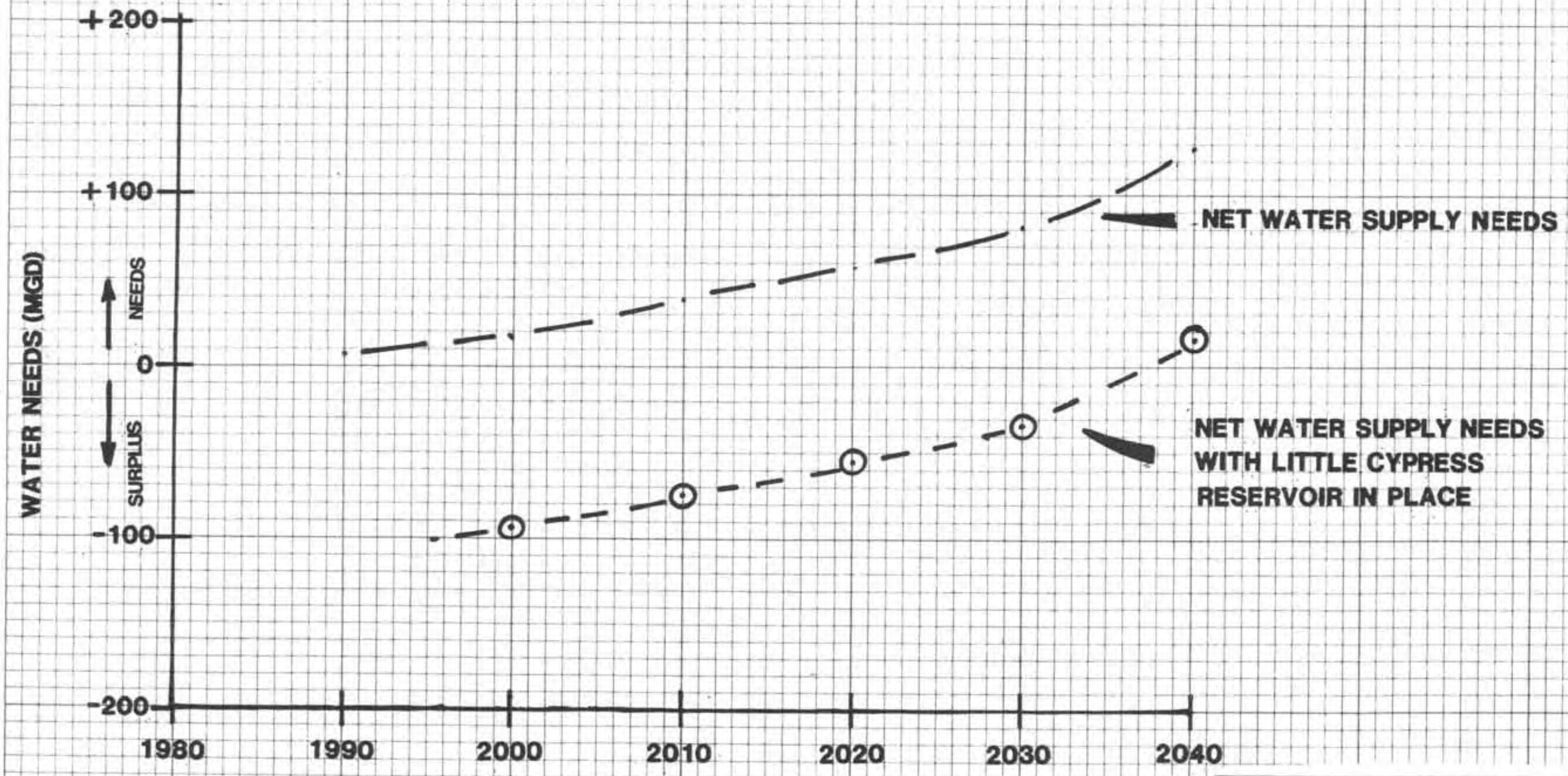
PLATE 26



SOURCE: FREESE AND NICHOLS 5-31-86

LAKE O' THE PINES
STORAGE CAPACITY
VS
YIELD

PLATE 26



CYPRESS BAYOU BASIN

NET WATER NEEDS

PLATE 28

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

ATTACHMENTS

DEPARTMENT OF THE ARMY
VICKSBURG DISTRICT, CORPS OF ENGINEERS
P. O. BOX 60
VICKSBURG, MISSISSIPPI 39180-0060

REPLY TO
ATTENTION OF:

January 21, 1986

NOTICE OF ISSUANCE OF SUMMARY REPORT
CADDO LAKE ENLARGEMENT STUDY
LOUISIANA AND TEXAS

A summary report which presents the results of studies performed to investigate the feasibility of the enlargement of Caddo Lake for additional municipal and industrial (M&I) water supply for the Caddo Lake area, including the Shreveport, Louisiana, metropolitan area, has been completed by the Vicksburg District.

The Caddo Lake Enlargement Study has been conducted under authority derived from two similar Congressional resolutions adopted by the Committees on Public Works of the United States Senate and the House of Representatives on 12 September 1959 and 24 February 1960, respectively. These resolutions authorized review of the report on Red River and Tributaries, Texas, Oklahoma, Arkansas, and Louisiana, downstream from Denison Dam, submitted in House Document No. 602, Seventy-ninth Congress, Second Session, and the report on Red River, Louisiana, Arkansas, Oklahoma, and Texas, submitted in House Document No. 320, Eightieth Congress, First Session, with a view to determining the desirability of developing a comprehensive, integrated plan of improvement by means of levees, bank stabilization, and channel improvement for navigation, flood control, and preservation of land in the main valley of the Red River.

Caddo Lake Dam is located in Caddo Parish, Louisiana, about 19 miles northwest of Shreveport, Louisiana, at the head of Twelvemile Bayou within the Cypress Bayou Basin. It forms the existing lake which has a surface area of approximately 26,800 acres and provides storage of 128,600 acre-feet at mean lake elevation of 168.5 feet, National Geodetic Vertical Datum. Although the dam of the lake is located in Caddo Parish, the lake surface involves portions of Caddo Parish and Marion and Harrison Counties, Texas. The major tributaries providing inflow to the lake are Black Cypress Bayou, Little Cypress Creek, and Big Cypress Creek. The lake is considered the only natural lake within Texas. The Corps of Engineers was assigned operation and maintenance responsibility for the non-Federal outlet works by the Water Resources Development Act of 1976 (Public Law 94-587, Section 174).

As a result of economic development within the Caddo Lake area, communities such as Shreveport, Louisiana, and Marshall, Texas, have expressed a need for additional future M&I water supplies. An assessment of current and estimated future M&I water use in the study area revealed that Shreveport, located in Caddo Parish, and Marshall, located in Harrison County, will require additional sources of M&I water supply to meet projected future demands.

ATTACHMENT 1

Alternatives considered in the formulation of plans included conservation measures and numerous structural options in addition to the enlargement of Caddo Lake. Screening of alternatives yielded three Caddo Lake alternatives, two Red River alternatives, and one alternative utilizing Toledo Bend Reservoir. The three Caddo Lake alternatives included: two 2-foot enlargement options; i.e., enlargement by permanent capping and enlargement with five hinged crest gates; and the third alternative consisted of construction of a storage reservoir which would be filled with water from Caddo Lake during periods of excess high flow. This third alternative would supply water only to Shreveport. The two Red River alternatives, which would also supply water to only Shreveport, included direct withdrawal from the Red River or Twelvemile Bayou and utilization of reverse osmosis treatment processes. One alternative included substantial storage (i.e., utilization of the same storage reservoir previously mentioned) while one did not. Toledo Bend Reservoir would supply water to both Shreveport and Marshall, and the primary features of this alternative would include water conveyance facilities.

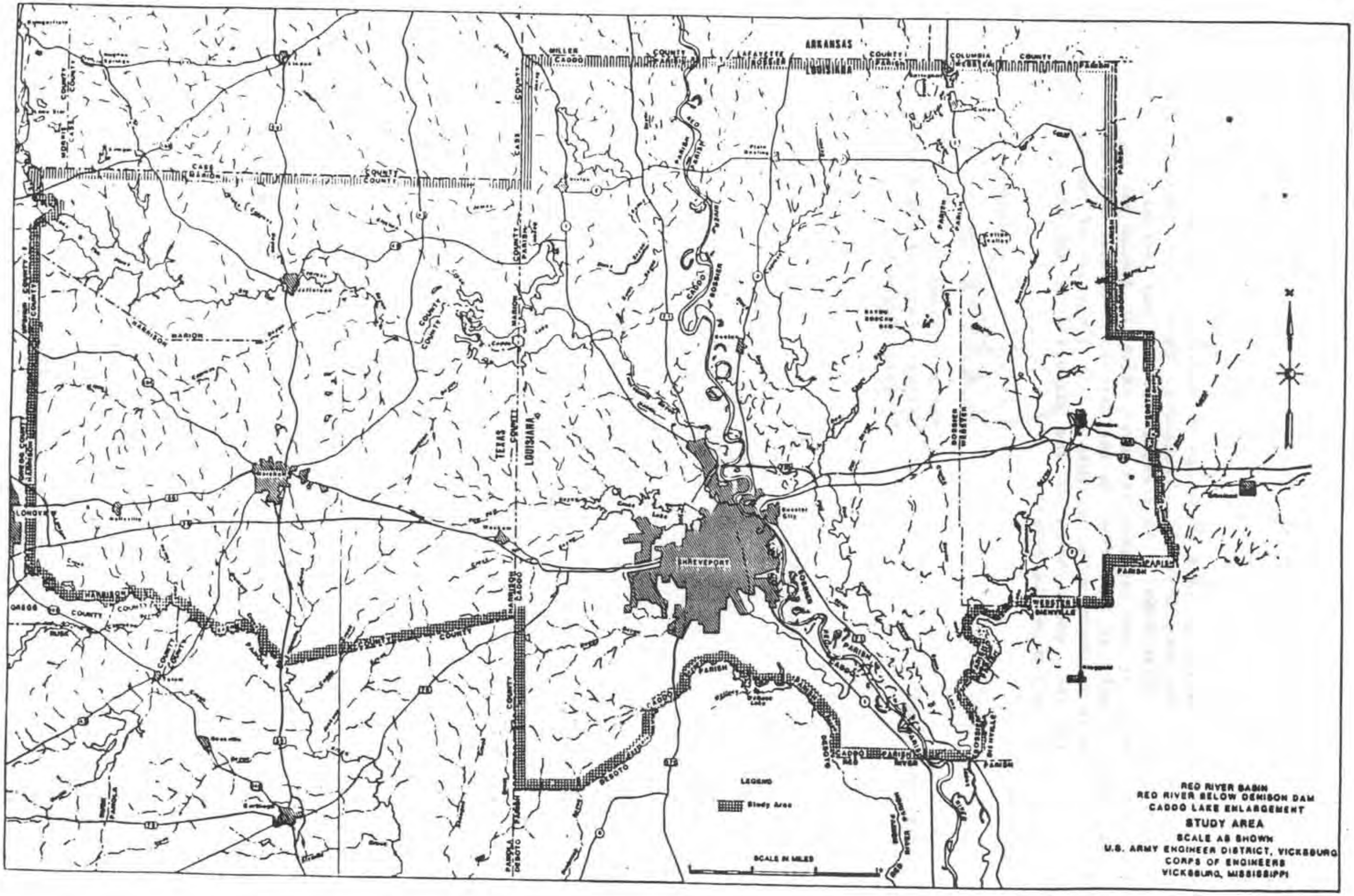
It has been determined that the plan that best satisfies the water supply objectives of the study in terms of providing the most economical source of needed water supply is the 2-foot raising of the water level in Caddo Lake. However, implementability is questionable because of long-standing opposition. The permanent weir or dam capping plan has an estimated first cost of $154,000,000. Based on an interest rate of 8-5/8 percent, a 50-year analysis period, and 1985 price levels, the average annual costs associated with this alternative are estimated to be approximately $15,990,000. Of the other alternatives investigated, the second least costly plan, and one which is considered more viable in terms of implementation, is the combination of providing Shreveport, Louisiana, water from the storage reservoir filled with Caddo Lake water when overflow is occurring at the Caddo Lake weir and providing Marshall, Texas, water from Toledo Bend Reservoir. This plan has an average annual cost of $20,707,000. Costs for all alternatives include necessary transmission facilities.

Although there is significant Federal interest in the long-range management of water supplies, the Summary Report does not recommend Federal action based on current USACE policy concerning Corps of Engineers involvement in the investigation and construction of single-purpose water supply projects. M&I water supply development is considered the primary responsibility of the states, municipalities, or other non-Federal entities. The report recommendation is that the study results be disseminated to local planning officials for their use in implementing water supply projects and that no further Federal water supply studies be conducted at this time.

Further information on this study may be obtained from the District Engineer, U. S. Army Engineer District, Vicksburg, Post Office Box 60, Vicksburg, Mississippi 39180-0060. Interested parties may purchase copies of the summary report at the reproduction cost, which is $30.00 per copy. Requests for copies should be addressed to the District Engineer with payment in the form of check or money order payable to the Treasurer of the United States. Please bring this announcement to the attention of any person you know who might be interested in the report.

Attachment
Study Area Map

Pat M. Stevens IV
Colonel, Corps of Engineers
District Engineer



RED RIVER BASIN
RED RIVER BELOW DENISON DAM
CADDO LAKE ENLARGEMENT

STUDY AREA

SCALE AS SHOWN
U.S. ARMY ENGINEER DISTRICT, VICKSBURG
CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI

ATTACHMENT

US Army Corps of Engineers
Fort Worth District

Cypress Bayou Basin Public Meeting

Marshall Civic Center
7 Flags Room
2501 E. End Blvd South
Marshall, Texas 75670

Tuesday, February 6, 1986 7:00 p.m.

The US Army Corps of Engineers is holding a public meeting to discuss water and related issues in the Cypress Bayou Basin.

The purpose of the meeting is to present alternative plans that address the feasibility of improvements for flood control, water supply, and other water resources related purposes in the Cypress Basin.

The most economically feasible alternative under consideration is a multipurpose dam and reservoir on the Little Cypress Bayou and the raising of structures in the 25-year floodplain from the proposed damsite downstream to Caddo Lake.

All persons interested in water issues in the Cypress Bayou Basin are urged to attend and make your views known.

- Come to the meeting
- Exchange your ideas with other area residents
- Tell us your thoughts; give your comments, either orally or in writing
- Encourage others to participate

If you have questions, please contact:
U.S. Army Corps of Engineers
Fort Worth District
P.O. Box 17300
ATTN: SWFPL, John Lucyshyn
Fort Worth, Texas 76102-0300
Phone (817) 334-2185

Map to the Marshall Civil Center on reverse

ATTACHMENT 2

US Army Corps
of Engineers
Fort Worth District

FACT SHEET

CYPRESS BAYOU BASIN STUDY

February 1986

BACKGROUND

STUDY - *The Cypress Bayou Basin Study was authorized by resolution adopted by the Committee of Public Works and Transportation of the United States House of Representatives and is being conducted by the Fort Worth District, Corps of Engineers, in coordination with interested Federal, State, and local officials and the public.*

PROGRESS - *Initial formulation studies indicate that a clear need for water supply and related purposes exists in the study area and that detailed planning be conducted on a project which would have the purposes of flood control, water supply, recreation, and fish and wildlife.*

The purpose of this fact sheet is to present to all interested persons the progress of formulation studies to determine the feasibility of water related improvements in the Cypress Bayou Basin.

THE STUDY

In a resolution adopted on May 9, 1979, the Committee on Public Works and Transportation of the U.S. House of Representatives requested that the U.S. Army Corps of Engineers investigate the feasibility of improvements for flood control, water conservation, and other water resources related purposes in the Cypress Bayou Basin in Harrison, Gregg, Marion, Cass, Morris, Titus, Franklin, Wood, and Upshur Counties, Texas, and Caddo Parish, Louisiana. The Corps of Engineers initiated a comprehensive feasibility study for the Cypress Bayou Basin in October 1979.

Corps of Engineers feasibility studies are accomplished in two phases: (1) reconnaissance study and (2) the final feasibility study. The reconnaissance study for the Cypress Basin was completed in July 1981. The feasibility portion is composed of two parts: (1) formulation of intermediate plans and (2) development of detailed plans and plan selection. The four planning tasks of problem identification, formulation of alternatives, impact assessment, and evaluation are repeated in each phase of the study. However, problem identification is emphasized in the reconnaissance study. Formulation of alternatives is emphasized in the formulation portion, and impact assessment and evaluation are emphasized during plan selection. The formulation studies that have been conducted concentrated upon the development of intermediate plans of improvement in the Cypress Bayou Basin.

The Cypress Bayou Basin Study is being conducted by the Fort Worth District of the Corps of Engineers in coordination with interested Federal, State, and local agencies and officials, and the public. An area economic and water supply study have been prepared by the Economic and Social Analysis Branch of the Southwestern Division of the Corps of Engineers. Coordination has been maintained with the U.S. Fish and Wildlife Service throughout the study, and they have submitted a series of planning aid letters to help in the formulation and evaluation of alternatives. The Vicksburg District of the Corps of Engineers is conducting a separate study of the feasibility of raising Caddo Lake to increase water supply. Close coordination has been maintained with this district to share results of analyses and prevent duplication of effort.

Information has been shared with the architect-engineer firm of Kindle, Stone and Associates which has conducted several water supply studies for cities in the study area. This firm has also served as a source of information on future plans for water resources development in the area. The Waterways Experiment Station is conducting a special aquatic habitat analysis in the streams of the basin to help in the evaluation of alternatives. The results of this study will be useful not only in the Cypress Basin but should prove of benefit to similar areas in the southeastern United States. The Tulsa District of the Corps of Engineers has provided hydropower analyses on several of the alternatives.

THE CYPRESS BAYOU BASIN

The Cypress Bayou Basin shown on plate 1, lies largely in Texas. In Texas, Cypress Bayou is treated as a separate river basin. Cypress Bayou rises in southwestern Hopkins County in northeast Texas. It is the watershed upstream of Caddo Dam in northeast Texas and northwest Louisiana. The basin is bounded on the north by the Sulphur River Basin, on the west and south by the Sabine River Basin, and on the east by the Twelvemile Bayou Basin. The Twelvemile Bayou Basin is bounded on the north by the Sulphur River Basin, and on the east and south by the Red River Basin.

The study area for the feasibility study was as basically outlined in the study resolution. It is comprised of the Texas counties of Camp, Cass, Franklin, Gregg, Harrison, Marion, Morris, Titus, Upshur, and Wood and includes Caddo Parish, Louisiana. These counties completely contain the Cypress Bayou Basin. The Longview-Marshall Standard Metropolitan Statistical Area (SMSA) and the Shreveport SMSA (part) are included in the study area.

PROGRESS OF STUDY

In order to provide for the water and related needs of the Cypress Bayou Basin a range of alternatives was formulated. Preliminary costs and benefits of the various alternatives were prepared and evaluated to determine the feasibility of the alternatives. The alternatives which were considered are:

Nonstructural

Water Conservation
Change operating procedure of Lake O' The Pines
Raise existing structures
Evacuate flood plain

Structural

Ground water utilization
Levees
Enlarged channel
Lakes
  Marshall site
  Black Cypress site
Addition of hydropower as a purpose to lakes
Caddo Lake enlargement
Navigation channel

PRELIMINARY RESULTS

Based on the data developed during the formulation studies, the following conclusions were reached:

- A clear need for water supply is apparent in the study area. Water needs will exceed existing supplies as early as 1990 and dependable new sources are needed. Lake alternatives at the Marshall and Black Cypress sites appear feasible for water supply, with Black Cypress being preferred for lower yields and Marshall being preferred for higher yields.

- The need for flood protection is also evident. Property owners in the middle and lower Cypress Bayou Basin, especially in the upper Caddo Lake area, suffer frequent flood losses.

- Recreation needs were shown to exist, especially water oriented varieties.

- Fish and wildlife resources were found to be in reasonable balance.

- The potential for navigation was found to exist, but the actual economics of navigation were found not favorable.

- Potential flood control and navigation benefits could evolve from conditions in and around the Longhorn Army Ammunition Plant (LAAP), particularly when considering potential conditions during mobilization.

- If a water supply lake were built, at the most desirable site for large yields, it would be established at the proposed Marshall site. It was further shown that this project could provide stage-reduction downstream of the project and therefore accrue flood control benefits.

- From a flood control standpoint, a non-structural project in the upper end of Caddo Lake could economically supplement stage reduction provided by a dam at the Marshall site.

STUDY STATUS

Based on the above conclusions, detailed studies will be conducted on a project which would have purposes of flood control, water supply, recreation, and fish and wildlife. The project will include a non-structural plan to raise structures in and around the upper end of Caddo Lake and a structural component consisting of Marshall Lake for purposes of limited flood protection, water supply, recreation, and fish and wildlife enhancement.

COMMENTS AND REQUESTS FOR ADDITIONAL INFORMATION

All interested individuals, groups, and agencies are invited to submit comments and information related to the study. Telephone communications should be directed to Chief, Basin/Special Studies Branch, at 817-334-2185. Comments, questions, and requests for additional information should be addressed to:

District Engineer
Fort Worth District, Corps of Engineers
ATTN: SWFPL-B
PO Box 17300
Fort Worth, Texas 76102-0300

Plate 1

BASIN MAP

ATTACHMENT 2

ATTACHMENT 3

PERTINENT CORRESPONDENCE

TEXAS COMMITTEE ON NATURAL RESOURCES
5934 Royal Lane, Suite 223
Dallas, Texas 75230
(214) 368-1791

March 17, 1987

Planning Division
District Engineer
U. S. Army Corps of Engineers
P. O. Box 17300
Fort Worth, Texas 76102-0300

Dear Sir:

Texas Committee on Natural Resources presents the following comments on your Feasibility Report, Cypress Bayou Basin, Texas:

1. Population: Since the period of 1950 to 1980 (pages B-1-5 forward) included some of the fastest growth rates in history, we request that you adjust your projections downward in accordance with subsequent experience and data.

2. Water demand: Your report indicates per capita use as 158 million gallons per day in 1980, (B-2-4), but does not state the current or projected per capita use rates. We request that you do so, for each ten year period, for each municipality and other users involved.

3. Conservation: Your report projects a decrease of 2 to 6 percent in per capita use as a result of conservation measures in five cities (B-2-ii,ff). We request that you increase this at least as high as projected in your supplemental EIS on Cooper Dam, Texas, and probably higher, in accordance with conservation trends in other cities of the nation. We also request that you present projections for conservation in other parts of the study area that would use the water, directly or indirectly, from each reservoir involved.

4. Alternative sources: Since Marshall and Longview are in the Sabine River Watershed, we request that you discuss fully the availability of water from Toledo Bend Reservoir to the study area.

5. Availability of water from Lake O' The Pines: Your report discusses only reallocating (pages 57-74). We request that you recite also the potential availability of all the water supply usable from Lake O' The Pines without a reallocation. This includes water appropriated and available for re-sale. Upwards of 55,000 acre-feet per year are unused and potentially available for sale. Please discuss what actions are necessary or possible for the proposed users of a new reservoir to obtain water from Lake O' The Pines.

Even if you are not able to discuss this matter in a revised or supplemental report, please send us a letter stating what facts and considerations you have. Please include among other items a complete tabulation of your population and water use projections.

Sincerely,

Edward C. Fritz wa

Edward C. Fritz
Chairman, Water Task Force

EFC/mhk

ATTACHMENT 3

NORTHEAST TEXAS MUNICIPAL WATER DISTRICT
EXECUTIVE OFFICE • P. O. BOX 955
HUGHES SPRINGS, TEXAS 75656

OFF: (214) 639-7538
PLANT: (214) 755-3115

HOMER TANNER
Manager

March 13, 1987

Mr. Michael J. Mocek, P.E.
Chief, Planning Division
U. S. Corps of Engineers, Ft.W. Dist.
P. O. Box 17300
Fort Worth, Texas 76102-0300

Dear Mr. Mocek:

I am in receipt of your report "Cypress Bayou Basin, Texas; Feasibility Report" dated February 1987.

Thank you for sending same and reviewing the document prior to the final printing. The report fairly sets forth a program for local interests to follow in the future development of the Water Supplies of Cypress Basin along with alternative approaches to meet short term and long term deficiencies.

I am sure those of us in the Basin will be well served by drafting and following guidelines that can be developed from your detailed studies.

Sincerely yours,

Homer Tanner

Homer Tanner
General Manager

LITTLE CYPRESS UTILITY DISTRICT
123 WEST MAIN STREET
P.O. BOX 630
HALLSVILLE, TEXAS 75650-0630
(214) 668-4884

GENERAL MANAGER
BILL HILLIARD, JR.

BOARD OF DIRECTORS
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W. LARRY MARTIN
JON B. RUFF
JACK WARD
MICHAEL L. WOOD

March 27, 1987

Mr. Michael J. Mocek, P.E.
Chief, Planning Division
Fort Worth District, Corps of Engineers
P.O. Box 17300
Fort Worth, TX 76102-0300

Dear Mr. Mocek:

Thank you for providing an advance copy of the Cypress Bayou Basin Feasibility Report for review and comment by the Little Cypress Utility District. We appreciate the considerable efforts of the Fort Worth District, Corps of Engineers in planning for the future water resources needs of East Texas.

As requested, the report has been reviewed by me and also by the District's engineering consultant Kindle, Stone & Associates, Inc. While the report clearly demonstrates the lack of adequate water supply for projected future growth of the overall study area and the consequent need for reservoir development, we feel the report understates future water supply needs of Gregg and Harrison counties, which are of primary interest to the Little Cypress Utility District. Our comments in this regard are as follows:

1. The projections of population and water usage for Gregg and Harrison counties, which are contained in Appendix B of the report, are substantially lower than projections developed by the Texas Water Development Board (TWDB) and utilized in their report "Water for Texas - A Comprehensive Plan for the Future", November 1984. The attached table presents a comparison of the two sources of data. Note that for Gregg and Harrison counties combined, year 2030 TWDB high case water usage of the two counties is more than double that estimated by the Corps, and year 2030 TWDB low case water usage is 69% greater than that estimated by the Corps. While the Corps report does indicate the need for additional water supply, we believe, as indicated by the TWDB data, the need is more critical than suggested in the Corps report.

2. The current groundwater supply of the City of Kilgore is presented in Table A-7, page B-2-28 of Appendix B as 7.0 mgd. The safe yield of the City of Kilgore well field is estimated by the City to be approximately 1.5 mgd. The City is able to meet its current water supply needs only by contracting with the City of Longview for treated surface water.

3. The report addresses the possibility of increasing the water supply yield of Lake O'the Pines by reallocation of a portion of the flood control storage to water supply storage. The report does not address the legal liability which will be incurred by some party (the Corps, Northeast Texas Municipal Water District, or water supply customers utilizing yield from reallocation) due to loss of downstream flood control benefits. We believe the liability issue should be fully explored and ascertained in order to allow consideration of all pertinent issues of each water supply alternative.

Again, we appreciate the opportunity to review and comment on the Cypress Basin Feasibility Report. If you have any questions regarding our comments, please do not hesitate to call.

Very truly yours,

Bill Hilliard Jr

Bill Hilliard, Jr.
General Manager

c: City of Longview
City of Marshall
City of Kilgore
Texas Water Development Board
Kindle, Stone & Associates, Inc.
Elbert Hooper

Enclosure

COMPARISON OF POPULATION AND WATER USE PROJECTIONS

Year 2030 Data	Gregg County	Harrison County	Total
FWD COE Popluation	180,000	82,000	262,000
TWDB High Case Population	189,998	116,899	306,897
TWDB Low Case Population	167,296	99,628	266,924
FWD COE Water Usage, mgd	63.3	48.9	112.2
TWDB High Case Water Usage, mgd	72.4	169.1	241.5
TWDB Low Case Water Usage, mgd	53.4	136.1	189.5

Planning Division
District Engineer
U. S. Army Corps of Engineers
P. O. Box 17300
Ft. Worth, Texas 76102

March 23, 1987

Dear Sir:

Thank you for sending me a copy of your Cypress Bayou Basin Feasability Report and inviting me to submit my comments. I have studied the document at length and have arrived at certain conclusions as to some of the data contained within.

1. Population growth in the study area: The figures in your Study (Appendix B) do not accurately reflect the present growth rates of the counties (and parish) and cities in the study area. Since the levelling-off of oil prices in the early 1980's, population growth has slowed as well. Since the rapid decline of crude prices in January 1985, some area communities have actually lost residents.

2. Water demand in the study area: It appears that projections of future water demand were based on past increases, even though some local industries, such as paper production, steel production, and petroleum processing, may have reached their limits of expansion. Observing recent trends, it appears that future industrial growth will be in the form of products assembly and light manufacturing. Wood-pulp processing will likely level-off (due to the limits of renewability of forestry resources), while petroleum related manufacturing will stabilize or decline.

3. Water supply in the study area: In studying Table 9, Water Supply Analysis, I could not help but think that Lake O' The Pines, with an average daily yeild of 182 million gallons, was overlooked. Indeed, the total daily yeild of all the reservoirs in the Big Cypress Creek watershed, both mainstem and tributary, is more than 280 million gallons. If one were to use the projected water demands in the report, development of existing surface water resources in this watershed alone could satisfy all of the area water demands in the year 2040, with the exception of Cass County and Caddo Parish. This would leave the Sabine River and existing ground water sources untouched.

4. Development of ground water resources: There has been a trend in the past to abandon ground water usage once treated municipal water is made available to customers. In some cases, the customers had no real choice in the matter. Additionally, some small water supply companies, as well as small communities that were annexed by a larger municipality, have made the change from well water to treated reservoir or river water. To best use the water that is available, an effort has to be made to integrate ground water use with reservoir water use. This would save millions of dollars as a result of avoiding the construction of reservoir and conveyance facilities, as well as keeping disruption of the environment to a minimum.

5. Benefit-cost ratio, Lake Marshall (Little Cypress): If Lake Marshall were the only reservoir in East Texas, then the recreational benefits assigned to the project might be accurate. However, this area is dotted with a plethora of reservoirs, all within easy travelling distance of the counties listed. The fact that there are so many reservoirs reduces Lake Marshall's value as a recreational destination.

As far as the water supply benefits are concerned, benefits could only be realized once water from the reservoir is actually being used, or is actually needed. If the total annual yeild of Lake Marshall is not used until the end of the 100-year analysis period, then the total water supply benefits will not be realized until that time.

6. Environmental concerns: The study area, at least from an environmetal standpoint, did not include Caddo Lake, and the effects of modified and/ or reduced instream flows, as well as the possibility of large allotments of water transferred out of the basin. The proposed instream flow requirements, while possibly being sufficient to maintain the fishery in the reach of Little Cypress Creek below the proposed Lake Marshall (Little Cypress) damsite, may not be sufficient to support the ecology of the flood plain in that reach. As this letter is written, flows in excess of 5000 cfs are occuring in the Little Cypress flood plain, with most of that water out of the stream banks.

Construction of the dam, with the accompanying changes to the flows below it, will undoubtedly cause erosion of the stream bank, as well as erosion at the confluence of tributaries and the main channel. This will most likely lead to changes in the natural pattern of sediment deposition downstream. Changes in flows, as well as disruption in natural sediment deposition patterns, are suspected culprits in the changes that have occured on Caddo Lake in the past thirty years. These effects need more investigation.

As I'm certain you are aware, an effort is underway to construct Little Cypress Reservoir, much the same size and in the same location of Lake Marshall. According to plans that have been released, only a small area adjacent to the reservoir will be provided for recreational use, with the remainder slated for lakeside development. If this occurs, then the wildlife habitat value of the littoral zone would be greatly reduced. In other words, any gains, as far as habitat for terrestrial species is concerned, would be nil. The only habitat gains would be in the form of lacustrine habitat. For the Lake Marshall project, the plans to manage adjacent and mitigated lands as wildlife habitat are to be commended, but I feel they are a rather meager remedy for the loss of 14,000 acres of bottomland hardwoods.

As for final comments on the Report, I feel that additional research as to projected population growths, increases in future water use, and possible water supply alternatives needs to be conducted before any projects are begun in the study area. Also, more thorough investigation into possible environmental effects resulting from those projects needs to be done. This would include changes on Caddo Lake from any upsteam developments.

If you are able, please send me some information on how the data for population growth and increased water use were obtained. In addition, I would like to know the methodology used in determining recreational use, in light of the other reservoirs in the region already providing recreational oppurtunities.

Sincerely,

John Umphress
Save Our Wetlands and Wildlife
P. O. Box 847
Marshall, Texas 75670

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX A - ECONOMIC ANALYSIS

CYPRESS BAYOU BASIN STUDY
FEASIBILITY REPORT

APPENDIX A
ECONOMIC ANALYSIS

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CHAPTER 1
FLOOD DAMAGES

GENERAL

This section of the report documents the economic investigations and analyses made to determine the extent and need for flood control protection in low-lying lands along Caddo Lake, Big Cypress, Little Cypress, and Black Cypress Bayous. As part of these activities, the following tasks were accomplished.

- Field surveys were made to identify the number and types of properties susceptible to flooding in the affected study area and to determine the current value of these investments.
- Existing flood plain land uses along the Little Cypress, Black Cypress, and Bid Cypress Bayous were identified and classified by major type of activity.
- Calculations were performed to develop estimates of annual flood damages and benefits that would accrue to flood control features for the various plans and improvement investigated.
- Forecasts were prepared on future probable growth trends in the flood plain lands to determine their likely effect on future flood damages and flood control benefits.

PURPOSE

The principal intent of these analyses was to identify the extent of the flood problem and, on a comparable basis, evaluate solutions to alleviate the identified flood losses. In order to accomplish these tasks, it was necessary:

- To determine the magnitude of the existing flood problem.
- To calculate estimates of the benefits that would accrue to the plans of improvement investigated.
- To assess probable future conditions that would influence the damages, as well as the potential benefits over the economic life of the project.

SCOPE

The economic analysis conducted followed procedures set forth in current Corps of Engineers regulations. Key assumptions incorporated into these economic analyses are the following:

- Estimates of existing flood damages and benefits presented herein reflect July 1984 and January 1986 prices at April 1981 level of development.
- 1990 was assumed to be the first year of operation for the plan.
- A 100-year project life was assumed, extending from 1990 to 2090.
- Forecasts of probable future conditions gave consideration to anticipated growth from 1984 through 2090.
- For preliminary plan evaluation the FY 1985 interest rate of 8-3/8 percent was applied to convert undiscounted future damages and benefits to average annual equivalent values.
- For detailed plan evaluation the current FY 86 interest rate of 8-5/8 percent was applied to convert undiscounted future damages and benefits to average annual equivalent values.

PLANS INVESTIGATED

These economic evaluations entailed detailed examination of eight plans of improvement which would provide the following levels of flood control storage.

Plan Number	Project Site	Flood Control Protection
1	Marshall Lake	10-year storage
2	Marshall Lake	25-year storage
3	Marshall Lake	50-year storage
4	Marshall Lake	None - water supply only project
5	Black Cypress Lake	10-year storage
6	Black Cypress Lake	25-year storage
7	Black Cypress Lake	50-year storage
8	Black Cypress Lake	None - water supply only project

IDENTIFYING THE FLOOD PROBLEM

General

This section describes the investigations made to determine the exent of the flood problem within the 500-year flood plain in the affected study area from the damsites on Little Cypress and Black Cypress Bayous, and along Big Cypress Bayou to the Caddo Lake dam.

Mapping

United States Geological Survey topographic maps were utilized in the inventory of flood plain properties. These maps, which display 10-foot contour intervals, aided in the identification of existing land uses and areas subject to flooding.

Flood Profiles and Flood Outlines

Water surface profiles for the controlling bank, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year flood events under existing conditions were developed by Fort Worth District. These profiles aided in the delineation of flood plain limits given different flood events, establishing the vertical control, and determining the relationship of damageable properties to both elevation and frequency of flood occurrence.

Reach Determinations

The flood plain lands below the two proposed damsites were divided into study areas. The limits of these areas gave consideration to such factors as:

- Isolation of significant damage centers from areas of minimal or negligible damage potential.
- The continuity of water surface profiles.
- The homogeneity of development and land use.
- Physical changes in the streams' characteristics.

Plate A-1 presents a map of the Cypress Bayou Basin and respective flood control areas utilized in the study.

Field Survey

Field investigations of the affected study area were conducted in April 1981. An inventory was made to identify all properties located within the 500-year flood plain. The area surveyed extended from the Marshall Lake damsite at river mile (RM) 21.3 on Little Cypress Bayou to the confluence of Big Cypress Bayou, the Black Cypress damsite at RM 17.0 on Black Cypress Bayou to the confluence of Big Cypress Bayou, the confluence of Little, Black, and Big Cypress Bayous to the headwaters of Caddo Lake, and the Caddo Lake area proper.

As part of these activities, studies were conducted to identify and classify current land use activities in the affected study area. This included identification of agricultural uses, numbers and types of urban and suburban structures, as well as determining the damage susceptibility of these flood plain activities.

A determination was made of the values of rural and agricultural flood plain properties. This included compiling agricultural statistics on current crop acreages and yields and the values of farm properties such as fences, barns, and related improvements. Appraisals were prepared on the value and types of urban/suburban investments such as (1) structure and contents for residential activities, and (2) structure, inventory, and equipment for manufacturing, commerical, and public activities. Estimates of the value of residential structures were based on fair market values. Existing residential contents were estimated to be 50 percent of the structure value. Commercial, manufacturing, and public buildings were evaluated on the basis of structure to content ratios determined from previous studies. For larger, more costly properties, personal interviews were conducted with owners, managers, or other knowledgeable personnel to obtain investment and damage susceptibility data. The different types of properties identified were then classified into the major damage categories below.

Damage Category	Items Included in Category
Urban and subruban properties	Residential, commerical, industrial, public, and semipublic properties, transportation, and utilities. Also includes public health and relief costs.
Rural properties	Agricultural products grown in the flood plain, farm properties other than crops (FPOTC), and rural (nonagricultural) properties.

MAGNITUDE AND EXTENT OF THE FLOOD PROBLEM

General

Descriptive data on the nature, magnitude, and extent of the existing flood problem is provided in this section. This includes results of the field investigations and followup office studies performed to determine the severity of the flood hazard and the need for flood protection. Pertinent information presented herein includes:

- Enumeration of the number of acres and types of crops, as well as number and types of properties located in the flood plain.
- Estimates of the value of investment in the flood plain, including structure and contents.
- Estimates of the single occurrence losses given different frequency events.
- Estimates of average annual flood losses to properties.

Structure and Investment Identified

The estimated value of flood plain investment was broken into three basic categories: (1) rural-agricultural activities, which include crops and FPOTC, (2) rural-nonagricultural activities, which include roads, highways, bridges, utilities, and all rural dwellings, and (3) urban-suburban activities, which include properties located in the various small communities situated in the flood plain. Investment data for all major damage categories by reach is shown on table A-1. A summary display of the estimated number of values of urban-suburban flood plain structures by major type and reach in each of the reporting areas is presented in table A-2.

FLOOD DAMAGE EVALUATION

Damage Susceptibility

Depth-damage relationships for different types of flood plain properties were determined in the field investigations and from data collected prior to the field studies. In establishing these relationships for each property type, consideration was given to such factors as the design of the structure, the type of equipment contained in the structure, the structure contents, and its damage susceptibility.

Stage-Damage Calculations

Stage-damage relationships were developed for each of the major damage categories which related the flood losses experienced given different stages of flooding. In brief, this was accomplished by applying the appropriate damage susceptibility coefficient for each successive foot of flooding from zero damage point of the affected crop or structure to the 500-year event. Damage to the various activities at each stage of flooding was then summed to produce a stage-damage function.

Single Occurrence Flood Loses

It is estimated that a 500-year event could potentially cause flood damage in excess of $20 million, July 1984 price levels. This would result in a loss of nearly 57 percent of the total flood plain investment. Comparatively, a 25-year flood event, which is less severe but more frequent, would produce damages of about $5.9 million, July 1984 price levels. Estimates of the flood losses given different single occurrence flood events, by reach, are presented in table A-3.

Average Annual Damage Calculation

Estimates of average annual damages under existing conditions were calculated through an integration process. Generally, this involved multiplying the mean damages (derived from the stage-damage function) by the difference in the exceedence probabilities for the same stages over the range of flooding. Average annual damages were calculated for agricultural and nonagricultural properties that could be inundated up to the 500-year event.

Expected Average Annual Flood Losses, Residual Losses, and Benefits

Existing average annual flood losses are estimated to be $982.3 thousand, based on July 1984 prices. These data, along with residual flood damages and are displayed in tables A-4 through A-6. As shown in table A-4, the greatest potential for flood losses exists in the Big Cypress area, with 53 percent of the total. Losses to agricultural and nonagricultural rural properties in the study area would account for about 25 percent of the total damages.

Varying degrees of residual damages are expected to continue with the proposed levels of flood protection. These damages would result primarily from floods which would exceed the capacity of the proposed flood control improvements and from uncontrolled runoff. Table A-5 displays the residual damages, by reach, that are expected to continue with the different plans of improvement in operation.

Estimates of inundation reduction benefits, by reach and category, that would be attributable to the eight plans investigated are displayed in table A-6. As shown, the greatest inundation reduction benefits would be provided by plan 3 (Marhshall Lake with 50-year flood control). This plan would potentially result in a reduction of 47 percent of the annual flood losses in the basin. Inundation reduction benefits would be the greatest in the Big Cypress reach, ammounting to $274.2 thousand, or 53 percent of the total.

FUTURE FLOOD DAMAGES AND BENEFITS

General

This section of the report describes the evaluations performed to identify future changes which possibly could alter damages and benefits accruing to the plans of improvement investigated. Items considered included potential hydrologic and hydraulic (H&H) changes in future flood conditions, possible changes in the value of residential property contents (affluence consideration), and possible changes in agricultural activities due to improved flood protection. Each of these categories is addressed below.

Change in Future Flood Conditions

The likelihood and extent of changes in future H&H conditions within the subject study area were examined. For any such change to occur, extensive new urban development would have to occur throughout the watershed. At the present time, there is only one small urban community in the flood plain (Jefferson, Texas). Limited growth is forecasted in this community, as well as for the rest of the study. Given these conditions, no measurable change in future H&H conditions is anticipated which would alter the existing damage and benefit estimates.

Change in Future Residential Contents (Affluence Consideration)

Calculations were made to estimate the damages, benefits, and residuals due to changes in the future value of household contents. These changes reflect increased expenditures for household items expected to occur as a result of greater purchasing power of the flood plain residents. Per capital personal income 1959-2050 forecasts based on SWD projections for Cypress Bayou Basin study area (23 September 1981) was the economic indicator selected to measure anticipated increases in residential contents and subsequently to project future changes in damages and benefits for this category. Table A-7 presents estimates of the per capita income growth rates for selected future years. As prescribed in the guidelines, a 75 percent ceiling was applied in the value of residential contents versus structure. This maximum limit is expected to be reached in the year 2004. Accordingly, the benefits claimed were held constant at the upper limit, thereafter over the remaining life of the project. A summary of the incremental future annual inundation reduction benefits to future household contents is displayed in table A-8.

Change in Future Agricultural Activities

No significant changes in agricultural activities in the study area are anticipated. Limited agricultural lands are currently committed to crop production primarily due to the marginal returns on investment for such activities. High conversion costs required to clear additional lands and the potential low profitability tend to discourage the more intensive use of agricultural lands in the future.

SUMMARY OF PRELIMINARY PROJECT AVERAGE ANNUAL INUNDATION REDUCTION BENEFITS

The preceding sections described the investigations and analyses made to estimate the existing and probable future conditions in the Cypress Bayou Basin flood plains. the undiscounted estimates of future inundation reduction benefits were converted to average annual equivalent values using the current Federal interest rate of 8-3/8 percent over a 100-year analysis period (1990-2090). Resultant estimates of the average annual project benefits by major type and reach for each of the eight preliminary plans are presented in table A-8. Based on these data, benefit curves for Marshall and Black Cypress Lakes were developed to help facilitate the economic evaluation of the numerous lake alternatives considered during the preliminary plan formulation stage, see plates A-2 and A-3.

DETAILED PLAN INVESTIGATIONS

As noted earlier in this report, eight plans of improvement were considered in the preliminary investigations in order to respond to the study area's water resource needs and problems. These preliminary analyses revealed, however, that none of the plans would economically justify the inclusion of flood control as a dedicated project purpose. Given these circumstances, several other alternative plans which would provide for varying levels of incidental flood protection were evaluated in the final detailed formulation studies. In addition, one nonstructural plan was considered. The alternatives evaluated are as follows:

- Marshall Lake - 400' weir

- Marshall Lake - 600' weir

- Marshall Lake - 1,000' weir

- Nonstructural - raising selected structures to a minimum of 8 feet

In order to place the project economics on a comparable basis with the project costs, selected flood damage data and benefits were updated to reflect January 1986 price levels. This was accomplished by the application of appropriate economic indexes. Estimates of the average annual flood losses, residual losses, and average annual flood control benefits for the four plans evaluated in the detailed investigations are displayed in table A-9.

Estimates of the future increase in residential contents for flood plain households were calculated using per capita personal income 1969-2035 forecast, 1985 OBERS, BEA regional projections (Volume 1 - State Projections). Table A-10 presents projections of the per capita income growth rates and related factors of increase that were applied in the affluence benefits calculations for the detailed plan evaluations. Using the growth factors in table A-10, calculations were then performed to estimate the affluence benefits assignable to each plan investigated.

The undiscounted estimates of future inundation reduction benefits were annualized using the current Federal interest rate of 8-5/8 percent over a 100-year analysis period (1990-2040). A summary of the total average annual benefits, with affluence, attributable to each plan of improvement is shown in table A-11.

CHAPTER 2
WATER SUPPLY BENEFITS

In accordance with current guidance, the water supply benefits were estimated by the annualized costs of supplying water by what would be, in the absence of a project, the most likely alternative. Accordingly, a detailed analysis was made of the location of the water demands in the study area, and a set of most probable water supply alternatives was developed. The list below presents the water supply alternatives evaluated as part of the water supply benefit analyses. Plate A-4 shows the location of the water demand centers in the study area the alternatives will supply.

WATER SUPPLY ALTERNATIVES EVALUATED FOR WATER SUPPLY BENEFIT ANALYSIS

Toledo Bend Reservoir
Ground Water
Toledo Bend Reservoir and Ground Water
Big Sandy Lake
Prairie Creek Lake
Caddo Lake Enlargement
Black Cypress Lake
Marshall Lake

Toledo Bend Reservoir is located on the Sabine River in southeast Texas. It was constructed and is owned by the Sabine River Authority. There is ample good quality water available for contract. Current price for most contracts is 7 cents per thousand gallons. There are ground water aquifers available in the study area. These aquifer would have to be developed with many shallow, low yield wells, and the water is acidic and contains large iron concentrations. Big Sandy Lake is a site under investigation by the Bureau of Reclamation. No definite size has been selected. Based on earlier studies done by the Fort Worth District, this site could develop a maximum yield of 74 mgd which would not meet the 2040 needs of the basin. This alternative would have to be used in combination with others. Prairie Creek Lake is a site under investigation by several of the cities in the study area. It would be situated on a tributary to the Sabine River and would involve a "scalping" of floodflows from this river. Estimated maximum yield for Prairie Creek Lake is 34 mgd. Because of the many prior permits for Sabine River water and the fact that most of the study area demand is in the Cypress Basin, it is assumed the yield for this alternative would be used entirely in the Sabine River Basin. Thus, this alternative would have to be developed in combination with another to meet the needs of the study area. Caddo Lake enlargement has been considered for many years. The Vicksburg District is doing a separate study of this alternative. Additional yields that could be developed range form 26 to 144 mgd depending on the height the dam is raised and the drawdown criteria selected. By the rules of the Red River Compact, discussed in Planning Constraints, Texas would receive half of any increased yield from Caddo Lake. Caddo Lake is a scenic and important recreation lake. There is much concern as to the impacts of raising the lake on terrestrial habitat and the people surrounding the lake. Much opposition has been expressed to this alternative. It would appear that severe institutional and implementation problems will be associated with this alternative. For this reason, this alternative is not considered as a probable alternative and is dropped from further consideration. Black Cypress Lake and Marshall Lake are proposed lake sites in the Cypress Basin. Black Cypress Lake is situated on Black Cypress Bayou, and Marshall Lake is on Little Cypress Bayou.

Costs for the different alternatives were developed from either the Methodology for Areawide Planning Studies (MAPS) computer program, studies done by others, or cost estimates based on unit prices and computed quantities. All transmission costs were developed using the MAPS. Costs were developed for different yields so a curve could be constructed. For yields above the ability of an alternative, this alternative was combined with another to complete the curve. All costs are based on July 1984 price level and use 8-3/8 percent interest and a 100-year period of analysis. Plates A-5 through A-10 show the transmission facilities schematics for each of the alternatives. Plate A-11 shows the annual cost including transmission for the alternatives and plate A-12 the annual transmission costs.

To compute benefits for an alternative, obtain the least costly other alternative cost for a selected yield form Plate A-11. Then determine the transmission costs of the alternative under consideration using Plate A-12. Subtract this cost form the other alternative cost, and this value becomes the water supply benefit for the alternative under consideration. The water supply benefits for Marshall and Black Cypress Lakes are shown on Plate A-13.

CHAPTER 3
NAVIGATION ANALYSIS

GENERAL

These investigations were undertaken to serve as a preliminary reassessment of the economic feasibility of extending the authorized Red River navigation channel from Shreveport, Louisiana, to the vicinity of Daingerfield, Texas. The study assumed that the authorized channel to Shreveport, Louisiana, would be completed. The study emphasis was placed on identifying the types of acceptable waterway commerce and to roughly quantify, where possible, applicable transportation savings.

In a 1980 Corps of Engineers study of the channel to Daingerfield, navigation and area redevelopment benefits made up 75 percent and 23 percent of total benefits, respectively.[1] Accordingly, study activities were directed at evaluating the potential benefits that would be generated by these two activities.

TRIBUTARY AREA

The tributary area for the proposed channel to Daingerfield was defined as that area which could be served by the waterway and result in a transportation savings to potential shippers and receivers. Generally, this consists of the counties adjacent to the waterway.

The Longview-Marshall area was excluded from the tributary area because it was felt that potential water traffic from this area would be transported to Shreveport for transfer to barge. Shreveport currently is a commercial center, and, as such, is likely to develop the loading and unloading facilities need to cheaply and efficiently handle bulk commodity shipments. Similar facilities in Jefferson would probably be underutilized due to lack of colume and thus be more expensive. Although the truck haul from Longview to Jefferson is 18 miles shorter than the Longview to Shreveport trip 961 - 48 = 18), it is 53 river miles longer. For the above reasons, it is anticipated that the potential transportation savings would be negligible for Longview companies trucking to Jefferson instead of Shreveport.

COMMODITY ANALYSIS

Various sources were examined to identify potential waterway shippers. The yellow pages of area telephone books and the Texas Directory of Manufacturers were initially screened to compile a list of companies to be contacted. Officials of local business organizations were interviewed. Each company representative interviewed was asked to recommend

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[1] "Transportation Economic Reanalysis, Red River Waterway, Shreveport, Louisiana, to Daingerfield, Texas," New Orleans District, February 1980, page 13.

additional potential shippers. A list of interviewed companies is shown in table A-12.

The major purpose of these interviews was to collect pertinent data on current and future economic and transportation conditions in the tributary area. The types of data solicited from the firms contacted included identification and use of commodities, origin and destination points, present means and routing of movements, volume and frequency of shipments, scheduling requirements, present transportation rate or charges, and the firm's interest in waterway transportation. Projected waterborne tonnages and navigation benefits are shown on table A-13.

AREA REDEVELOPMENT

In the 1980 Corps analysis, area redevelopment benefits totaled $5,732,000 (May 1979 price level). It is anticipated that these benefits would be significantly lower in this reanalysis for the following reasons.

- Current guidelines do not allow area redevelopment benefits to be claimed for operation, maintenance, and replacement activities. In the 1980 analysis, 7 percent of area redevelopment benefits were based on O&M operations.
- Current guidelines limit unemployed labor to a maximum of 47 percent of the skilled labor total and 30 percent of the unskilled labor total in areas which do not have a local hire rule. (A total hire rule would not be applicable to this project.) In the 1980 analysis, unemployed labor made up about 65 percent of the total labor.
- Under current guidelines, only 4 of the 29 counties within a commuting distance of the project are clasified as eligible areas to claim area redevelopment benefits. In the 1980 analysis, all counties within commuting distance of the project were classified as eligible counties.

In the current reanalysis, a 50-mile commuting distance from the project was estimated as the area from which local labor would be drawn. Each county's labor force within this area was estimated. The cummuting area labor force in counties which qualify for area redevelopment benefits was divided by the total commuting area labor force to calculate the percent of local labor eligible for area redevelopment benefits. The resultant figure amounted to 8.1 percent.

Area redevelopment benefits could not be calculated because cost data were not available. Table A-14 shows the manner in which area redevelopment benefits should be calculated once cost data are available.

TABLE A-1

ESTIMATED VALUE OF EXISTING INVESTMENTS SUBJECT TO FLOODING WITHIN THE 500-YEAR FLOOD PLAIN
(Based on July 1984 prices)

Reach	Agricultural		Rural/Non-Agricultural	Urban/Suburban	Total
	Crops	FPOTC			
			(In thousands of dollars)		
Black Cypress	$ 84.0	$ 30.3	$ 80.3	$ 2,400.4	$ 2,595.0
Little Cypress	419.2	165.9	400.2	217.8	1,203.1
Big Cypress	741.3	293.3	707.7	14,660.3	16,402.6
Caddo Lake	0.0	0.0	413.3	15,653.2	16,066.5
Total	$1,244.5	$489.5	$1,601.5	$32,931.7	$36,267.2

TABLE A-2

ESTIMATED NUMBER AND VALUE OF EXISTING INVESTMENT WITHIN SPF LIMITS

Reach	Residential	Commercial	Public	Industrial	Agricultural	Marine	Transportation	Communications and Utilities	Total	Percent
					Number					
Black Cypress	17	0	0	3	1	0	0	0	21	(3)
Little Cypress	4	0	0	0	1	0	1	0	6	(1)
Big Cypress	348	7	1	0	1	0	5	1	363	(46)
Caddo	359	31	6	0	1	1	4	0	402	(50)
Totals	728	38	7	3	4	1	10	1	792	(100)
Percent	(92)	(5)	(1)	(*)	(1)	(*)	(1)	(*)	(100)	
					Value					
Black Cypress	$ 1,765.2	$ 0.0	$ 0.0	$353.6	$42.2	$0.0	$ 106.0	$ 133.5	$ 2,400.5	(7)
Little Cypress	181.0	0.0	0.0	0.0	3.0	0.0	22.3	11.5	217.8	(1)
Big Cypress	12,675.3	179.6	135.2	0.0	8.7	0.0	698.4	963.1	14,660.3	(44)
Caddo	12,745.9	427.4	665.0	0.0	42.2	6.0	894.9	871.8	15,653.2	(48)
Totals	$27,367.4	$607.0	$800.2	$353.6	$96.1	$6.0	$1,721.6	$1,979,9	$32,931.8	(100)
Percent	(83)	(2)	(2)	(1)	(*)	(*)	(5)	(6)	(100)	

*Less than 1 percent.

TABLE A-3

ESTIMATED SINGLE OCCURRENCE FLOOD LOSSES FOR VARIOUS FREQUENCY EVENTS
(July 1984 prices)

Area	Flood Event					
	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr
Black Cypress	$ 36.2	$ 88.4	$ 188.5	$ 367.7	$ 569.6	$ 1,073.1
Little Cypress	23.6	24.4	28.3	62.9	110.3	191.1
Big Cypress	254.3	885.7	3,081.8	4,902.0	5,990.7	9,493.2
Caddo Lake	33.9	362.7	2,606.4	4,920.5	6,490.1	9,875.6
Totals	$348.0	$1,361.2	$5,905.0	$10,253.1	$13,166.7	$20,633.0

TABLE A-4

ESTIMATES OF EXISTING AVERAGE ANNUAL FLOOD LOSSES
(Based on July 1984 prices)

Reporting Reach	Agricultural	Nonagricultural	Urban/ Suburban	Total
	(in thousands of dollars)			
Black Cypress	$ 8.2	$ 5.6	$ 32.9	$ 46.7
Little Cypress	41.6	27.3	2.4	71.3
Big Cypress	73.1	48.8	395.4	517.3
Caddo Lake	0.0	40.0	307.0	347.0
Totals	$122.9	$121.7	$737.7	$982.3

TABLE A-5

ESTIMATES OF RESIDUAL AVERAGE ANNUAL FLOOD LOSSES
(Based on July 1984 prices)

Damage Clasification	Plan No.*							
	1	2	3	4	5	6	7	8
	(In thousands of dollars)							
Black Cypress Bayou Reach								
Agricultural	$ 8.2	$ 8.2	$ 8.2	$ 8.2	$ 4.3	$ 4.3	$ 4.3	$ 6.9
Nonagricultural	5.6	5.6	5.6	5.6	2.8	2.8	2.8	4.7
Urban/Suburban	32.3	32.2	32.2	32.3	4.7	2.6	2.4	9.5
Subtotals	$ 46.1	$ 46.0	$ 46.0	$46.1	$ 11.8	$ 9.7	$ 9.5	$ 21.1
Little Cypress Bayou Reach								
Agricultural	25.8	25.8	25.8	32.4	41.6	41 6	41.6	41.6
Nonagricultural	16.7	16.7	16.7	21.2	27.3	27.3	27.3	27.3
Urban/Suburban	.1	.1	0.0	1.3	2.4	2.4	2.4	2.4
Subtotals	$ 42.6	$ 42.6	$ 42.5	$ 54.9	$ 71.3	$ 71.3	$ 71.3	$ 71.3
Big Cypress Bayou Reach								
Agricultural	61.3	61.3	61.3	68.7	68.4	68.4	68.4	70.7
Nonagricultural	40.9	40.9	40.9	45.9	45.7	45.7	45.7	47.2
Urban/Suburban	153.1	151.3	140.9	302.1	280.3	266.3	263.1	333.9
Subtotals	$255.3	$253.5	$243.1	$416.7	$394.4	$380.4	$377.2	$451.8
Caddo Lake Reach								
Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nonagricultural	24.2	24.2	24.2	34.2	30.0	30.0	30.0	36.8
Urban/Suburban	124.5	123.8	111.0	228.3	213.2	197.3	193.2	252.9
Subtotals	$148.7	$148.0	$135.2	$262.5	$243.2	$227.3	$223.2	$289.7
Totals								
Agricultural	95.3	95.3	95.3	109.3	114.3	114.3	114.3	119.2
Nonagricultural	87.4	87.4	87.4	106.9	105.8	105.8	105.8	116.0
Urban/Suburban	310.0	307.4	284.1	564.0	500.6	468.6	461.1	598.7
Grand Totals	$492.7	$490.1	$466.8	$780.2	$720.7	$688.7	$681.2	$833.9

*See page 3, Plans Investigated, for plan description.

TABLE A-6

ESTIMATES OF INUNDATION REDUCTION BENEFITS
(Based on July 1984 prices)

Damage Clasification	Plan No.*							
	1	2	3	4	5	6	7	8
	(In thousands of dollars)							
	Black Cypress Bayou Reach							
Agricultural	$ 0.0	$ 0.0	$ 0.0	$ 0.0	$ 3.9	$ 3.9	$ 3.9	$ 1.3
Nonagricultural	0.0	0.0	0.0	0.0	2.8	2.8	2.8	0.9
Urban/Suburban	0.6	0.7	0.7	0.6	28.2	30.3	30.5	23.4
Subtotals	$ 0.6	$ 0.7	$ 0.7	$ 0.6	$ 34.9	$ 37.0	$ 37.2	$ 25.6
	Little Cypress Bayou Reach							
Agricultural	15.8	15.8	15.8	9.2	0.0	0.0	0.0	0.0
Nonagricultural	10.6	10.6	10.6	6.1	0.0	0.0	0.0	0.0
Urban/Suburban	2.3	2.3	2.4	1.1	0.0	0.0	0.0	0.0
Subtotals	$ 28.7	$ 28.7	$ 28.8	$ 16.4	$ 0.0	$ 0.0	$ 0.0	$ 0.0
	Big Cypress Bayou Reach							
Agricultural	11.8	11.8	11.8	4.4	4.7	4.7	4.7	2.4
Nonagricultural	7.9	7.9	7.9	2.9	3.1	3.1	3.1	1.6
Urban/Suburban	242.3	244.1	254.5	93.3	115.1	129.1	132.3	61.5
Subtotals	$262.0	$263.8	$274.2	$100.6	$122.9	$136.9	$140.1	$ 65.5
	Caddo Lake Reach							
Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nonagricultural	15.8	15.8	15.8	5.8	10.0	10.0	10.0	3.2
Urban/Suburban	182.5	183.2	196.0	78.7	93.8	109.7	113.8	54.1
Subtotals	$198.3	$199.0	$211.8	$ 84.5	$103.8	$119.7	$123.8	$ 57.3
	Totals							
Agricultural	27.6	27.6	27.6	13.6	8.6	8.6	8.6	3.7
Nonagricultural	34.3	34.3	34.3	14.8	15.9	15.9	15.9	5.7
Urban/Suburban	427.7	430.3	453.6	173.7	237.1	260.1	276.6	139.0
Grand Totals	$489.6	$492.2	$515.5	$202.1	$261.6	$293.6	$301.1	$148.4

*See page 3, Plans Investigated, for plan description.

TABLE A-7

PROJECTIONS OF PER CAPITA INCOME

Year	Per Capita Income	Index Used to Project Household Contents
1990	$ 5,188	1.000
1995	6,114 1/	1.178
2000	7,041	1.357
2004	7,952 1/	1.533
2010	9,319	1.533
2020	11,951	1.533
2030	13,653	1.533
2040	14,596	1.533
2050	15,099	1.533
2090	17,111 2/	1.533

1/ Interpolated value
2/ Extrapolated value

TABLE A-8

ESTIMATES OF TOTAL FLOOD CONTROL AVERAGE ANNUAL BENEFITS
(Based on July 1984 prices and 8-3/8 percent Interest)

Damage Classification	Plan No.*							
	1	2	3	4	5	6	7	8
	(In thousands of dollars)							
				Black Cypress Bayou Reach				
Agricultural	$ 0.0	$ 0.0	$ 0.0	$ 0.0	$ 3.9	$ 3.9	$ 3.9	$ 1.3
Nonagricultural	0.0	0.0	0.0	0.0	2.8	2.8	2.8	0.9
Urban/Suburban	0.6	0.7	0.7	0.6	28.2	30.3	30.5	23.4
Affluence	0.1	0.1	0.1	0.1	4.9	5.1	6.2	3.8
Subtotals	$ 0.7	$ 0.8	$ 0.8	$ 0.7	$ 39.8	$ 42.1	$ 42.4	$ 29.4
				Little Cypress Bayou Reach				
Agricultural	15.8	15.8	15.8	9.2	0.0	0.0	0.0	0.0
Nonagricultural	10.6	10.6	10.6	6.1	0.0	0.0	0.0	0.0
Urban/Suburban	2.3	2.3	2.4	1.1	0.0	0.0	0.0	0.0
Affluence	0.3	0.3	0.4	0.2	0.0	0.0	0.0	0.0
Subtotals	$ 29.0	$ 29.0	$ 29.2	$ 16.6	$ 0.0	$ 0.0	$ 0.0	$ 0.0
				Big Cypress Creek Reach				
Agricultural	11.8	11.8	11.8	4.4	4.7	4.7	4.7	2.4
Nonagricultural	7.9	7.9	7.9	2.9	3.1	3.1	3.1	1.6
Urban/Suburban	242.3	244.1	254.5	93.3	115.1	129.1	132.3	61.5
Affluence	35.9	36.3	38.0	13.8	17.2	19.3	19.8	9.1
Subtotals	$297.9	$300.1	$312.2	$114.2	$140.1	$156.2	$159.9	$ 74.6
				Caddo Lake Reach				
Agricultural	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nonagricultural	15.8	15.8	15.8	5.8	10.0	10.0	10.0	3.2
Urban/Suburban	182.5	183.2	196.0	78.7	93.8	109.7	113.8	54.1
Affluence	27.2	27.3	29.3	12.0	14.4	16.2	17.0	7.4
Subtotals	$225.5	$226.3	$241.1	$ 96.5	$118.2	$135.9	$140.8	$ 64.7
				Totals				
Agricultural	$ 27.6	$ 27.6	$ 27.6	$ 13.6	$ 8.6	$ 8.6	$ 8.6	$ 3.7
Nonagricultural	34.3	34.3	34.3	14.8	15.9	15.9	15.9	5.7
Urban/Suburban	427.7	430.3	453.6	173.7	237.1	269.1	276.6	139.0
Affluence	63.5	64.0	67.8	26.1	36.5	40.6	42.0	20.3
Grand Totals	$553.1	$556.2	$583.3	$228.2	$298.1	$334.2	$343.1	$168.7

*See page 3, Plans Investigated, for plan description.

TABLE A-9

AVERAGE ANNUAL FLOOD LOSSES, RESIDUAL LOSSES, AND FLOOD CONTROL BENEFITS

(Based on January 1986 prices)

Plan Investigated	Average Annual Damages	Annual Residual Damages	Annual Benefits
Marshall Lake - 400' weir	$991,400	$702,700	$288,760
Marshall Lake - 600' weir	991,400	833,600	157,800
Marshall Lake - 1,000' weir	991,400	872,800	118,600
Nonstructural	991,400	647,100	294,300

TABLE A-10

PROJECTIONS OF PER CAPITA INCOME

Year	Per Capita Income	Index Used to Project Household Contents
1990	$ 6,435	1.000
1995	6,923 1/	1.076
2000	7,356	1.143
2005	7,760 1/	1.206
2015	8,468	1.316
2020	8,880 1/	1.380
2030	9,703 1/	1.500
2035	10,114	1.500
2050	11,347 2/	1.500
2070	12,995 2/	1.500
2090	14,641 2/	1.500

1/ Interpolated value
2/ Extrapolated value

TABLE A-11

TOTAL AVERAGE ANNUAL FLOOD CONTROL BENEFITS

(Based on January 1986 prices and 8-5/8% interest)

Plan Investigated	Flood Control Benefits	Affluence	Total
Marshall Lake - 400' weir	$288,700	$51,500	$340,200
Marshall Lake - 600' weir	157,800	29,200	187,000
Marshall Lake - 1,000' weir	118,600	20,000	138,600
Nonstructural	294,300	56,500	350,800

TABLE A-12

COMPANIES CONTACTED

Company	Representative
Baker Reels	Henry Henderson, Manager
Blackburn Syrup	Jerry Blackburn, part owner
East Texas Forest Products	O'Neal Parker, partner
International Paper	Bill Hughes, land manager
Lone Star Lumber	Carolyn Ender, partner
Lone Star Steel	John Morris, V-P corporate affairs
Longhorn Army Ammunition Plant (Morton-Thicol)	Mr. Davis, general manager
Pacific Studs	Earl Benjamin, manager
Paul Manufacturing	Harlen Murry, manager
Scurlock Oil	Boyce Templeton, manager
Southwestern Electric Power	Leslie Dillahunty, superintendent of power

TABLE A-13

PROJECTED WATERBORNE TONNAGES AND NAVIGATION BENEFITS CHANNEL TO DAINGERFIELD (March 1985 price level)

Year	Projected Annual Commerce (in tons)	Annual Transportation Savings
1979	1,260,000	$ 8,542,800
1985	1,738,800	11,789,100
1990	2,142,000	14,522,800
2000	2,721,600	18,452,400
2030	3,528,000	23,919,800
2040	3,792,600	25,713,800
2090	3,792,600	25,713,800

Average annual equivalent (8-3/8%. 100 years) $18,047,000

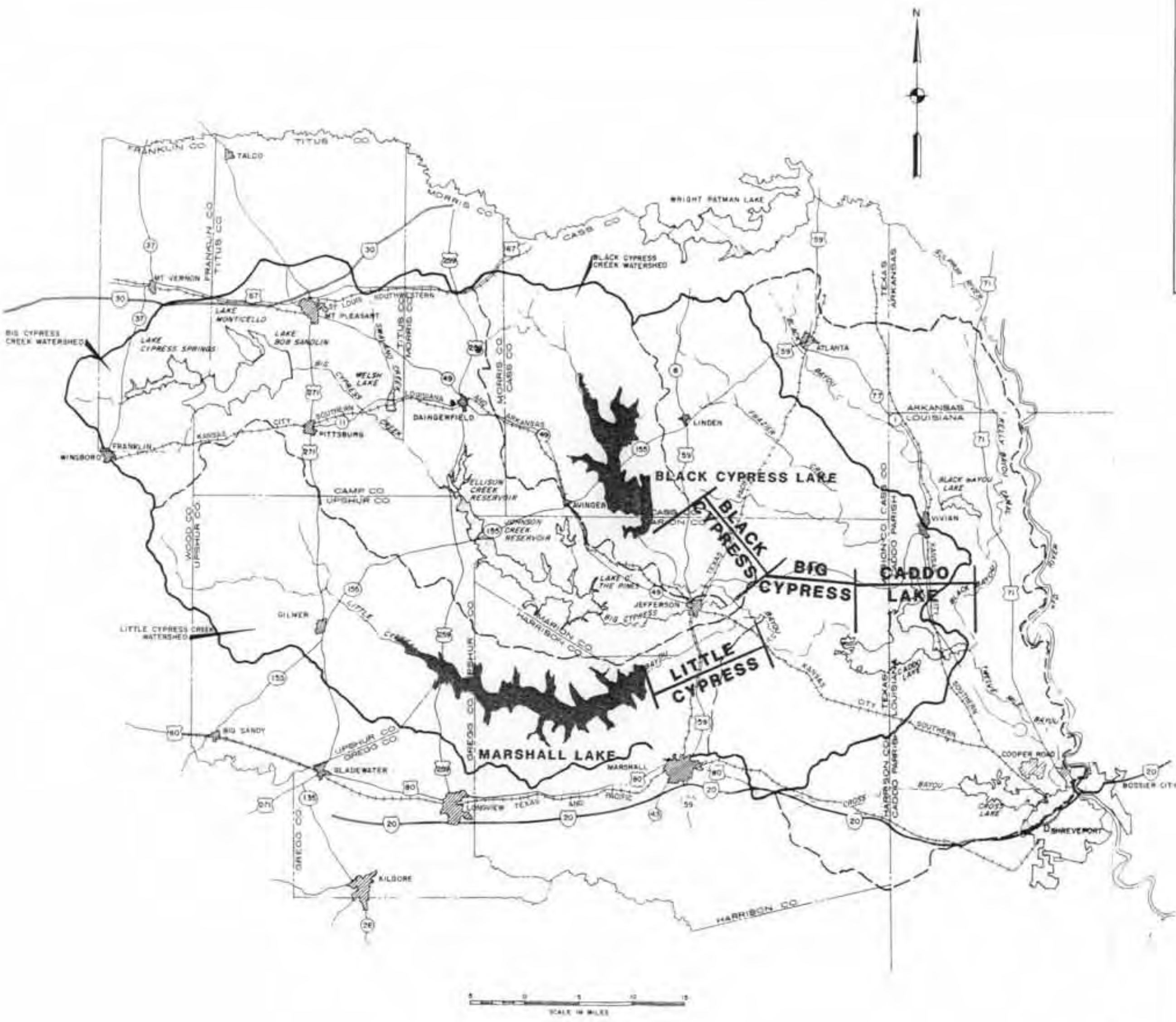
TABLE A-14

AVERAGE ANNUAL EQUIVALENT AREA REDEVELOPMENT BENEFIT COMPUTATION ($1,000)

	Type of Labor			
	Skilled	Unskilled	Other	Total
Wages for labor	$71,395	$118,991	$47,596	
x portion of local labor	.3	.47	.35	
Subtotal	$21,419	$ 55,926	$16,659	$94,004
x portion of local labor from qualifying counties				.081
x interest and amortization factor (8-3/8%, 100 years)				.08378
Average annual equivalent area redevelopment benefits				638

CORPS OF ENGINEERS

U.S. ARMY



VICINITY MAP

NOT TO SCALE

LEGEND

EXISTING RESERVOIR

RIVER

INTERSTATE HIGHWAY

U.S. HIGHWAY

STATE HIGHWAY

RAILROAD

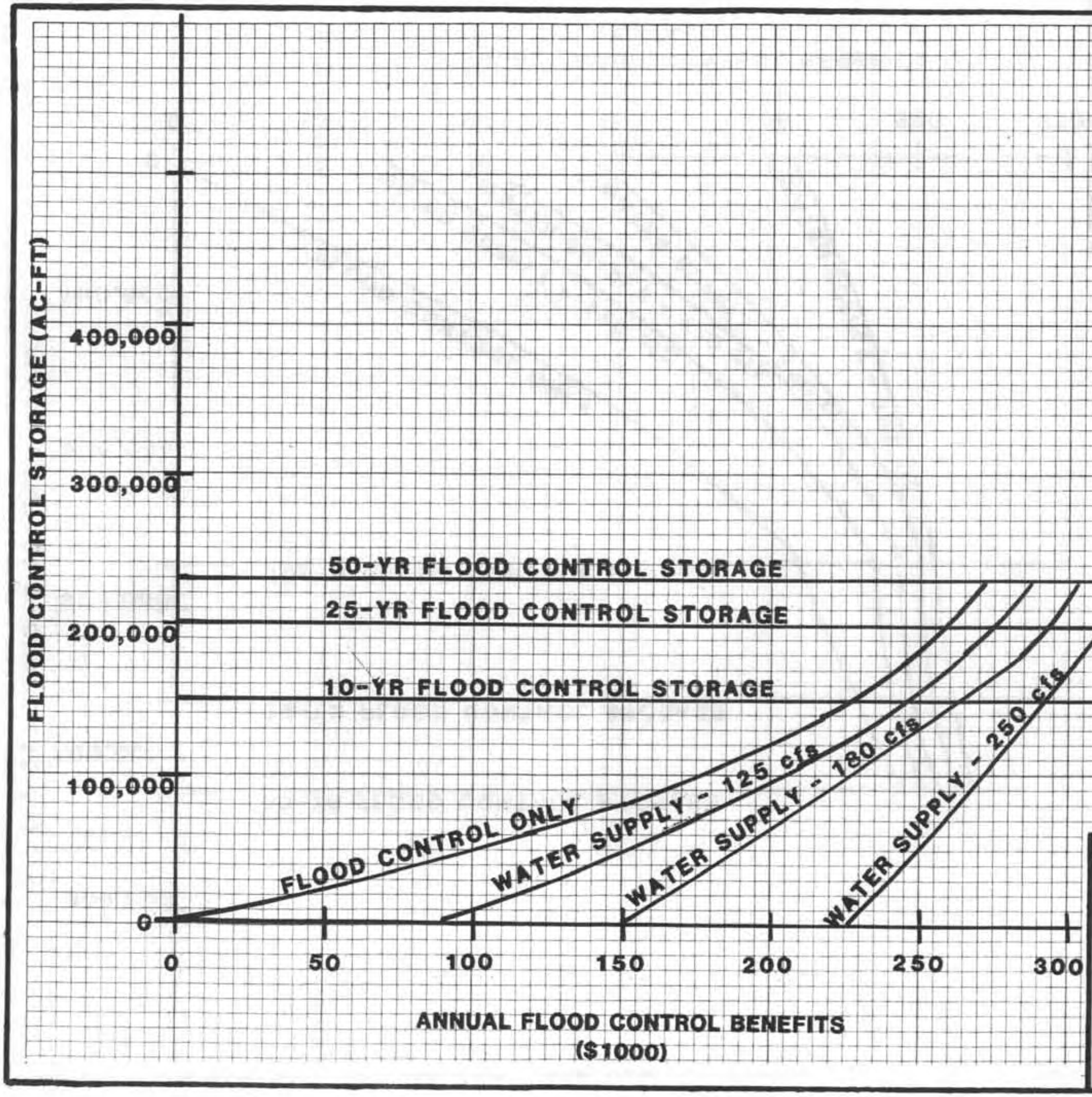
PROPOSED LAKE

CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

FLOOD CONTROL REACHES

U.S. ARMY ENGINEER DISTRICT, FORT WORTH JULY 1981

FILE NO. PLATE A-1



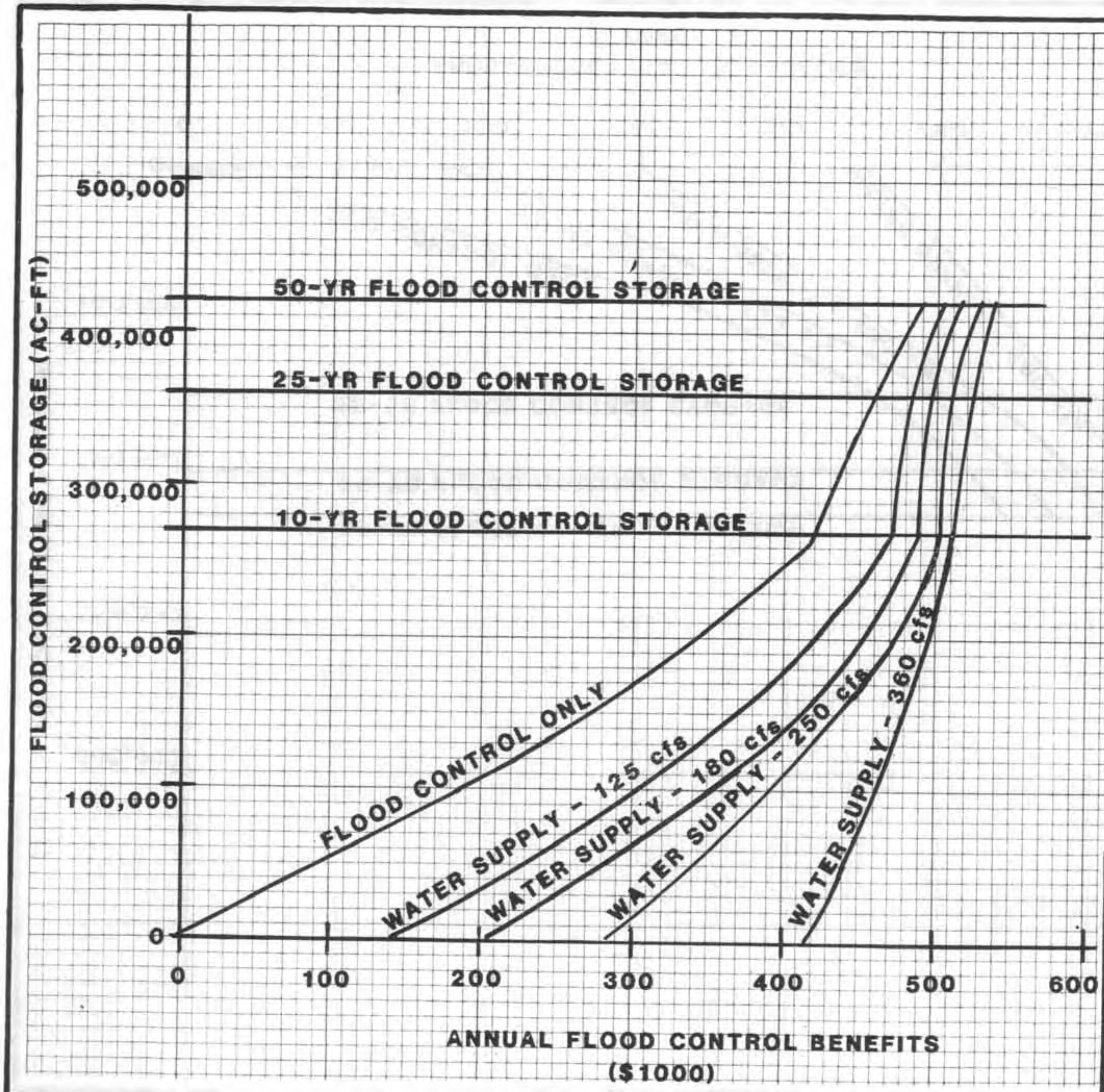
CYPRESS BAYOU BASIN

FLOOD CONTROL BENEFITS

BLACK CYPRESS LAKE ALTERNATIVES

(JULY 1984 PRICE LEVELS)

PLATE A-2



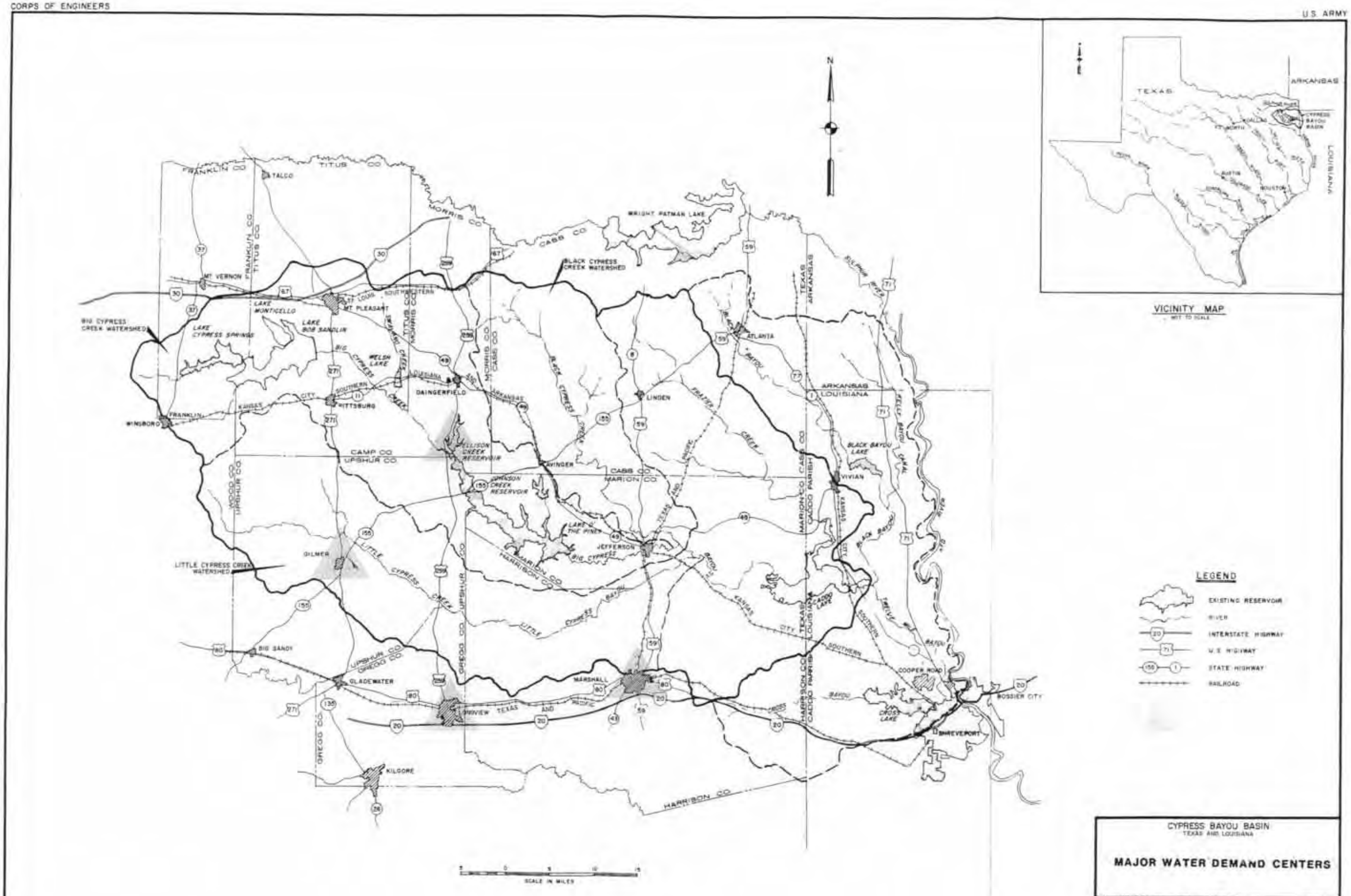
CYPRESS BAYOU BASIN
FLOOD CONTROL BENEFITS
MARSHALL LAKE
ALTERNATIVES

(JULY 1984 PRICE LEVELS)

PLATE A-3

CORPS OF ENGINEERS

U.S. ARMY

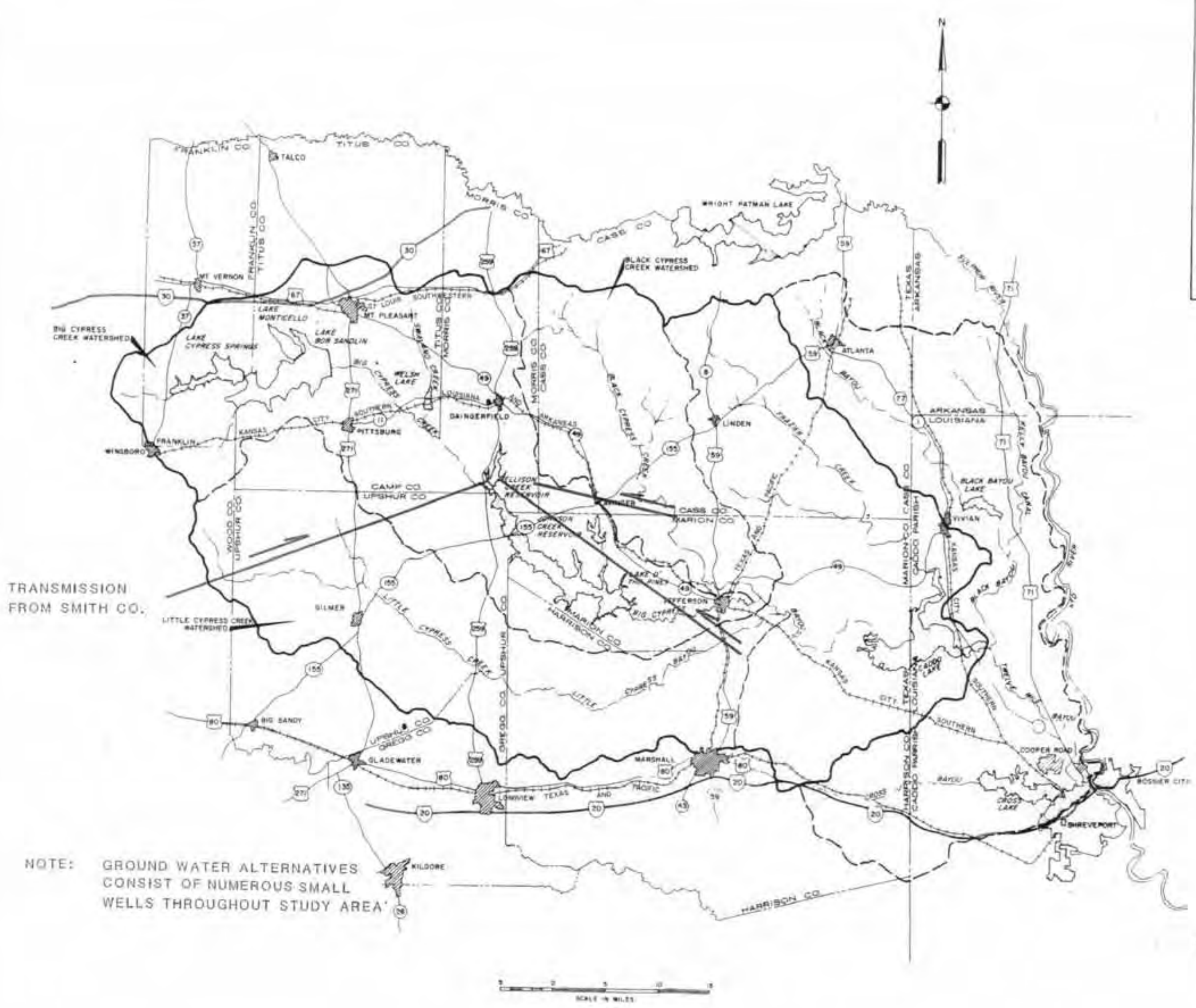


CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

MAJOR WATER DEMAND CENTERS

U.S. ARMY ENGINEER DISTRICT, FORT WORTH JULY 1981

FILE NO. **PLATE A-4**



NOTE: GROUND WATER ALTERNATIVES CONSIST OF NUMEROUS SMALL WELLS THROUGHOUT STUDY AREA

VICINITY MAP
NOT TO SCALE

LEGEND

EXISTING RESERVOIR

RIVER

INTERSTATE HIGHWAY

U.S. HIGHWAY

STATE HIGHWAY

RAILROAD

PIPELINE FOR WATER SUPPLY TRANSMISSION

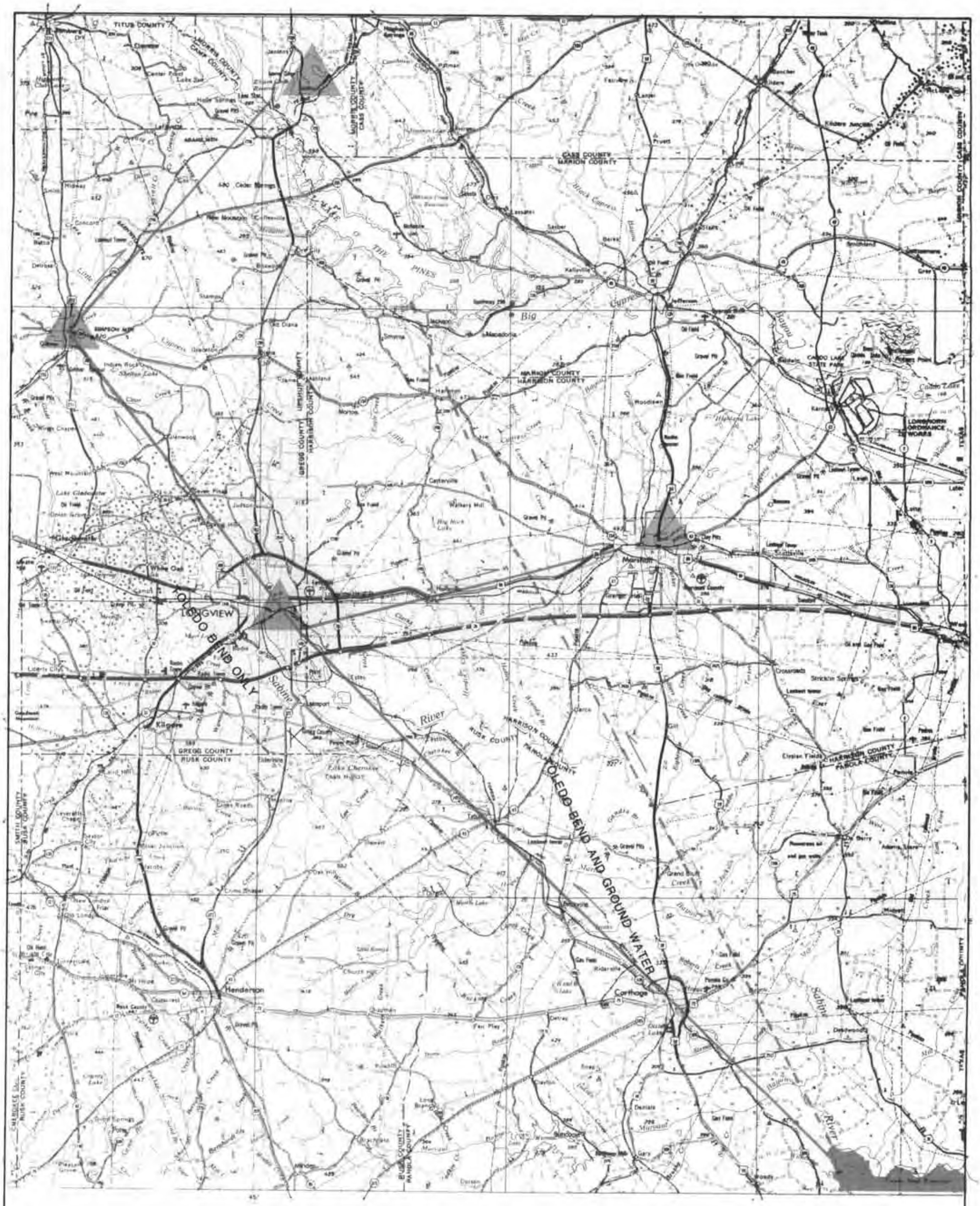
CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

GROUND WATER

WATER SUPPLY ALTERNATIVES

U.S. ARMY ENGINEER DISTRICT, FORT WORTH JULY 1981

FILE NO PLATE A-5

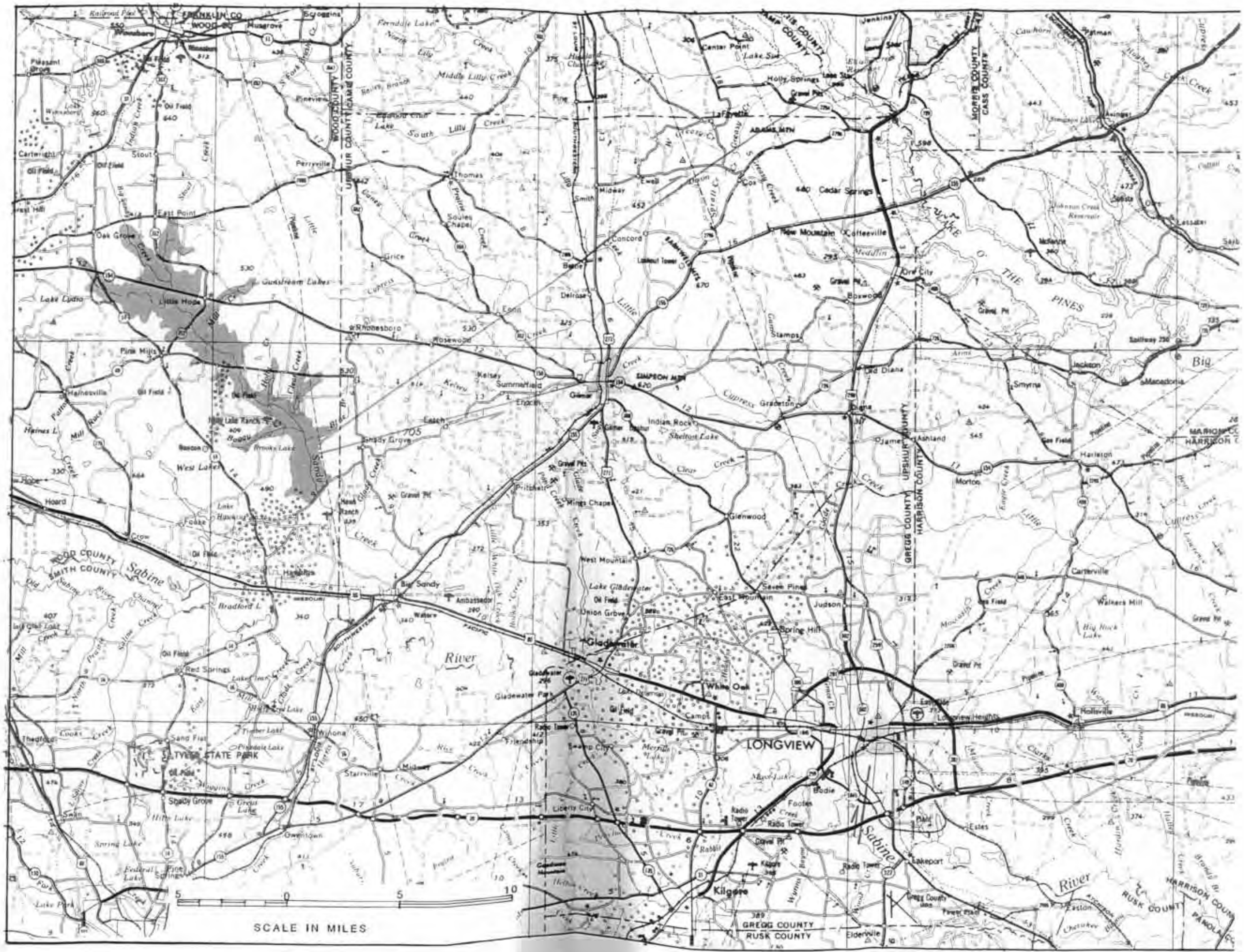


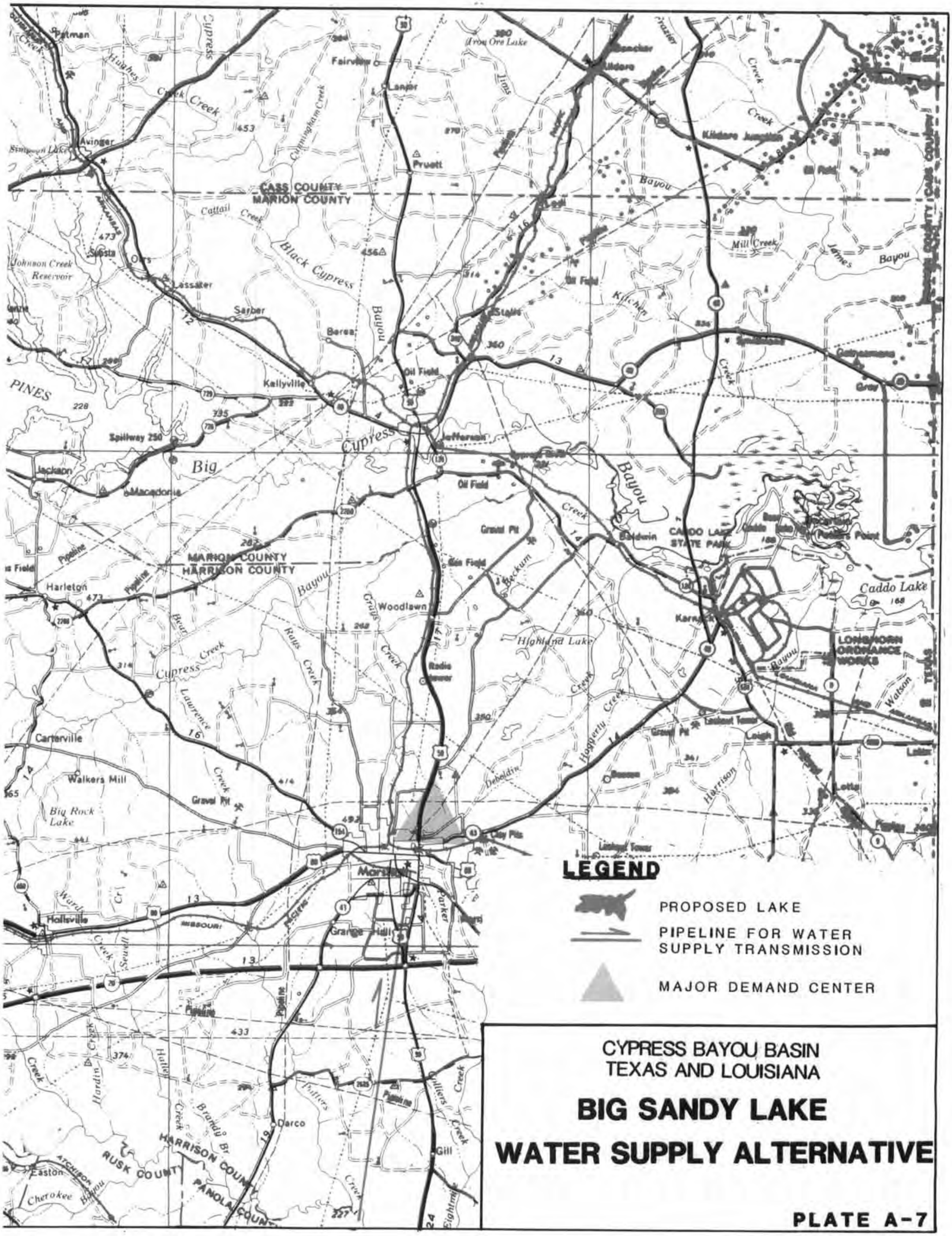
CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

TOLEDO BEND RESERVOIR ONLY
AND
TOLEDO BEND RESERVOIR AND GROUND WATER

WATER SUPPLY ALTERNATIVES

PLATE A-6

FRANKLIN CO
WOOD CO
WOOD COUNTY
UPSHUR COUNTY
CAMP COUNTY
MORRIS COUNTY
CASS COUNTY
SMITH COUNTY
GREGG COUNTY
HARRISON COUNTY
RUSK COUNTY
MARION CO
PANOLA CO
LONGVIEW
Gladewater
Gilmer
Kilgore
Big Sandy
Hawkins
White Oak
Ore City
Winona
Tyler State Park
Lake O' The Pines
Sabine River
Little Hope
Lake Lydia
Pine Mills
Rhonesboro
Rosewood
Kelsey
Summerfield
Simpson Mtn
Indian Rock
Glenwood
West Mountain
Lake Gladewater
Union Grove
East Mountain
Judson
Spring Hill
Liberty City
Sabine
Camp
Friendship
Longview Heights
Hallsville
Harleton
Diana
Ashland
Jackson
Smyrna
Macedonia
Lakeport
Easton
Eldenville
Thomas
Soules Chapel
Concord
Midway
LaFayette
Cedar Springs
New Mountain
Coffeeville
Pittsburg
Red Springs
Starrville
Owentown
Sand Flat
Shady Grove
Hoard
Crow
Perryville
Pineview
Grice
East Point
Oak Grove
Gravel Pit
Oil Field
SCALE IN MILES
5
0
5
10



LEGEND

PROPOSED LAKE

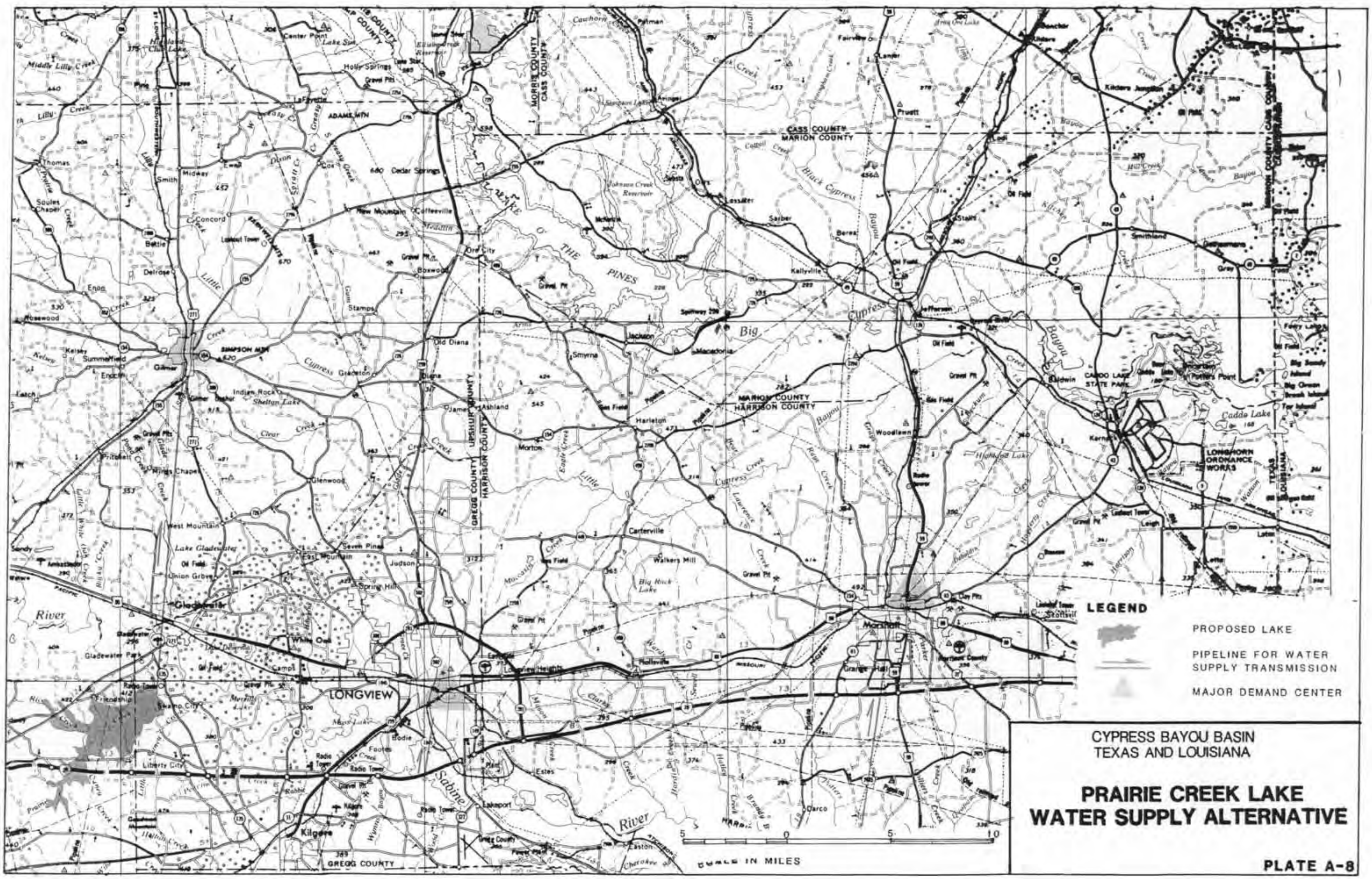
PIPELINE FOR WATER SUPPLY TRANSMISSION

▲ MAJOR DEMAND CENTER

CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

BIG SANDY LAKE
WATER SUPPLY ALTERNATIVE

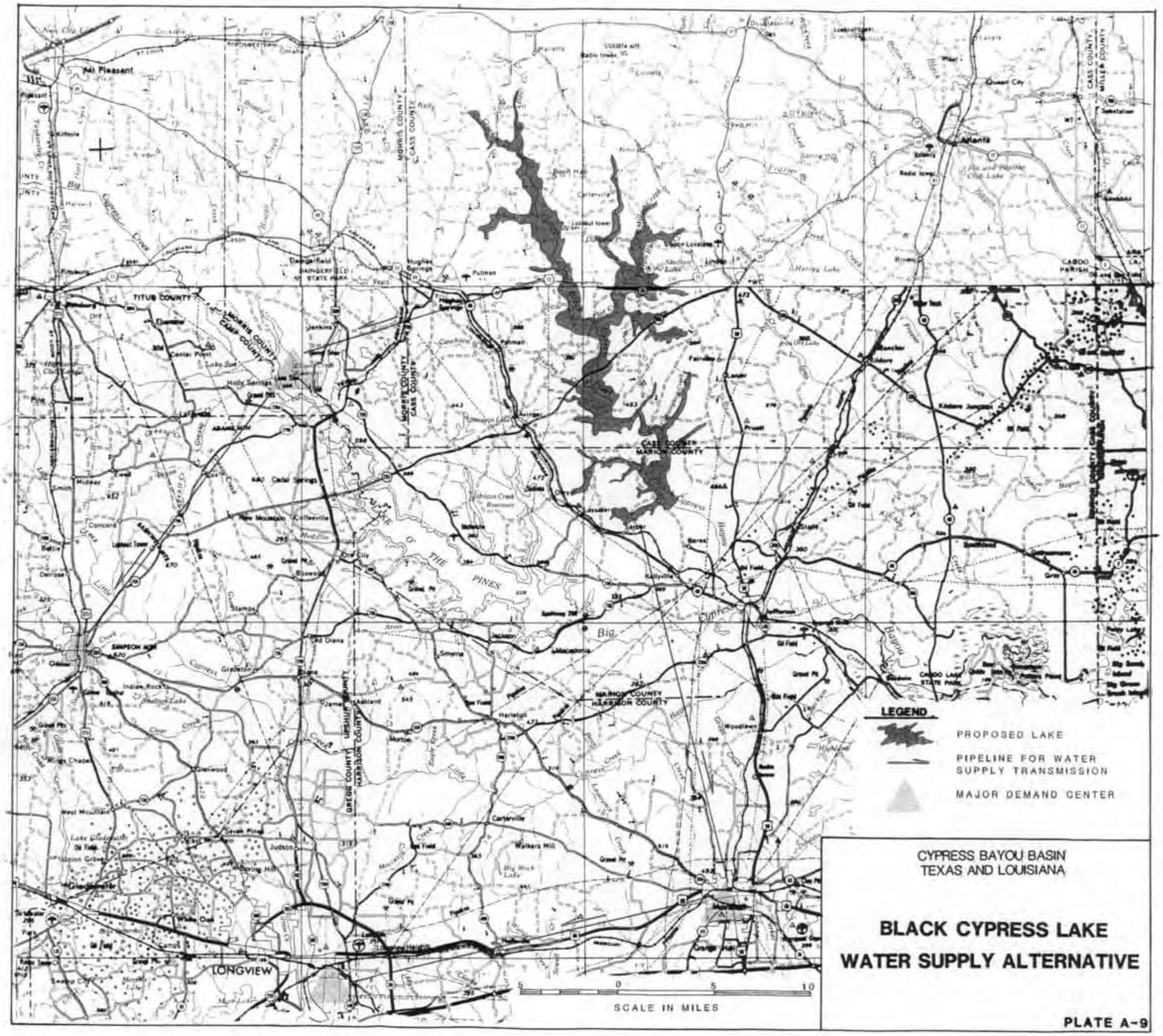
PLATE A-7



CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

PRAIRIE CREEK LAKE
WATER SUPPLY ALTERNATIVE

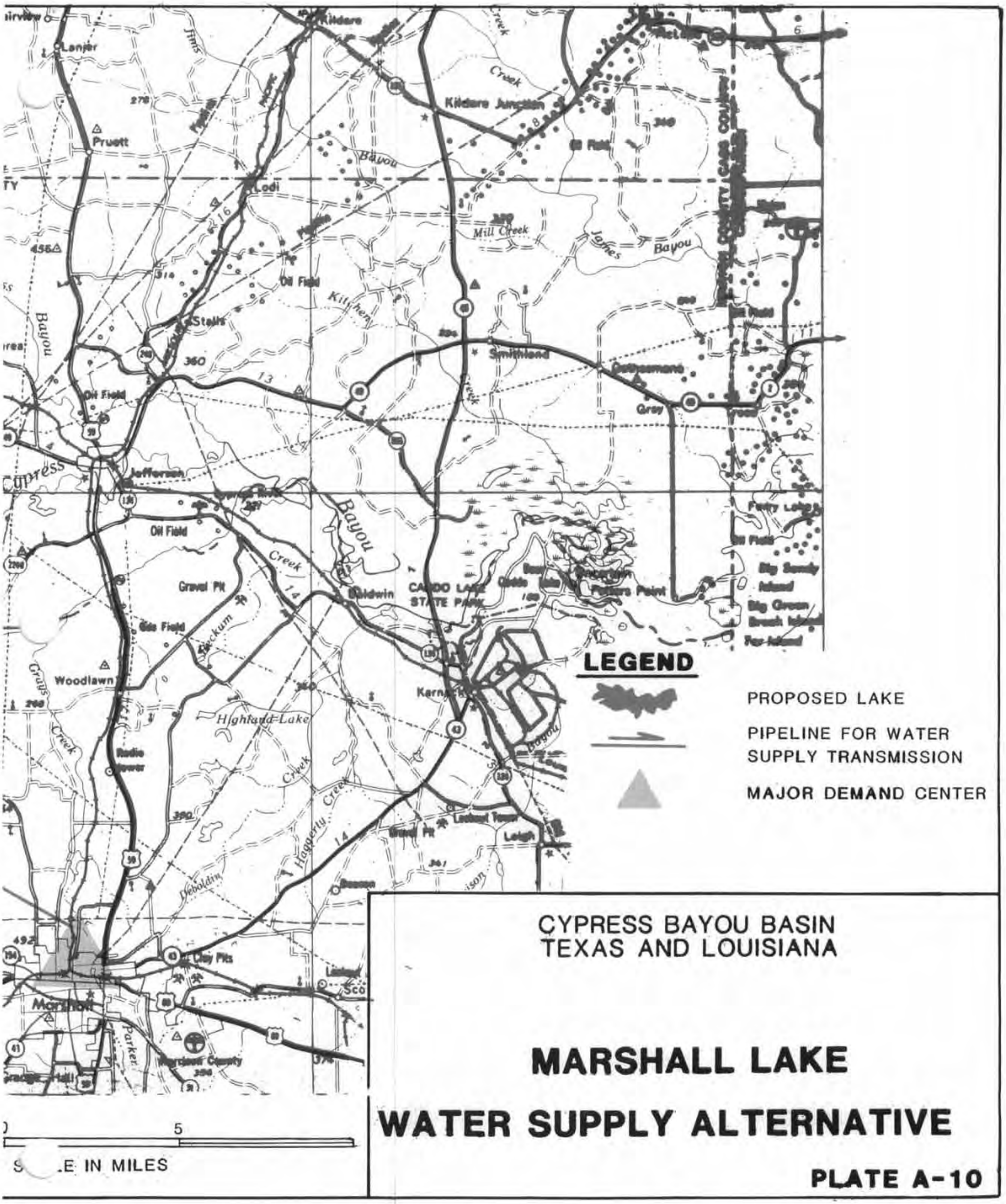
PLATE A-8



CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

BLACK CYPRESS LAKE
WATER SUPPLY ALTERNATIVE

PLATE A-9



CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

MARSHALL LAKE

WATER SUPPLY ALTERNATIVE

PLATE A-10


LONGVIEW
GREGG COUNTY
UPSHUR COUNTY
HARRISON COUNTY
MARION COUNTY
HARRISON COUNTY
MORRIS COUNTY
CASS COUNTY
CASS COUNTY
MARION COUNTY
LAKE O' THE PINES
Big Cypress
Marshall
Gilmer
Ore City
Diana
Ashland
Harleton
Jefferson
Glenwood
Gladewater
Woodlawn
Karnack
SCALE IN MILES
5
0
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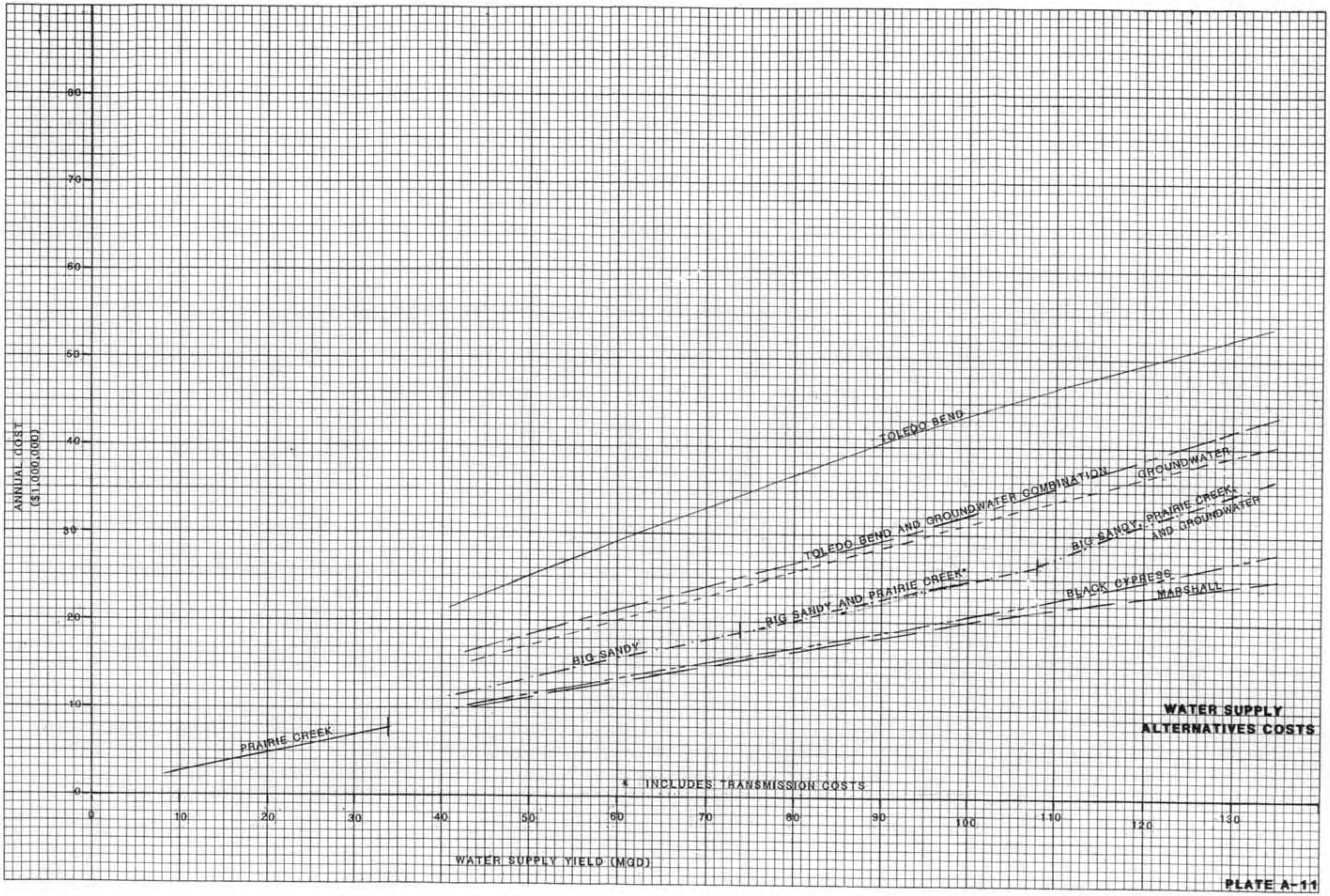


WATER SUPPLY
ALTERNATIVES COSTS

PLATE A-11

WATER SUPPLY ALTERNATIVES TRANSMISSION COSTS

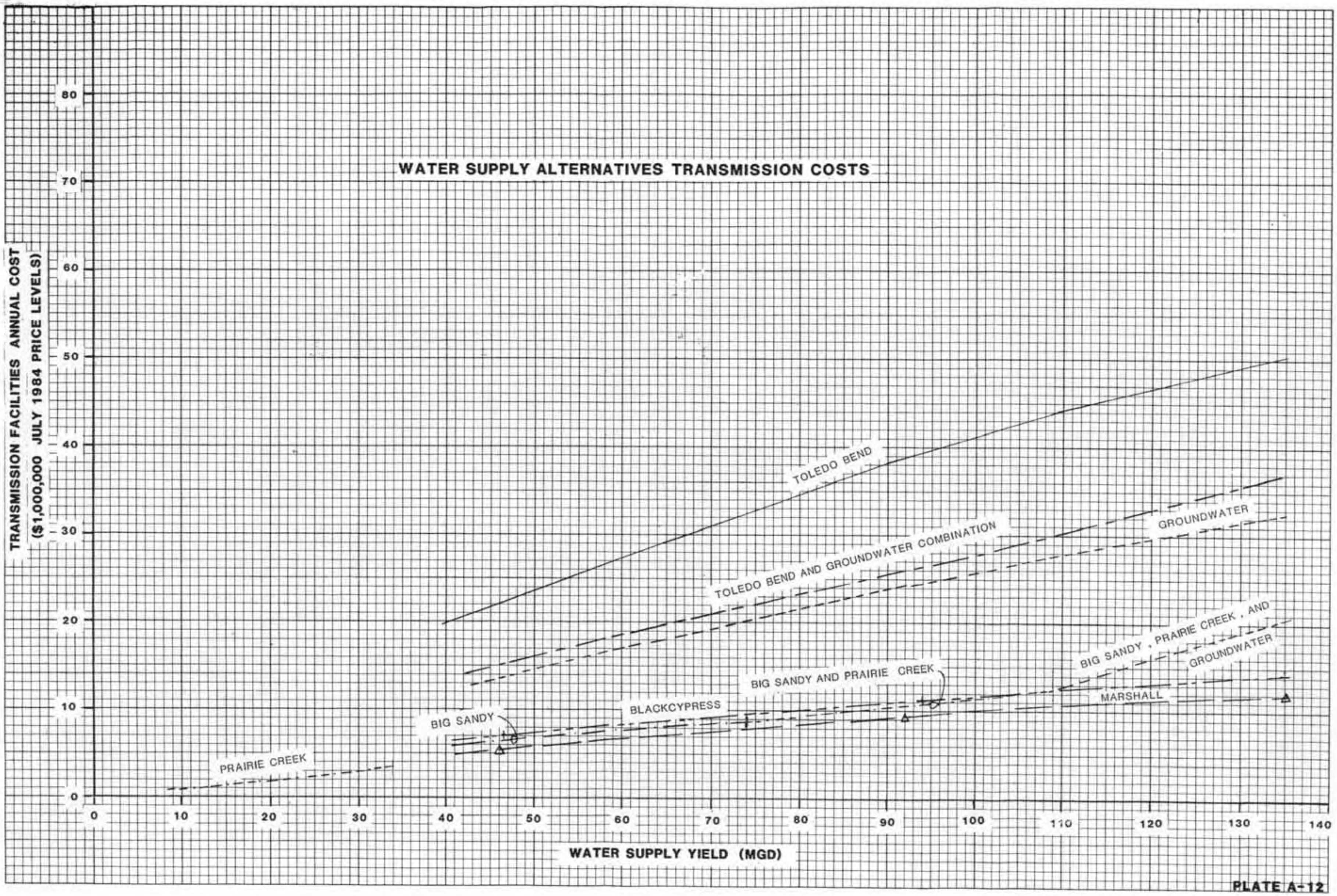
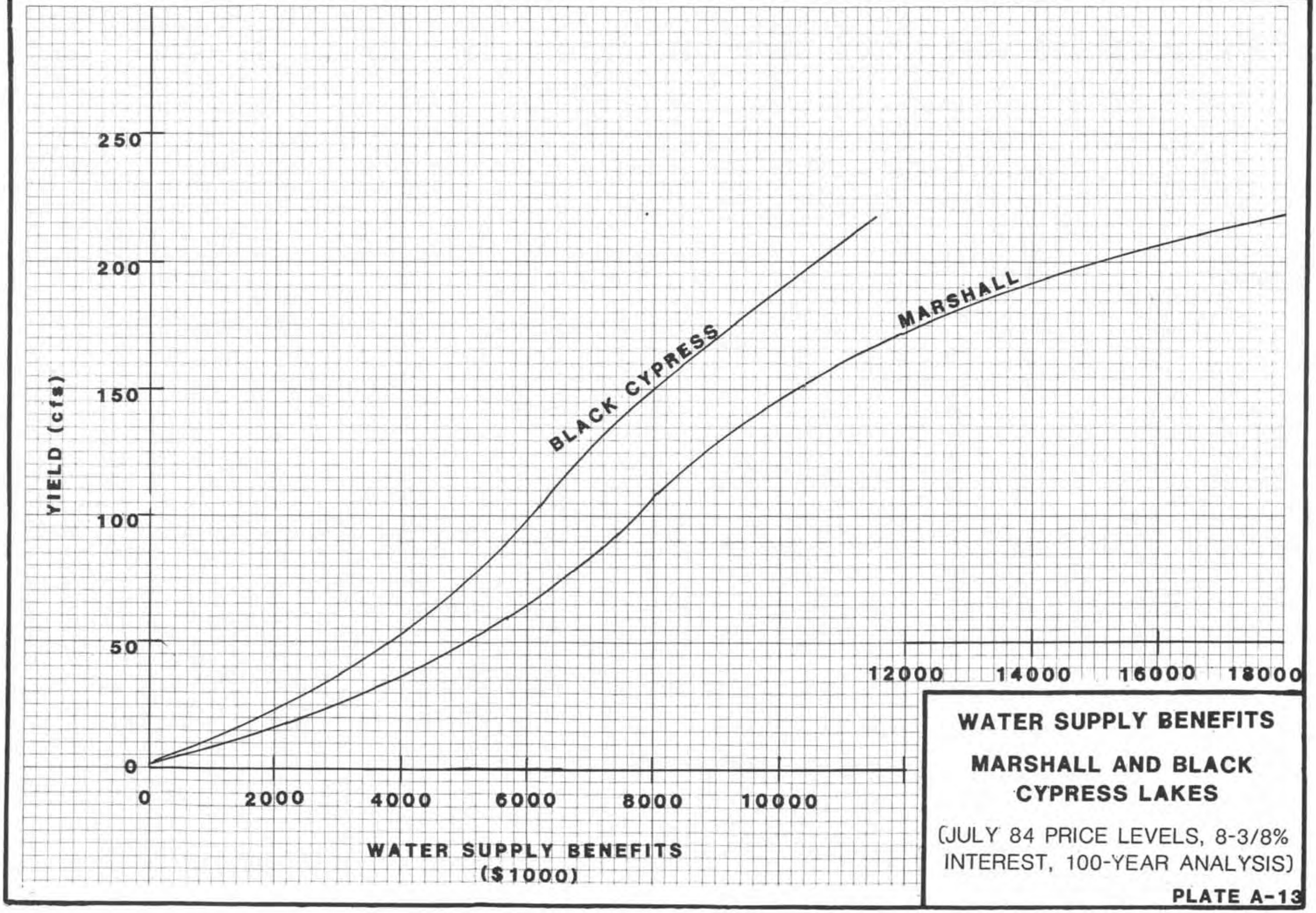


PLATE A-12



WATER SUPPLY BENEFITS

MARSHALL AND BLACK CYPRESS LAKES

(JULY 84 PRICE LEVELS, 8-3/8%
INTEREST, 100-YEAR ANALYSIS)

PLATE A-13

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX B - AREA ECONOMIC
AND WATER SUPPLY STUDIES

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX B

AREA ECONOMIC AND WATER SUPPLY STUDIES

SECTION 1 - AREA ECONOMIC STUDY FOR CYPRESS BAYOU BASIN, TEXAS-LOUISIANA

SECTION 2 - LITTLE CYPRESS WATER SUPPLY STUDY

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX B

AREA ECONOMIC AND WATER SUPPLY STUDIES

SECTION 1 - AREA ECONOMIC STUDY FOR CYPRESS BAYOU BASIN, TEXAS-LOUISIANA

DEPARTMENT OF DEFENSE UNITED STATES OF AMERICA

DEPARTMENT OF THE ARMY
SOUTHWESTERN DIVISION, CORPS OF ENGINEERS
1114 COMMERCE STREET
DALLAS, TEXAS 75242

REPLY TO
ATTENTION OF

23 SEP '81

SWDPL-EA

SUBJECT: Area Economic Study for Cypress Bayou Basin, Texas-Louisiana

Commander, Fort Worth District
ATTN: SWFED-PE

Inclosed is the draft subject study. The summary of the area economic study has been designed for use in the main body of the new style Planning Report should the District desire. Pertinent data and projective material from the text of the area economic study should be integrated into the Economic Volume of the Planning Report.

If there are any questions or suggested revisions, please contact SWDPL-EA by 30 October 1981.

FOR THE COMMANDER:

William L. Pearce

1 Incl
as

for BARRY G. ROUGHT, P.E.
Chief, Planning Division

CYPRESS BAYOU BASIN

Area Economic Study

ARTHUR BIRDWELL
Regional Economist

Department of the Army
Southwestern Division, Corps of Engineers
Dallas, Texas

SUMMARY OF THE REPORT

The study area is comprised of Camp, Cass, Franklin, Gregg, Harrison, Marion, Morris, Titus, Upshur, and Wood Counties, Texas, and Caddo Parish, Louisiana; and includes the Longview-Marshall SMSA and the Shreveport SMSA (Part). The study area is located in northeast Texas and northwest Louisiana, and covers approximately 5,862 square miles.

The study area economy is quite diversified, and has a rapidly growing industrial sector. The study area's economic strength is evidenced by the rapidly growing population and employment levels, ever increasing levels of personal income, and strong services, trade, and manufacturing sectors. The availability of resources such as oil, natural gas, and lignite also add strength to the study area's economic base and future viability.

Historically, population in the study area has grown at a substantial rate. For the 30 year period 1950 to 1980, study area population increased from 406,316 in 1950 to 549,367 in 1980. During this period the Longview-Marshall SMSA represented approximately 27 percent of the study area population, and the Shreveport SMSA (Part) represented nearly 43 percent of the study area population. The "Most Probable" population projections are shown in Table S-1 and indicate continued study area growth to 971,600 inhabitants by 2050. The Longview-Marshall SMSA will represent approximately 31 percent of the study area population, while the Shreveport SMSA (Part) will represent approximately 40 percent of the population.

Employment in services, trade and manufacturing accounted for approximately 70 percent of study area employment in 1970. The Longview-Marshall SMSA represented nearly 30 percent of study area employment in these sectors, and in total employment; while the Shreveport SMSA (Part) represented nearly 50 percent of study area employment in these sectors and in total employment. Two of the largest employers in the study area are Western Electric in Shreveport, with 7,500 employees, and Lone Star Steel in Lone Star, Texas, with 5,000 employees. Employment projections are shown in Table S-1, and indicate continued growth in study area employment to 402,600 by 2050. The Longview-Marshall SMSA will continue to represent approximately 33 percent of the study area employment, while the Shreveport SMSA (Part) will represent approximately 40 percent of the employment, reflecting projected growth in the Non-SMSA portion of the study area.

Per capita personal income (PCPI) in the study area rose 106 percent from $1,926 in 1959 to $3,965 in 1978. For this 19 year period study area PCPI was less than that of the State of Texas and the U.S., but exceeded that of the State of Louisiana. Study area PCPI is projected to increase to $15,099 by 2050, remaining less than that of the U.S. and Texas, but exceeding that of Louisiana. Historically, PCPI in the Longview-Marshall SMSA and the Shreveport SMSA (Part) has exceeded that of the study area, and will continue to do so through the year 2050.

Manufacturing, agriculture, and the oil and natural gas industry have played, and will continue to play, significant roles in the economic processes of the study area economy. Major manufacturing industries include fabricated metals, food and kindred, and machinery (except electrical). Livestock dominates agricultural production in the study area. The oil and natural gas industry is the leading minerals industry in the study area, and is located in one of the largest "oil fields" in the continental United States. Lignite, a low BTU coal, is also found in the study area. Its use, at present, is limited to use as a mine-mouth fuel source at the Montécello Power Plant in Titus County, Texas.

TABLE S-1

SUMMARY OF SELECTED ECONOMIC INDICATORS
CYPRESS BAYOU BASIN STUDY AREA

YEAR	POPULATION	EMPLOYMENT	PER CAPITA INCOME
1950	406,316	146,660	1,926[1]
1980	549,367	210,029	3,965[2]
2000	681,700	282,500	7,041
2050	971,600	402,600	15,099

[1] 1959 data.
[2] 1978 data.
SOURCES: Population, Tables 1 and 4; Employment, Table 6; and Per Capita Income, Table 7.

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CYPRESS BAYOU BASIN

INTRODUCTION

Purpose and Scope. The purpose of this area economic study is to provide basic economic, demographic and other information and projected future growth rates for selected indicators for use in the evaluation of the Cypress Bayou Basin flood control project. Historical and projected data are presented for the United States, the State of Texas, the State of Louisiana, the Cypress Bayou Basin Study Area, the Longview-Marshall SMSA and the Shreveport SMSA (Part: Caddo Parish only). Figure 1 defines the 11-county Cypress Bayou Basin study area, the Longview-Marshall SMSA, the Shreveport SMSA (Part) and the cities of Longview, Marshall, and Shreveport. Indicators projected are population, employment, and per capita income. Historic data including selected manufacturing statistics, farmland use, value of farm products sold (VFPS), and value of mineral production (VMP) have also been incorporated into this study.

Location and Delineation of the Study Area. The study area is comprised of Camp, Cass, Franklin, Gregg, Harrison, Marion, Morris, Titus, Upshur, and Wood Counties, Texas, and Caddo Parish, Louisiana; and includes the Longview-Marshall SMSA and the Shreveport SMSA (Part). The study area is located in northeast Texas and northwest Louisiana, and covers approximately 5,862 square miles. Figure 1 defines the relative location of the eleven county Cypress Bayou Basin study area.

The study area is located in the Gulf Coastal Plain and is characterized by rolling to hilly surface covered with a heavy growth of pine, with hardwoods mixed in the bottomlands along the major rivers and streams. The climate is characterized by hot, humid summers and mild winters.

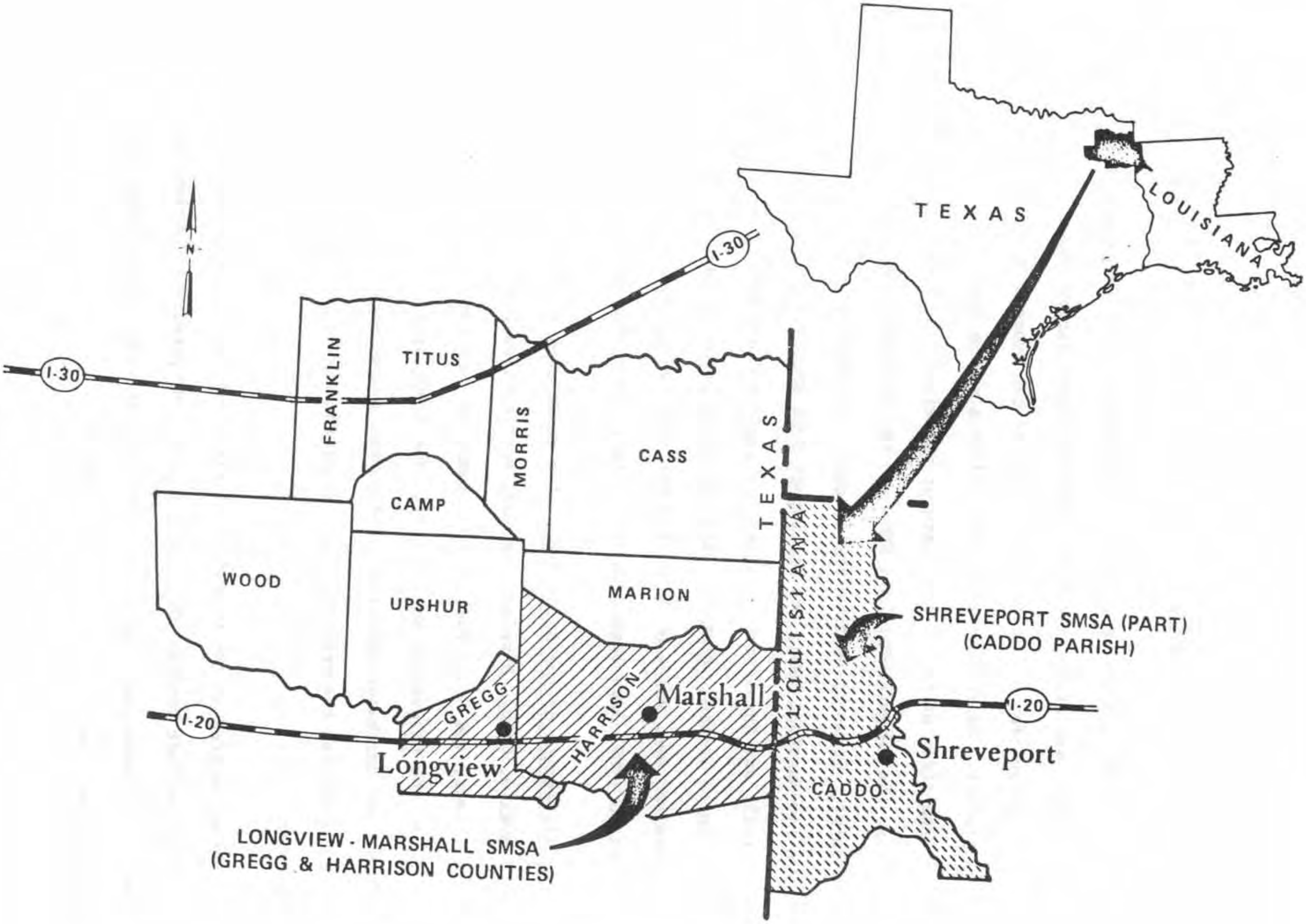

FIGURE 1. CYPRESS BAYOU BASIN STUDY AREA.

The study area has three major cities; Shreveport, Longview, and Marshall. The City of Shreveport, located in Caddo Parish Louisiana, may be considered the "economic center" of the "Ark-La-Tex" region including the study area. The cities of Longview (Gregg County) and Marshall (Harrison County) are located west of Shreveport approximately 60 miles and 35 miles respectively, and comprise the Longview-Marshall SMSA. The remainder of the 11 county study area outside these three urban centers is mainly rural in nature.

The study area is comprised of portions of Bureau of Economic Analysis (BEA) economic areas 130, 131, and 132, and BEA economic area SMSA 211 Shreveport, Louisiana. (The Longview-Marshall SMSA was not identified as a BEA economic area SMSA in the OBERS published data (April, 1974) that were used in the formulation of this study.)

Transportation. Principal highways serving the Cypress Bayou Basin study area include Interstate Highways 20 and 30; U.S. Highways 59, 67, 80, 259, and 271; Texas State Highways 8, 11, 43, 49, 77, 154, 155, and 300; and numerous Farm to Market roads. Interstate Highway 20 is a major east-west highway connecting Shreveport, Louisiana and other major southeastern cities with Dallas/Fort Worth, Texas and other major southwestern cities. Interstate Highway 30 is a major east-west highway connecting Dallas/Fort Worth, Texas with Little Rock, Arkansas. Railroads serving the study area include the Missouri Pacific; Southern Pacific; Kansas City Southern; Louisiana and Arkansas; Atchison, Topeka, and Santa Fe; and the St. Louis and Southwestern. The major airport serving the study area is the Shreveport Regional Airport with regional, national, and international flights daily. The study area is also served by numerous smaller public and private airfields.

River transportation is also planned for the future with the development of the Red River Navigation System. This river navigation system as presently planned, would make the Red River (western boundary of Caddo Parish) navigable from the City of Shreveport to the Mississippi. Estimated completion date of the project is the late 1980's-early 1990's. The Caddo-Bossier Port Commission was formed to develop a river port and industrial park in conjunction with the Red River Navigation project. This planned 2,500 acre park is to be located at Red River in Caddo Parish on the southeast side of Shreveport. To date, 825 acres of undeveloped property in Caddo Parish have been purchased; negotiations are currently underway to purchase an additional, adjacent 300 acres.

HISTORICAL AND PROJECTED ECONOMIC GROWTH

The economic indicators used in this study to measure historical economic growth and development are population, employment, per capita income, farm land use, value of farm products sold, and oil and natural gas and lignite production.

Historical Population. Population in the United States, the State of Texas, the State of Louisiana, the Cypress Bayou Basin study area, the Longview-Marshall SMSA, the Shreveport SMSA (Part) and the non-SMSA portion of the study area is shown in Table 1. For the period 1950 to 1980, population in the State of Texas increased by 6,517,189 inhabitants, or by 85 percent from 7,711,194 inhabitants in 1950 to 14,228,383 inhabitants in 1980 at an average annual rate of 2.06 percent. For the same period 1950 to 1980, population in the State of Louisiana increased from 2,683,516 inhabitants in 1950 to 4,203,972 inhabitants in 1980 at an average annual rate of 1.51 percent. The rates of growth for both the State of Texas and the State of Louisiana exceeded that of the United States which grew at an average annual rate of 1.35 percent for the same period. Such population growth in Texas and Louisiana for this 30 year period is reflective of the trend of U.S. population movement to the south and southwest, especially in the last decade.

The study area also showed substantial population growth during this 30 year period. For the period 1950 to 1980, the study area population increased by 143,051 inhabitants or by 35 percent from 406,316 in 1950 to 549,367 in 1980 at an average annual rate of 1.01 percent.

The Longview-Marshall SMSA population increased by 42,749 inhabitants, or by 39 percent from 1950 to 1980, from 109,003 inhabitants in 1950 to 151,752 in 1980 at an average annual rate of 1.11 percent.

The Shreveport SMSA (Part) population increased by 75,747 inhabitants, or by 43

TABLE 1

HISTORICAL POPULATION, 1950-1980
UNITED STATES, TEXAS, LOUISIANA, CYPRESS BAYOU BASIN STUDY AREA,
LONGVIEW-MARSHALL SMSA, SHREVEPORT SMSA (PART)1/, NON-SMSA PORTION

YEAR	UNITED STATES		TEXAS		LOUISIANA		STUDY AREA		LONGVIEW-MARSHALL SMSA		SHREVEPORT SMSA(PART)		NON-SMSA PORTION	
	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE
1950	151,325,798		7,711,194		2,683,516		406,316		109,003		176,547		120,766	
1960	179,323,175	1.71	9,579,677	2.19	3,257,022	1.96	450,157	1.03	115,030	0.54	223,859	2.41	111,268	-0.82
1970	203,235,298	1.26	11,198,655	1.57	3,644,637	1.13	465,477	0.34	120,770	0.49	230,184	0.28	114,523	0.29
1980	226,505,000	1.09	14,228,383	2.42	4,203,972	1.44	549,367	1.67	151,752	2.31	252,294	0.92	145,321	2.41
1950-1980		1.35		2.06		1.51		1.01		1.11		1.20		0.62
FACTORS OF CHANGE FROM 1950														
1950	1.00		1.00		1.00		1.00		1.00		1.00		1.00	
1960	1.18		1.05		1.21		1.11		1.06		1.27		.92	
1970	1.34		1.22		1.36		1.15		1.11		1.30		.95	
1980	1.50		1.85		1.57		1.35		1.39		1.43		1.20	

1/ Caddo Parish, Louisiana only. Bossier Parish and Webster Parish are officially part of the Shreveport, La. SMSA. However, these two parishes were not included in the study area.
SOURCES: U.S. Bureau of Census, Census of Population, 1950, 1960, 1970, 1980.

percent for the period 1950 to 1980 from 176,547 inhabitants in 1950 to 252,294 inhabitants in 1980 at an average annual rate of 1.20 percent.

The population of the non-SMSA portion of the Cypress Creek Bayou Basin study area increased by 24,555 inhabitants, or by 20 percent for the period 1950 to 1980 from 120,766 inhabitants in 1950 to 145,321 inhabitants in 1980 at an average annual rate of 0.62 percent. A trend of population movement from rural areas to the city is seen as one aspect of the decline in study area non-SMSA population from 1950 to 1960. Population in the non-SMSA portion of the study area declined by 9,498 inhabitants or by 8 percent for the period 1950 to 1960 from 120,766 in 1950 to 111,268 in 1960 at an average annual rate of -0.82 percent. A recent returning of study area non-SMSA population from the city back to the rural areas is reflected in the population growth from 1970 to 1980. Population in the non-SMSA portion of the study area increased by 30,798 inhabitants or by 27 percent for the period 1970 to 1980 from 114,523 inhabitants in 1970 to 145,321 inhabitants in 1980 at an average annual rate of 2.41 percent. This growth rate closely approximates that of the State of Texas and exceeds that of the U.S., the State of Louisiana, the study area, Longview-Marshall SMSA, and the Shreveport SMSA (Part).

Table 2 shows historical population, 1950-1980, for 31 study area communities with a 1980 population of 1,000 or more. Of the communities indicated, 17, or over half, recorded population increases in excess of 50 percent during the period 1950 to 1960, with 8 of these communities recording population increases in excess of 100 percent. Only one community, Jefferson, experienced a decline in population for the 30 year period. Overall, these communities experienced an aggregate population increase of 154,636, from 230,082 inhabitants in 1950 to 384,718 inhabitants in 1980; a 67 percent increase in population by this group of communities.

TABLE 2

CYPRESS BAYOU BASIN COMMUNITIES OVER 1,000 POPULATION IN 1980

COUNTY/ STATE COMMUNITY	1950	1960	1970	1980	% Increase 1950-1980
CADDO PARISH, LA.	176,547	223,859	230,184	252,294	42.90
Blanchard	----	----	806	1,128	39.95 6/
Greenwood	----	----	212	1,043	391.98 6/
Oil City	422	1,430	907	1,323	213.51
Shreveport (Part) 1/	127,206	164,269	181,814	204,943	61.11
Vivian	2,426	2,624	4,046	4,146	70.90
CAMP COUNTY, TX.	8,740	7,849	8,005	9,275	6.12
Pittsburg	3,142	3,976	3,844	4,245	35.11
CASS COUNTY, TX.	26,732	23,496	24,133	29,430	10.09
Atlanta	3,782	4,076	5,007	6,272	65.84
Hughes Springs	1,445	1,813	1,701	2,196	51.97
Linden	1,744	1,832	2,264	2,443	40.08
Queen City	511	1,081	1,227	1,748	242.07
FRANKLIN COUNTY, TX.	6,257	5,101	5,291	6,893	10.16
Mount Vernon	1,433	1,338	1,806	2,025	43.41
GREGG COUNTY, TX.	61,258	69,436	75,929	99,487	62.41
Gladewater 2/	5,305	5,742	5,574	6,548	23.43
Kilgore 3/	9,638	10,092	9,495	10,968	14.20
Liberty City	----	----	----	1,121	----
Longview 4/	24,502	40,050	45,547	62,762	156.15
White Oak	----	1,250	2,300	4,415	253.20
HARRISON COUNTY, TX.	47,745	45,594	44,841	52,265	9.47
Hallsville	617	684	1,038	1,556	152.19
Marshall	22,327	23,846	22,937	24,921	11.62
Waskom	719	1,336	1,460	1,821	153.27
MARION COUNTY, TX.	10,172	8,049	8,517	10,360	1.85
Jefferson	3,164	3,082	2,866	2,643	-16.47
MORRIS COUNTY, TX.	9,433	12,576	12,310	14,629	55.08
Daingerfield	1,668	3,133	2,630	3,030	81.65
Lone Star	----	1,530	1,760	2,036	33.07
Naples	1,346	1,692	1,726	1,908	85.29

TABLE 2 (cont.)

COUNTY/ COMMUNITY STATE	1950	1960	1970	1980	% Increase 1950-1980
TITUS COUNTY, TX.	17,302	16,785	16,702	21,442	23.93
Mt. Pleasant	6,342	8,027	9,459	11,003	73.49
UPSHUR COUNTY, TX.	20,822	19,759	20,976	28,595	37.33
Big Sandy	689	848	1,022	1,258	82.58
Gilmer	4,096	4,312	4,196	5,167	26.15
Ore City	---	819	830	1,050	28.21[7]
WOOD COUNTY, TX.	21,308	17,653	18,589	24,697	15.90
Hawkins	493	868	977	1,302	164.10
Mineola	3,626	3,810	3,926	4,346	19.86
Quitman	927	1,237	1,494	1,893	104.21
Winnsboro[5]	2,512	2,675	3,064	3,458	37.66

1/ Shreveport City portion in Bossier Parish, La., not included
2/ Includes portion in Upshur County
3/ Includes portion in Rusk County
4/ Includes portion in Harrison County
5/ Includes portion in Franklin County
6/ 1970-1980 percentage change
7/ 1960-1980 percentage change

SOURCE: 1960, 1970, and 1980 (Adv.) Census of Population

The substantial growth experienced by the State of Texas, State of Louisiana, the study area, the Longview-Marshall SMSA, the Shreveport SMSA (Part), and the non-SMSA portion of the study area (especially in the last decade) is reflective of the U.S. in-migration of population to the south and southwest.

Population Projections. Table 3 shows historical and alternative population projections for the Cypress Bayou Basin study area. There are two sets of projections shown. The first set is OBERS Series "E". The second set, designated as "most probable", was developed by SWD based primarily on Texas Department of Water Resources (TDWR) projections.

The OBERS Series "E" projections are the most conservative of the two indicating an increase of only 35,923 inhabitants for the period 1970 to 1980, from 465,477 inhabitants in 1970 to 501,400 inhabitants in 1980 at an average annual rate of 0.75 percent; and indicating an increase of 151,400 inhabitants at an average annual rate of 0.38 percent for the 70 year projection period 1980 to 2050. This substantially underestimated 1980 population (47,967 less than the 1980 U.S. Census figure) and average annual growth rate of only 0.38 percent for the period 1980 to 2050 do not seem likely given the study area's growth of 83,890 inhabitants from 1970 to 1980 at an average annual rate of 1.67 percent, and a historical 30 year growth of 143,051 inhabitants from 1950 to 1980 at an average annual rate of 1.01 percent.

The second set of population projections to the year 2000 are based on Texas County projections developed by TDWR, and Caddo Parish, Louisiana, population projections developed by the State of Louisiana, (with adjustments for the 1980 Census figures) and represents the "most probable" future population to the year 2000 for the study area. "Most probable" projections from the year 2000 to 2050 are extrapolations by SWD using linear regression analysis. (Excepting the

TABLE 3

ALTERNATIVE POPULATION PROJECTIONS
CYPRESS BAYOU BASIN STUDY AREA

YEAR	OBERS SERIES "E"		MOST PROBABLE	
	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE
1950	406,316		406,316	
		1.03		1.03
1960	450,137		450,137	
		0.34		0.34
1970	465,477		465,477	
		0.75		1.67
1980	501,400		549,367	
		0.76		1.07
1990	540,600		611,300	
		0.36		1.10
2000	560,200		681,700	
		0.33		0.78
2010	578,700		736,800	
		0.32		0.82
2020	597,400		799,400	
		0.29		0.70
2030	615,000		856,800	
		0.30		0.64
2040	633,400		913,300	
		0.30		0.62
2050	652,800		971,600	
1980-2050		0.38		0.82

FACTORS OF CHANGE FROM 1980

1980	1.00	1.00
1990	1.08	1.11
2000	1.18	1.24
2010	1.15	1.34
2020	1.19	1.46
2030	1.23	1.56
2040	1.26	1.66
2050	1.30	1.77

SOURCE: U.S. Bureau of Census, Census of Population, 1950, 1960, 1970, 1980.
OBERS Series "E", April 1974.
Texas Dept. of Water Resources Population Projections, LP-126, January 22, 1980.
Louisiana State Projections, University of New Orleans, by telephone, April, 1981.

population projections for Marion County, Texas, which are OBERS Series "E" disaggregated population projections adjusted to the 1980 U.S. Census differential). "Most probable" study area population projections indicate an increase of 77 percent for the 70 year period 1980 to 2050, from 549,367 inhabitants in 1980 to 971,600 inhabitants in 2050, at an average annual rate of 0.82 percent. These projections are reflective of historical and recent growth trends in the study area.

Table 4 shows the "most probable" population projections for the United States, State of Texas, State of Louisiana, the Cypress Bayou Basin study area, the Longview-Marshall SMSA, the Shreveport SMSA (Part) and the Non-SMSA Portion of the study area. The United States projections, State of Texas projections, and the State of Louisiana projections are by the U.S. Department of Commerce, Bureau of Economic Analysis. These projections were published in Survey of Current Business, Nov. 1980. The Cypress Bayou Basin study area population projections are as defined above. The Longview-Marshall SMSA population projections are an aggregate of the population projections for Gregg and Harrison Counties, Texas, which comprise the Longview-Marshall SMSA. "Most probable" population projections for the Longview-Marshall SMSA indicate an increase of nearly 100 percent (doubling) in population for the 70 year period 1980 to 2050, from 151,752 in 1980 to 301,500 in 2050 at an average annual rate of 0.99 percent.

The Shreveport SMSA (Part) population projections are those populations projections for Caddo Parish, Louisiana. "Most probable" population projections for the Shreveport SMSA (Part) indicate an increase of 51 percent in population for the 70 year period 1980 to 2050, from 252,294 in 1980 to 380,300 in 2050 at an average annual rate of 0.59 percent.

TABLE 4

MOST PROBABLE POPULATION PROJECTIONS - 1980-2050
UNITED STATES, TEXAS, LOUISIANA, CYPRESS BAYOU BASIN STUDY AREA, LONGVIEW-MARSHALL SMSA, SHREVEPORT SMSA (PART), NON SMSA PORTION

	UNITED STATES		TEXAS		LOUISIANA		STUDY AREA		LONGVIEW-MARSHALL SMSA		SHREVEPORT SMSA (PART)		NON-SMSA PORTION	
YEAR	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE	POPULATION	AVERAGE ANNUAL % CHANGE
1980	226,505,000		14,228,383		4,203,972		549,367		151,752		252,294		145,321	
		0.70		1.16		0.77		1.07		1.35		0.72		1.38
1990	242,979,000		15,972,000		4,539,000		611,300		173,500		271,000		166,700	
		0.67		1.28		0.77		1.10		1.48		0.63		1.42
2000	259,845,000		18,130,000		4,901,000		681,700		201,000		288,700		192,000	
		0.56		0.94		0.70		0.78		0.88		0.59		0.95
2010	274,802,000		19,915,000		5,253,000		736,800		219,500		306,200		211,100	
		0.53		0.68		0.70		0.82		0.99		0.59		0.97
2020	289,582,000		21,317,000		5,582,000		799,400		242,300		324,700		232,400	
		0.35		0.42		0.35		0.70		0.78		0.56		0.80
2030	299,817,000		22,240,000		5,780,000		856,800		262,000		343,200		251,600	
		0.35		0.42		0.35		0.64		0.70		0.53		0.73
2040	310,413,000		232,030,000		5,985,000		913,300		281,000		361,800		270,500	
		0.35		0.42		0		0.62				0.50		0.69
2050	321,385,000		24,208,000		6,197,300		971,600		301,500		380,300		289,800	
		0.50		0.76		0.56		0.82		0.99		0.59		0.99

FACTORS OF CHANGE FROM 1980

1980	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1990	1.07	1.12	1.08	1.11	1.14	1.07	1.15
2000	1.15	1.27	1.17	1.24	1.32	1.14	1.32
2010	1.21	1.40	1.25	1.34	1.45	1.21	1.45
2020	1.28	1.50	1.33	1.46	1.60	1.29	1.60
2030	1.32	1.56	1.37	1.56	1.73	1.36	1.73
2040	1.37	1.63	1.42	1.66	1.85	1.43	1.86
2050	1.42	1.70	1.47	1.77	1.99	1.51	1.99

SOURCES: Bureau of Economic Analysis, State Projections, Survey of Current Business, Nov. 1980.

The population projections for the Non-SMSA Portion of the Cypress Bayou Basin study area were computed as the difference between the study area population projections and those of the SMSA's. "Most probable" population projections for the Non-SMSA Portion of the study area indicate an increase of nearly 100 percent (doubling) in population for the 70 year period 1980 to 2050, from 145,321 inhabitants in 1980 to 289,800 inhabitants in 2050, at an average annual rate of 0.99 percent.

The "most probable" population projections indicate continued population growth in the Cypress Bayou Basin study area, and are reflective of the national trend of migration to the south and southwest. Local factors conducive to continued growth include: assertive Chambers of Commerce activity throughout the study area; available labor supply; mild year-round climate; and readily available natural gas and water for industry. Other factors such as favorable Texas state tax policies also contribute to the attractiveness for people and industry to locate in the study area. Favorable Texas state tax policies prevailing in the study area include no corporate or personal income tax; lowest unemployment tax rate to employers in U.S.; low state and local property tax burden per capita ($50 below national average); second lowest per capita tax burden in the U.S.; and the lowest motor fuels tax in the United States.

The Non-SMSA Portion of the study area showed significant population growth, especially in the recent decade 1970 to 1980 with population increasing by 27 percnt for that period. Such growth is expected to continue for the 70 year period 1980 to 2050, with the Non-SMSA Portion comprising 26 to 30 percent of the study area population during the period. A growth in small "bedroom farms" of 10 to 20 acres will continue as inhabitants find attraction to the rural environment of the study area. Families will continue to work "in town"; not necessarily in the large urban centers of the study area (though they will continue to grow), but also in the small towns of the study area where job-providing industries will continue to locate.[1]

Employment. Employment by industry in 1970 for the United States, Texas, Louisiana, the Cypress Bayou Basin study area, the Longview-Marshall SMSA, the Shreveport SMSA (Part), and the Non-SMSA Portion of the study area is shown in Table 5. The percentage distribution by industry is also shown. Employment in 1970 totaled 78,551,334 in the United States, 4,308,360 in Texas, 1,161,571 in Louisiana, 170,139 in the Cypress Bayou Basin study area, 46,499 in the Longview-Marshall SMSA, 83,496 in the Shreveport SMSA (Part), and 40,144 in the Non-SMSA Portion of the study area. Services, manufacturing and trade were leading employment sectors of the study area economy. Services was the leading sector of the study area economy with the percentage distribution of the study area work force employed in services exceeding that of the U.S., the State of Texas, the Longview-Marshall SMSA and the Non-SMSA Portion of the study area; but less than that of the State of Louisiana and the Shreveport SMSA (Part). Approximately 27.3 percent of the study area work force was employed in the services sector compared with 25.6 percent for the U.S., 25.9 for Texas, 29 percent for Louisiana, 25.4 percent for the Longview-Marshall SMSA, 30.5 percent (largest of the economic areas considered) for the Shreveport SMSA (Part), and only 22.8 percent for the Non-SMSA Portion of the study area. The Caddo Parish School Board with approximately 5,300 employees, Louisiana State University Medical Center with approximately 2,500 employees, and Shumpert Medical Center with approximately 1,600 employees, all located in the City of Shreveport, contribute significantly to the strong services sector of the study area economy.[2]

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[1] Fred Pass, Dallas Morning News, May 6, 1981.

[2] Shreveport Chamber of Commerce, List of Major Shreveport/Bossier Employees, 1981.

TABLE 5

EMPLOYMENT BY INDUSTRY SECTOR-1970
FOR THE UNITED STATES, TEXAS, LOUISIANA, CYPRESS BAYOU BASIN STUDY AREA, LONGVIEW-MARSHALL SMSA, SHREVEPORT SMSA (PART)

JSTRY SECTOR	UNITED STATES		TEXAS		LOUISIANA		STUDY AREA		LONGVIEW-MARSHALL SMSA		SHREVEPORT SMSA (PART)		NON-SMSA PORTIO	
	EMPLOYMENT	PERCENT OF TOTAL	EMPLOYMENT	PERCENT OF TOTAL	EMPLOYMENT	PERCENT OF TOTAL	EMPLOYMENT	PERCENT OF TOTAL	EMPLOYMENT	PERCENT OF TOTAL	EMPLOYMENT	PERCENT OF TOTAL	EMPLOYMENT	PERCE TOT
ICULTURE	2,840,488	3.6	194,635	4.5	47,999	4.1	4,526	2.7	744	1.6	1,368	1.6	2,414	6.0
ING	630,788	0.8	103,075	2.4	46,584	4.0	5,679	3.3	1,710	3.7	2,977	3.6	992	2.4
STRUCTION	4,572,235	5.8	317,758	7.7	96,609	8.3	11,699	6.9	3,282	7.1	5,280	6.3	3,137	7.8
JFACTURING	19,837,208	25.3	765,119	17.8	184,024	15.8	36,762	21.6	11,455	24.6	14,916	17.9	10,391	25.
NSPORTATION, OMMUNICATION UTILITIES	5,186,101	6.6	286,195	6.6	95,757	8.2	11,934	7.0	2,898	6.2	6,467	7.8	2,569	6.
LESALE & ETAIL TRADE	15,372,880	19.6	918,693	21.3	245,661	21.2	35,093	20.6	9,496	20.4	18,341	22.0	7,256	18.
NCE, INSURANCE, REAL ESTATE	3,838,387	4.9	213,261	4.9	51,250	4.4	7,012	4.1	1,685	3.6	4,233	5.1	1,094	2.
ICES	20,073,860	25.6	1,116,993	25.9	336,841	29.0	46,430	27.3	11,792	25.4	25,495	30.5	9,143	22.
LIAN GOVERNMENT	4,201,652	5.3	225,800	5.2	53,520	4.6	6,393	3.8	1,306	2.8	3,499	4.2	1,588	4.0
D FORCES	1,997,735	2.5	166,831	3.9	3,326	0.3	4,611	2.7	2,131	4.6	920	1.1	1,560	3.
TOTAL	78,551,334	100.0	4,308,360	100.0	1,161,571	100.0	170,139	100.0	46,499	100.0	83,496	100.0	40,144	100.0

SOURCE: U.S. Bureau of Census, 1970 Census of Population, General and Economic Characteristics

Manufacturing was the second-leading sector of the study area economy with the percentage distribution of the study area work force employed in manufacturing exceeding that of Texas, Louisiana, and the Shreveport SMSA (Part); but less than that of the U.S., the Longview-Marshall SMSA and the Non-SMSA Portion of the SMSA. Approximately 21.6 percent of the study area work force was employed in the manufacturing sector compared with 17.8 percent for Texas, 15.8 percent for Louisiana, 17.9 percent for the Shreveport SMSA (Part), and approximately 25 percent each for the U.S., the Longview-Marshall SMSA and the Non-SMSA Portion of the study area. Western Electric in Shreveport, with approximately 7,500 employees; Lone Star Steel in Lone Star, Texas, with approximately 5,000 employees;3/ Marathon LeTourneau Co. in Longview, Texas, with approximately 1,600 employees; Texas Eastman Co. in Longview, with approximately 2,200 employees; Kast Metal Corp. in Shreveport, with approximately 1,600 employees and Riley Beaird, Inc. in Shreveport, with approximately 1,300 employees contribute significantly to the strong manufacturing sector of the study area economy.

Approximately 20.6 percent of the study area work force was employed in the wholesale and retail trade sector, the third leading economic sector in terms of employment. This percentage distribution closely approximated that of the U.S., Texas, Louisiana, the Longview-Marshall SMSA, the Shreveport SMSA (Part), the Non-SMSA Portion of the study area.

The study area also had a relatively high percentage of the workforce (3.3 percent) employed in the mining sector (in this case, the oil and gas industry) compared to that of the U.S. (0.8 percent). Texas, Louisiana, the Longview-Marshall SMSA, the Shreveport SMSA (Part) and the Non-SMSA Portion of the study area also had relatively high percentages of the workforce employed in the mining sector (oil

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3/ Field trip to Lone Star Steel, Public Affairs Office, Lone Star, Texas, May 14,1981.

and gas industry) ranging between 2.4 and 4.0 percent. Such workforce distribution is reflective of the importance of the oil and gas industry in Texas, Louisiana, and the study area.

Study area employment distribution in the agriculture; construction, transportation, communications and utilities; finance, insurance and real estate; civilian government; and armed forces sectors of the economy was very similar to that of the U.S., Texas, Louisiana, the Longview-Marshall SMSA, the Shreveport SMSA (Part), and the Non-SMSA Portion of the study area. Two exceptions should be noted, however. The Non-SMSA Portion of the study area showed a relatively high percentage of the workforce employed in agriculture (6.0 percent) compared to the other economies; and Louisiana and the Shreveport SMSA (Part) showed relatively low percentages of the workforce employed in the armed forces (0.3 percent and 1.1 percent, respectively) compared to other economic areas.

Overall, the Shreveport SMSA (Part) employment level of 83,496 in 1970 represented 49 percent of the 11 county study area total of 170,139, reflecting the importance of the Shreveport SMSA (Part) in the study area economy. The Longview-Marshall SMSA employment level of 46,499 in 1970 represented 27 percent of the study area employment total, with the remaining 40,144 or 24 percent located throughout the remaining eight county Non-SMSA Portion of the study area.

The City of Shreveport and its urban fringe is the largest employement center in the study area. Currently the Shreveport area has 12 companies with over 1,000 employees; 13 companies with 500 to 1,000 employees; 14 companies with 300 to 499 employees; 21 companies with 200 to 299 employees; and 36 companies with 100 to 199 employees. These companies produce a variety of goods and services for local, regional, national and international markets. These goods and services include education, medical and health services, electronic components and equipment, oil and natural gas products, chain saws, glassware, batteries & trucking services, fabricated metal products, etc. [4]

Included among employers in the educational services sector of the study area economy are six colleges: East Texas Baptist College at Marshall with approximately 44 faculty; Kilgore College at Kilgore with approximately 135 faculty; LeTourneau College at Longview with 62 faculty; Centenary College in Shreveport with 107 facultry; Louisiana State University at Shreveport with 122 faculty; and Southern University at Shreveport with 48 faculty.

Employment Projections. Employment projections to the year 2050 are shown in Table 6 for the United States, Texas, Louisiana, the Cypress Bayou Basin study area, the Longview-Marshall SMSA, the Shreveport SMSA (Part), and the Non-SMSA Portion of the study area. Employment projections were developed by applying the OBERS Series "E" employment/population ratios to the "most probable" population projections for the respective years shown in Table 4. Employment in the study area is projected to total 402,600 by 2050, an increase of 92 percent over 1980 figures, with an average annual growth rate of 0.93 for the 70 year period. The study area employment growth rate for the 70 year period will exceed the average annual growth rate of the U.S. (0.50 percent); the State of Louisiana (0.71 percent), and the Shreveport SMSA (Part) (0.70 percent); but will be less than that of the State of Texas (1.23 percent); the Longview-Marshall SMSA (1.06 percent); and the Non-SMSA Portion of the study area (1.17 percent). The Shreveport SMSA will continue to have the largest percentage of the study area employment, though its share of the aggregate is expected to decline slightly from approximately 47 percent in 1980 to approximately 40 percent in 2050. The Longview-Marshall SMSA percentage share of the study area employment is expected to increase slightly from

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[4] Shreveport Chamber of Commerce, List of Major Shreveport/Bossier Employers, 1981.

TABLE 6

EMPLOYMENT, 1950-2050
FOR THE UNITED STATES, TEXAS, LOUISIANA, CYPRESS BAYOU BASIN STUDY AREA, LONGVIEW-MARSHALL SMSA, SHREVEPORT SMSA (PART), NON-SMSA PORTION

YEAR	UNITED STATES		TEXAS		LOUISIANA		STUDY AREA		LONGVIEW-MARSHALL SMSA		SHREVEPORT SMSA (PART)		NON-SMSA PORTION	
	EMPLOYMENT	AVERAGE ANNUAL % CHANGE	EMPLOYMENT	AVERAGE ANNUAL % CHANGE	EMPLOYMENT	AVERAGE ANNUAL % CHANGE	EMPLOYMENT	AVERAGE ANNUAL % CHANGE	EMPLOYMENT	AVERAGE ANNUAL % CHANGE	EMPLOYMENT	AVERAGE ANNUAL % CHANGE	EMPLOYMENT	AVERAGE ANNUAL % CHANGE
1950	57,474,912		2,860,272		886,432		146,660		39,974		68,017		38,669	
1960	66,372,649	1.45	3,480,858	1.98	1,026,911	1.48	155,353	0.58	40,019	0.01	80,906	1.75	34,428	-1.15
1970	78,551,334	1.70	4,308,360	2.16	1,158,245	1.21	170,139	0.91	46,499	1.51	83,496	0.32	40,144	1.55
1980	97,270,000	2.16	6,057,000	3.47	1,549,200	2.95	210,029	2.13	63,533	3.17	97,700	1.58	48,796	1.97
1990	106,338,000	0.90	6,898,600	1.31	1,702,800	0.95	242,400	1.44	73,000	1.40	108,700	1.07	60,700	2.23
2000	117,891,000	1.04	8,314,600	1.88	1,937,400	1.30	282,500	1.54	86,500	1.71	120,800	1.06	75,200	2.17
2010	128,018,000	0.83	9,383,700	1.22	2,106,500	0.84	305,300	0.80	96,000	1.05	128,700	0.64	80,600	0.70
2020	130,534,000	0.19	10,513,000	1.14	2,269,600	0.75	331,300	0.82	106,000	1.00	137,400	0.66	87,900	0.87
2030	133,099,200	0.19	11,642,400	1.03	2,369,800	0.43	355,100	0.70	116,000	0.63	144,100	0.48	95,000	0.78
2040	135,649,400	0.19	12,898,700	1.03	2,453,800	0.35	378,500	0.64	123,500	0.63	152,000	0.54	103,000	0.81
2050	138,248,900	0.19	14,290,600	1.03	2,540,900	0.35	402,600	0.62	132,500	0.71	159,700	0.50	110,400	0.70
1980-2050		0.50		1.23		0.71		0.93		1.06		0.70		1.17

FACTORS OF CHANGE FROM 1980

YEAR	UNITED STATES	TEXAS	LOUISIANA	STUDY AREA	LONGVIEW-MARSHALL SMSA	SHREVEPORT SMSA (PART)	NON-SMSA PORTION
1980	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1990	1.09	1.14	1.10	1.15	1.15	1.11	1.24
2000	1.21	1.37	1.25	1.35	1.36	1.24	1.54
2010	1.32	1.55	1.36	1.45	1.51	1.32	1.65
2020	1.34	1.74	1.47	1.58	1.67	1.41	1.80
2030	1.37	1.92	1.53	1.69	1.83	1.47	1.95
2040	1.39	2.13	1.58	1.80	1.94	1.56	2.11
2050	1.42	2.36	1.64	1.92	2.09	1.63	2.26

SOURCES: U.S. Bureau of Census, Census of Population 1950, 1960, 1970.
Texas Employment Commission.
OBERS Series "E", April 1974.

approximately 30 percent in 1980, to approximately 33 percent in 2050. Likewise, the Non-SMSA Portion of the study area percentage share of the study area employment is expected to increase slightly from approximately 23 percent in 1980 to 27 percent in 2050. The relatively high employment growth rates reflect the diversified economy of the study area and the national trend of migration of population, labor and business to the south and southwest.

Per Capita Personal Income. As is shown in Table 7, in each of the years 1959, 1969, and 1978, per capita income in Texas, Louisiana, the study area, the Longview-Marshall SMSA, the Shreveport SMSA (Part) and the Non-SMSA Portion of the study area was less than that of the United States. Per capita personal income (PCPI) in the Cypress Bayou Basin study area exceeded that of the State of Louisiana, but was less than that of the State of Texas and the United States for the years 1959, 1969, and 1978. Both the Shreveport SMSA (Part) PCPI and the Longview-Marshall SMSA PCPI exceed that of the study area for 1969 and 1978. PCPI in the Non-SMSA Portion of the study area was exceeded by that of the study area for each of the years 1959, 1969, and 1978. Per capita personal income for the U.S. increased from $2,490 in 1959 to $4,317 in 1978, a 73 percent increase for the 19 year period. PCPI for the State of Texas increased 97 percent for the same period from $2,163 in 1959 to $4,265 in 1978. PCPI for the State of Louisiana increased 96 percent for the same period from $1,857 in 1959 to $3,644 in 1978. PCPI for the Cypress Bayou Basin study area increased 106 percent for the 19 year period from $1,926 in 1959 to $3,965 in 1978.

Within the study area, for the 19 year period 1959 to 1978, the Non-SMSA Portion of the study area showed the largest percentage increase in PCPI with 149 percent followed by the Longview-Marshall SMSA with 121 percent and the Shreveport SMSA (Part) with 81 percent.

Per Capita Personal Income Projections. The Per Capita Personal Income (PCPI) projections for the U.S., the State of Texas, the State of Louisiana, the Cypress Bayou Basin study area, the Longview-Marshall SMSA, the Shreveport SMSA (Part), and the Non-SMSA Portion of the study area are shown in Table 7. The PCPI projections to the year 2020 are computed using OBERS Series "E" PCPI growth rates applied to 1980 estimated PCPI figures. Extrapolations to 2030, 2040, and 2050 are by SWD. PCPI for the Cypress Bayou Basin study area is expected to grow at an average annual growth rate comparable to that of the United States and the State of Texas, but slightly lower than that of the State of Louisiana for the 72 year period 1978 to 2050. During this period, study area PCPI is expected to remain slightly below that of both the U.S. and the State of Texas, but will

TABLE 7

PER CAPITA PERSONAL INCOME - 1959-2050
UNITED STATES, TEXAS, LOUISIANA, CYPRESS BAYOU BASIN STUDY AREA, LONGVIEW-MARSHALL SMSA, & SHREVEPORT SMSA (PART)

YEAR	UNITED STATES		TEXAS		LOUISIANA		STUDY AREA		LONGVIEW-MARSHALL SMSA		SHREVEPORT SMSA (PART)		NON-SMSA PORTION	
	PER CAPITA INCOME	AVERAGE ANNUAL % CHANGE	PER CAPITA INCOME	AVERAGE ANNUAL % CHANGE	PER CAPITA INCOME	AVERAGE ANNUAL % CHANGE	PER CAPITA INCOME	AVERAGE ANNUAL % CHANGE	PER CAPITA INCOME	AVERAGE ANNUAL % CHANGE	PER CAPITA INCOME	AVERAGE ANNUAL % CHANGE	PER CAPITA INCOME	AVERAGE ANNUAL % CHANGE
1959	2,490		2,163		1,857		1,926		1,904		2,199		1,471	
		3.39		3.44		3.54		3.73		4.24		3.05		4.41
1969	3,397		3,034		2,630		2,778		2,884		2,969		2,265	
		2.70		3.86		3.31		4.03		4.31		3.34		5.47
1978	4,317		4,265		3,644		3,965		4,217		3,991		3,659	
		5.23		2.41		2.67		2.27		2.02		2.84		1.45
1980	4,780		4,473		3,841		4,147		4,389		4,221		3,766	
		2.85		2.41		2.67		2.26		2.03		2.85		1.45
1990	6,166		5,675		4,997		5,188		5,365		5,590		4,351	
		2.85		2.93		3.11		3.10		3.17		3.04		3.25
2000	8,165		7,573		6,788		7,041		7,331		7,539		5,988	
		2.44		2.83		3.04		2.84		2.70		3.01		2.75
2010	10.394		10,009		9,156		9,319		9,573		10,145		7,856	
		2.44		2.21		2.43		2.52		2.70		2.32		2.76
2020	13,232		12,450		11,639		11,951		12,496		12,755		10,310	
		1.22		1.26		1.37		1.34		1.44		1.33		1.46
2030	14,938		14,111		13,336		13,653		14,416		14,557		11,916	
		0.61		0.63		0.68		0.67		0.72		0.67		0.73
2040	15,875		15,026		14,271		14,596		15,488		15,562		12,815	
		0.31		0.32		0.32		0.34		0.36		0.34		0.37
2050	16,374		15,514		14,734		15,099		16,055		16,099		13,297	
1978-2050		1.87		1.81		1.96		1.87		1.87		1.96		1.81

FACTORS OF CHANGE FROM 1978

1978	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1980	1.11	1.05	1.05	1.05	1.04	1.06	1.03
1990	1.43	1.33	1.37	1.31	1.27	1.40	1.19
2000	1.89	1.78	1.86	1.78	1.74	1.89	1.64
2010	2.41	2.35	2.51	2.35	2.27	2.54	2.15
2020	3.07	2.92	3.19	3.01	2.96	3.20	2.82
2030	3.46	3.31	3.66	3.44	3.42	3.65	3.26
2040	3.68	3.52	3.92	3.68	3.67	3.90	3.50
2050	3.79	3.64	4.04	3.81	3.81	4.03	3.63

1/ Interpolated by SWD.
2/ Extrapolated by SWD - 2030 at 1/2 2000-2020 rate; 2040 at 1/2 2030 rate; 2050 at 1/2 2040 rate.
SOURCES: Survey of Current Business, April, 1980.
OBERS Series E, April, 1974.

continue to exceed that of the State of Louisiana. The projected average annual growth rates for the study area, Texas, Louisiana and the U.S. for the 72 year period are 1.87 percent, 1.81 percent, 1.96 percent and 1.87 percent, respectively.

The PCPI average annual growth rates for the Longview-Marshall SMSA and the Non-SMSA Portion of the study area for the 72 year period 1978 to 2050 are comparable to those of the study area, the State of Texas and the United States. The PCPI average annual growth rate for the Shreveport SMSA (Part) for this same period approximates that of the State of Louisiana. For the 72 year period 1978 to 2050 the PCPI of the Longview-Marshall SMSA and the Shreveport SMSA (Part) are expected to exceed that of the study area, the State of Louisiana and the State of Texas, but be slightly lower than that of the United States. PCPI for the Non-SMSA portion of the study area for the same period is expected to be substantially less than that of the other areas.

Manufacturing. Table 8 shows selected manufacturing statistics for the Cypress Bayou Basin study area, the Longview-Marshall SMSA and the Shreveport SMSA (Part) for the years 1967 and 1977. In the 11 county study area the number of establishments increased 37 percent from 537 in 1967 to 737 in 1977. Value Added By Manufacture (VAM) increased by 77 percent from $388.2 million in 1967 to $688.2 million in 1977 at an average annual rate of 5.89 percent. Total manufacturing employment increased by 57 percent from 27,200 in 1967 to 42,700 in 1977.

The Longview-Marshall SMSA also showed substantial growth in manufacturing for the ten year period 1967 to 1977. In the Longview-Marshall SMSA, the number of establishments increased 50 percent from 161 in 1967 to 242 in 1977. Value Added By Manufacture (VAM) increased by 55 percent from $212.1 million in 1967 to $328.7 million in 1977, at an average annual rate of 4.47 percent. Total manufacturing employment increased by 23 percent from 12,900 in 1967 to 15,900 in 1977.

TABLE 8

SELECTED MANUFACTURING STATISTICS-CYPRESS BAYOU BASIN STUDY AREA, LONGVIEW-MARSHALL SMSA, & SHREVEPORT SMSA (PART) - 1967,1977
(MILLIONS OF 1967 DOLLARS)

	CYPRESS BAYOU BASIN STUDY AREA						LONGVIEW-MARSHALL SMSA						SHREVEPORT SMSA (PART)					
	ESTABLISHMENTS		VALUE ADDED BY MANUFACTURE		EMPLOYMENT (1,000)1/		ESTABLISHMENTS		VALUE ADDED BY MANUFACTURE		EMPLOYMENT (1,000)1/		ESTABLISHMENTS		VALUE ADDED BY MANUFACTURE		EMPLOYMENT (1,000)1/	
SIC CODE	1967	1977	1967	1977	1967	1977	1967	1977	1967	1977	1967	1977	1967	1977	1967	1977	1967	1977
-- ALL INDUSTRIES	537	737	388.2	688.2	27.2	42.7	161	242	212.1	328.7	12.9	15.9	22.2	296	149.8	293.7	11.7	22.2
20 FOOD AND KINDRED	73	70	6.5	180.9	.5	1.5	16	15	----	41.0	----	----	30	27	6.5	42.0	.5	1.5
22 & 23 TEXTILES & APPAREL	26	35	4.9	33.5	.1	.7	9	13	2.3	9.4	.5	----	7	7	2.6	5.7	.5	.7
24 LUMBER & WOOD PRODUCTS	109	94	3.8	17.7	.6	----	25	19	----	6.0	----	----	27	24	3.8	----	.6	----
25 FURNITURE & FIXTURES	13	11	----	----	----	----	7	2	----	----	----	----	4	4	----	----	----	----
26 PAPER & ALLIED PRODUCTS	4	9	----	----	----	----	2	4	----	----	----	----	2	3	----	----	----	----
27 PRINTING & PUBLISHING	60	96	8.8	10.4	.7	----	13	22	----	3.5	----	----	31	51	8.8	----	.7	----
28 CHEMICALS, ALLIED PROD.	21	32	----	----	----	----	6	13	----	----	----	----	13	14	----	----	----	----
29 PETROLEUM, COAL PROD.	12	11	----	----	----	----	3	2	----	----	----	----	8	6	----	----	----	----
30 RUBBER, MISC. PLASTICS	3	8	----	----	----	----	----	2	----	----	----	----	2	6	----	----	----	----
32 STONE, CLAY, GLASS	33	56	----	28.0	----	----	13	17	----	9.5	----	----	14	17	----	----	----	----
33 PRIMARY METALS	17	26	----	25.4	----	----	6	12	----	8.6	----	----	5	11	----	----	----	----
34 FABRICATED METALS	41	74	24.6	195.3	1.8	6.6	14	34	----	44.3	----	3.3	23	33	24.6	64.5	1.8	3.3
35 MACHINERY, EXCEPT ELECT.	69	116	30.2	112.8	3.0	2.5	33	55	5.5	38.2	1.9	2.5	28	46	13.5	----	----	----
36 ELECTRIC, ELECTRONIC EQUIP.	13	24	----	----	----	----	3	11	----	----	----	----	9	10	----	----	----	----
37 TRANSPORTATION EQUIP.	17	25	----	51.3	----	----	7	11	----	17.4	----	----	6	9	----	----	----	----

SOURCES: U.S. Bureau of Census, 1972 Census of Manufacturing
U.S. Bureau of Census, 1977 Census of Manufacturing

1/ Industry group data for groups with less than 450 employees are not shown.

In 1977, the Longview-Marshall SMSA represented 33 percent of the study area number of establishments, 48 percent of the study area VAM, and 37 percent of the study area manufacturing.

The Shreveport SMSA (Part) also showed substantial growth in manufacturing from 1967 to 1977. The number of establishments in the Shreveport SMSA (Part) increased 33 percent from 222 in 1967 to 296 in 1977. Value Added By Manufacture (VAM) increased by 96 percent from $149.8 million in 1967 to $293.7 million in 1977 at an average annual rate of 6.96 percent. Total manufacturing employment increased by 90 percent for 11,700 in 1967 to 22,200. In 1977, the Shreveport SMSA (Part) represented 40 percent of the study area number of establishments, 43 percent of the study area VAM, and 52 percent of the study area manufacturing employment.

In terms of VAM, for those standard industrial classification (SIC) codes shown and data disclosed, fabricated metals (SIC Code 34) was the major manufacturing group in the study area. In this group, VAM increased by $170.7 million for the 10 year period, from $24.6 million in 1967 to $195.3 million in 1977; an increase of 694 percent. This group represented 28 percent of the study area VAM in 1977. The fabricated metals industry showed the largest employment increase (of those industries disclosed) for the 10 year period from 1,800 employees in 1967 to 6,600 in 1977; an increase of 267 percent. There were 74 fabricated metals establishments in the study area in 1977 compared to 41 in 1967. Fabricated metals was also the major manufacturing group in terms of VAM in the Longview-Marshall SMSA and the Shreveport SMSA (Part). In the Longview-Marshall SMSA in 1977 fabricated metals VAM amounted to $44.3 million representing 23 percent of the study area total. In the Shreveport SMSA (Part), in 1977, VAM for this industry group amounted to $64.5 million; representing 33 percent of the study area total. The fabricated metals group was also the leading industry in terms of employment in the Shreveport SMSA (Part) and the second leading industry in terms of employment in the Longview-Marshall SMSA with both SMSA's employing approximately 3,300 employees. The Longview-Marshall SMSA had approximately 34 fabricated metals establishments in 1977; the Shreveport SMSA (Part) had approximately 33 such establishments in 1977. Machinery except electrical (SIC Code 35) was the leading industry in the Longview-Marshall SMSA in 1977 in terms of employment with 5,500 employees.

Food and kindred (SIC Code 20) ranked second in terms of VAM (based on data disclosed) for the study area. In this group, VAM increased by $174.4 million for the 10 year period, from $6.5 million in 1967 to $180.9 million in 1977. This group represented 26 percent of the study area VAM in 1977. Study area employment in this group increased from 500 in 1967 to 1500 in 1977; an increase of 200 percent. There were 70 study area establishments in this group in 1977, down slightly from 73 such establishments in 1967. Food and Kindred was also the second leading manufacturing group in terms of VAM in the Longview-Marshall SMSA and the Shreveport SMSA (Part). In the Longview-Marshall SMSA, in 1977, food and kindred VAM amounted to $41.0 million representing 23 percent of the study area total. In the Shreveport SMSA (Part), in 1977, VAM for the food and kindred industry amounted to $42 million, representing 23 percent of the study area total. The food and kindred industry ranked second in terms of employment in the Shreveport SMSA (Part) in the 1977 with 1,500 employees. Food and kindred industry employment was not disclosed for the Longview-Marshall SMSA for 1967 or 1977. The Longview-Marshall SMSA had approximately 15 food and kindred establishments in 1977; the Shreveport SMSA (Part) had 27 such establishments.

Machinery, except electrical (SIC Code 35), ranked third in terms of VAM (based on data disclosed) for the study area. In this industry group, VAM increased by $82.6 million for the 10 year period from $30.2 in 1967 to $112.8 in 1977; an increase of 274 percent. This group represented 16 percent of the study area VAM in 1977. Study area employment in this group decreased from 3,000 in 1967 to 2,500 in 1977. There were 116 establishments in this group in 1977 compared to 69 in 1967. Machinery, Except Electrical, was also the third leading industrial group in terms of VAM in the Longview-Marshall SMSA with an increase of $32.7 million, from $5.5 million in 1967, to $38.2 million in 1977. Machinery, Except Electrical was the third leading industry group in the Shreveport SMSA (Part) in 1967 in terms of VAM with $13.5 million. VAM for 1977 was undisclosed. Employment for this industry group in the Longview-Marshall SMSA increased from 1,900 in 1967 to 2,500 in 1977. Employment for this industry group in the Shreveport SMSA (Part) was not disclosed for either 1967 or 1977.

Agricultural Land Use. Agriculture plays a significant role in the economic processes of the Cypress Bayou Basin study area. Table 9 shows the farms and farmland use characteristics for the study area, the Longview-Marshall SMSA and the Shreveport SMSA (Part) for 1969 and 1978. In 1969, nearly 50 percent of the study area was farmland. By 1978, study area farmland had declined to approximately 43 percent, from 1,872,472 acres in 1969 to 1,596,097 acres in 1978. Longview-Marshall SMSA farmland also declined from nearly 45 percent in 1969 to approximately 38 percent in 1978, from 337,160 acres in 1969 to 287,062 acres in 1978. Shreveport SMSA (Part) farmland declined from 48.2 percent in 1969 to 44 percent in 1978, from 277,386 acres in 1969 to 253,543 acres in 1978.

The number of farms in the study area declined by 1,465, or 17 percent, from 8,467 farms in 1969 to 7,002 in 1978. Similarly, the number of farms in the Longview-Marshall SMSA declined by 117, or 8 percent, from 1,425 in 1969 to 1,308 in 1978. The number of farms in the Shreveport SMSA (Part) also declined, by 195 or 24 percent, from 807 in 1969 to 612 in 1978.

TABLE 9

FARMS AND FARMLAND USE - 1969, 1978
CYPRESS BAYOU BASIN STUDY AREA, LONGVIEW-MARSHALL SMSA, & SHREVEPORT SMSA (PART)

	LAND AREA (ACRES)	1969						1978				
		NUMBER OF FARMS	LAND IN FARMS (ACRES)	% OF LAND IN FARMS	CROPLAND (ACRES)	% OF FARMS IN CROPS	NUMBER OF FARMS	LAND IN FARMS (ACRES)	% OF LAND IN FARMS	CROPLAND (ACRES)	% OF FARMS IN CROPS
STUDY AREA	3,751,768	8,467	1,872,472	49.91	718,593	38.38	7,002	1,596,097	42.54	738,939	46.30
LONGVIEW-MARSHALL SMSA	752,512	1,425	337,160	44.80	112,179	49.56	1,308	287,062	38.15	106,498	37.10
SHREVEPORT SMSA (PART)	575,296	807	277,386	48.22	141,783	51.11	612	253,543	44.07	120,053	47.35

SOURCE: U.S. Census of Agriculture, 1969, 1978.

Study area use of farmland for crop production increased slightly during this 9 year period by 20,346 acres or 3 percent, from 718,593 acres in 1969 to 738,939 acres in 1978. However, the metropolitan areas of the study area showed declines in cropland for the nine year period. Longview-Marshall SMSA cropland declined by 5,681 acres or 5 percent from 112,179 acres in 1968 to 106,498 acres in 1978. Shreveport SMSA (Part) cropland declined by 21,730 or 15 percent, from 141,783 acres in 1969 to 120,053 acres in 1978.

Such changes in farm and farmland use characteristics are exemplary of national trends of urban encroachment, and reflective of urban growth which took place in the study area during the nine year period 1969 to 1978.5/

Agriculture. Table 10 shows the value of farm products sold (VFPS) in the Cypress Bayou Basin study area, (including those counties comprising the study area), the State of Texas, and the State of Louisiana. The value of farm products sold (VFPS) in 1978 totaled $64.8 million in the study area, $3.9 billion in the State of Texas, and $594.7 million in the State of Louisiana. As shown in Table 10, livestock production accounts for the majority of the value of farm production sold in the study area amounting to $55.8 million, or 86 percent of its VFPS, and in the State of Texas amounting to $2.6 billion or 66 percent of its VFPS. Crop production, however, accounts for the majority of the value of farm production sold in Caddo Parish (the only portion of the study area in Louisiana) amounting to $5.2 million of 58 percent of its VFPS, and in the State of Louisiana, amounting to $47.1 million or 70 percent of its VFPS. The large amount of cropland of the Red River floodplain in Caddo Parish contributes substantially to such relatively high value of crop production sold (mainly soybeans, hay and cotton) compared to value of livestock production sold in the Parish.

5/ Farmline, June 1981.

TABLE 10

VALUE OF FARM PRODUCTS SOLD - 1978
(1967 THOUSANDS OF DOLLARS)

COUNTY/STATE	CROPS ($1,000)	LIVESTOCK ($1,000)	TOTAL VFPS ($1,000)	CROPS % OF TOTAL	LIVESTOCK % OF TOTAL
CADDO PARISH, LA	5,178	3,701	8,879	58.3	41.7
CAMP COUNTY, TX	192	10,675	10,867	1.7	98.2
CASS COUNTY, TX	298	3,735	4,033	7.4	92.6
FRANKLIN COUNTY, TX	128	6,261	6,389	2.0	98.0
GREGG COUNTY, TX	221	1,463	1,684	13.1	86.9
HARRISON COUNTY, TX	372	4,064	4,436	8.4	91.6
MARION COUNTY, TX	76	1,032	1,108	6.9	93.1
MORRIS COUNTY, TX	562	1,869	2,431	23.1	76.9
US COUNTY, TX	237	5,643	5,880	4.0	96.0
UPSHUR COUNTY, TX	315	8,109	8,424	3.7	96.3
WOOD COUNTY, TX	1,381	9,264	10,645	13.0	87.0
STUDY AREA TOTAL	8,960	55,816	64,776	13.8	86.2
TEXAS	1,335,625	2,609,174	3,944,799	33.9	66.1
LOUISIANA	417,115	177,620	594,735	70.1	29.9

SOURCE: U.S. Census of Agriculture, 1978.

In the 11 county study area, Camp County, Texas had the highest value of farm products sold in 1978, amounting to $10,867,000; $10,675,000 or 98 percent of which was value of livestock production sold, and $192,000, or 2 percent was value of crop production sold. Camp County value of farm products sold represented 17 percent of the study area total VFPS in 1978. Wood County, Texas, followed closely with value of farm products sold amounting to $10,645,000; $9,264,000, or 87 percent, of which was value of livestock production sold; and $1,381,000, or 13 percent was value of crop production sold. Wood County value of farm products sold represented 16 percent of the study area total VFPS in 1978. Marion County, Texas had the lowest value of farm products sold in 1978, amounting to $1,108,000; $1,032,000, or 93 percent of which was value of livestock production sold, and $76,000 or 7 percent was value of crop production sold. Marion County value of farm products sold represented less than 2 percent of the study area total VFPS in 1978.

Agricultural Projections. Value of farm products sold (VFPS) and projections for the period 1969 to 2050, for the United States, the State of Texas, the State of Louisiana, and the Cypress Bayou Basin study area are shown in Table 11. VFPS for the study area increased by $15.2 million from $49.5 million in 1969 to $64.8 million in 1978. These figures represent an increase of approximately 31 percent for the 9 year period, at an average annual rate of 3.02 percent. For this same 9 year period, Louisiana VFPS increased by $52.3 million from $542.4 million in 1969 to $594.7 million in 1978, representing an increase of 9.7 percent at an average annual rate of 1.03 percent. Texas VFPS, for this same period, increased by $954 million from $2.99 billion in 1969 to $3.94 billion in 1978, representing an increase of 31.9 percent at an average annual rate of 3.12 percent. VFPS in the United States for the period 1969 to 1978 increased by $9.4 billion from $42.2 billion in 1969 to $51.6 billion in 1978, representing an increase of 22 percent at an average annual rate of 2.26 percent.

TABLE 11

VALUE OF FARM PRODUCTS SOLD - 1969-2050
UNITED STATES, STATE OF TEXAS, STATE OF LOUISIANA, & CYPRESS BAYOU BASIN STUDY AREA

YEAR	UNITED STATES		TEXAS		LOUISIANA		STUDY AREA	
	VFPS (MILLIONS)	AVERAGE ANNUAL % CHANGE	VFPS (THOUSANDS)	AVERAGE ANNUAL % CHANGE	VFPS (THOUSANDS)	AVERAGE ANNUAL % CHANGE	VFPS (THOUSANDS)	AVERAGE ANNUAL % CHANGE
1969	42,230.6		2,990,800		542,393		49,541	
		-0.05		0.52		1.77		0.78
1974	42,126.2		3,069,400		592,016		51,499	
		5.22		6.47		0.11		5.90
1978	51,642.1		3,944,799		594,735		64,776	
		0.47		6.02		0.20		6.90
1980	52,124.3		4,434,076		597,150		74,030	
		1.35		1.43		1.65		1.48
1990	59,612.9		5,111,929		703,246		85,763	
		1.26		1.38		1.56		1.45
2000	67,570.8		5,860,163		820,903		99,047	
		0.62		0.71		0.77		0.74
2010	71,879.7		6,289,006		886,533		106,621	
		0.63		0.71		0.77		0.74
2020	76,511.7		6,749,353		957,414		114,777	
		0.63		0.71		0.77		0.74
2030	81,442.9		7,243,527		1,033,966		123,560	
		0.63		0.71		0.77		0.74
2040	86,722.0		7,774,023		1,116,642		133,017	
		0.63		0.71		0.77		0.74
2050	92,343.0		8,343,522		1,205,933		143,202	
1978-2050		0.81		1.05		0.99		1.11
FACTORS OF CHANGE FROM 1978								
1978	1.00		1.00		1.00		1.00	
1980	1.01		1.12		1.00		1.14	
1990	1.15		1.30		1.18		1.32	
2000	1.31		1.49		1.38		1.53	
2010	1.39		1.59		1.49		1.65	
2020	1.48		1.71		1.61		1.77	
2030	1.58		1.84		1.74		1.91	
2040	1.68		1.97		1.88		2.05	
2050	1.79		2.12		2.03		2.21	

SOURCES: U.S. Bureau of Census, Census of Agriculture, 1969, 1974, 1978.
OBERS Series "E" Supplement, Agricultural Projections, May, 1975.

The VFPS projections for the period 1980 to 2050 are based on OBERS Series "E" projections of crop and livestock productions for the United States, Texas, Louisiana, and Water Resources Subarea 1114 (Lower Red). For the 72 year period 1978 to 2050, VFPS in the study area is projected to increase by $78.4 million from $64.8 million in 1978 to $143.2 million in 2050. This represents a 121 percent increase in VFPS in the study area, at an average annual rate of 1.11 percent. This study area growth for the 72 year period will exceed that of the State of Texas, the State of Louisiana, and the United States for the same period.

Minerals. The oil and natural gas industry is the leading minerals industry in the Cypress Bayou Basin study area. In fact, the study area is part of what is known as the "East Texas Oil Field", with oil reserves considered to be among the largest in the continental United States.[6] For the 9 year period 1970 to 1979, every county in the study area was productive with oil and natural gas except Morris County, Texas. Table 12 shows production levels of oil and natural gas in the study area, the State of Texas and the State of Louisiana for the years 1970, 1973, 1974, and 1979.

Crude oil production in the study area showed a general trend of decline over the 9 year period, 1970 to 1979. Crude oil production increased by approximately 8.5 million barrels, or 8 percent, from approximately 109.2 million barrels in 1970 to 117.8 million barrels in 1973, but then decreased by approximately 117.8 million barrels in 1973 to 114.3 million in 1974. Crude oil production declined further, by approximately 30.6 million barrels, or by 27 percent, from approximately 114.3 million barrels in 1974 to approximately 83.7 million barrels in 1979. Similar trends were recorded for crude oil production in the State of Texas and the State of Louisiana from 1970 to 1979. State of Texas production increased from approximately 1,235.8 billion barrels in 1970 to 1,284.2 billion barrels in 1973; but

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[6] The East Texas Story..., East Texas Chamber of Commerce, p. 17; 1980.

TABLE 12

NATURAL GAS & CRUDE OIL PRODUCTION - 1970, 1973, 1974, 1979
TEXAS, LOUISIANA, & CYPRESS BAYOU BASIN STUDY AREA

COUNTY/STATE	CRUDE OIL				NATURAL GAS			
	1970 1,000 BBLS	1973 1,000 BBLS	1974 1,000 BBLS	1979 1,000 BBLS	1970 MMCF	1973 MMCF	1974 MMCF	1979 MMCF
CADDO PARISH, LA	5,185.5	4,525.9	4,575.0	3,295.9	31,169.5	23,541.0	19,129.3	15,637.8
CAMP COUNTY, TX	935.0	731.2	691.2	389.5	74.9	2,725.7	5,097.6	2,866.7
CASS COUNTY, TX	3,837.5	1,339.2	1,426.0	829.5	18,337.4	21,306.0	24,547.3	22,020.9
FRANKLIN COUNTY, TX	3,722.4	3,032.9	2,667.9	1,767.7	17,689.1	18,876.5	18,001.6	17,106.3
CREGG COUNTY, TX	48,690.1	53,239.9	51,604.8	44,743.4	32,797.6	34,598.3	33,407.4	24,121.1
HARRISON COUNTY, TX	3,789.3	1,739.7	1,468.7	965.0	41,232.9	24,329.8	22,723.1	29,238.8
MARION COUNTY, TX	1,917.5	1,048.2	748.1	464.2	5,917.0	3,971.5	3,048.2	7,328.1
MORRIS COUNTY, TX	----	----	----	----	----	----	----	----
TITUS COUNTY, TX	2,749.9	2,573.3	2,394.9	2,083.1	15.0	18.3	11.8	15.0
UPSHUR COUNTY, TX	3,111.1	2,893.4	2,583.6	549.3	6,168.9	10,699.1	9,852.7	15,189.5
WOOD COUNTY, TX	35,295.7	46,662.5	46,165.3	28,650.0	31,825.5	39,556.7	43,210.7	45,414.4
STUDY AREA TOTAL	109,234.1	117,786.2	114,325.6	83,737.5	185,225.7	179,623.4	179,030.1	178,939.0
TEXAS	1,235,849.5	1,284,233.8	1,251,785.0	1,006,845.1	9,421,071.0	9,328,254.7	8,895,282.4	7,115,818.1
LOUISIANA	895,838.9	505,032.7	428,126.8	226,848.3	7,796,747.1	5,425,916.0	4,675,443.8	2,976,173.4

SOURCES: Texas Railroad Commission Annual Reports, 1970, 1973, 1974, 1979
Louisiana Department of Natural Resources

1/ Subject to final audit

then declined to approximately 1,251.8 billion barrels in 1974; and further declined to 1,006.8 billion barrels in 1979. State of Louisiana crude oil production has shown a trend of general decline in crude oil production for the period 1970 to 1979 from 895.8 million barrels in 1970, to approximately 266.8 million barrels in 1979.

Gregg County, Texas (part of the Longview-Marshall SMSA) was the leading crude oil producer in the study area for the selected years shown. In 1970, 1973, and 1974 Gregg County represented approximately 45 percent of total study area crude oil production; in 1979, Gregg County production represented over 53 percent of the total study area crude oil production.

Wood County, Texas, is also a major producer of study area crude oil representing approximately 32 percent of total study area production in 1970; approximately 40 percent in 1973 and 1974; and 34 percent in 1979. The Texas Railroad Commission Annual Reports show Morris County, Texas is the only study area county which recorded no crude oil production in 1970, 1973, 1974, and 1979.

Natural gas production in the study area remained relatively constant for the nine year period 1970 to 1979. Natural gas production declined slightly from 185.2 million MCF in 1970 to 179.6 million MCF in 1973. However, production remained relatively constant thereafter approximating 179.0 million MCF in 1974, and 178.9 million MCF in 1979. Natural gas production in the State of Texas recorded a trend of general decline for the period 1970 to 1979. Production decreased from approximately 9,421.1 million MCF in 1970 to approximately 7,115.8 million MCF in 1979; a decline in production of approximately 24 percent from 1970 to 1979. Natural gas production in the State of Louisiana showed substantial decline for the nine year period 1970 to 1979. Production declined from approximately 7,796.7 million MCF in 1970 to 2,976.2 million MCF in 1979, a decline in natural gas production of approximately 62 percent.

In 1979, Wood County, Texas, was the leading producer of natural gas in the study area, increasing from approximately 31.8 million MCF in 1970 to 45.4 million MCF in 1979; an increase of approximately 43 percent. In 1979, Wood County natural gas production represented approximately 25 percent of the study area total.

Upshur County also showed substantial gain in production from approximately 6.2 million MCF in 1970 to approximately 15.2 million MCF in 1979; an increase of approximately 145 percent. Caddo Parish, Louisiana, and Gregg and Harrison Counties, Texas, showed substantial declines in natural gas production for the 9 year period 1970 to 1979. Caddo Parish production declined from approximately 31.2 million MCF in 1970 to approximately 15.6 million MCF in 1979; a decline of approximately 50 percent. Gregg County production declined from approximately 32.8 million MCF in 1970 to approximately 24.1 million MCF in 1979; a decline of approximately 27 percent. Harrison County production declined from approximately 41.2 million MCF (largest in the study area) in 1970 to approximately 29.2 million MCF in 1979; a decline of approximately 29 percent. The remaining five counties of the study area maintained relatively constant levels of natural gas production for the 9 year period (Morris County, Texas, produced no natural gas for the years shown).

Value of crude oil and natural gas production for the years 1970, 1973, 1974, and 1979, for the Cypress Bayou Basin study area, the State of Texas, and the State of Louisiana is shown in Table 13. Value of study area crude oil and natural gas production increased by approximately 7 percent from $375.1 million in 1970 to $400.7 million in 1973; but then declined by approximately 3 percent to $389.8 million in 1974, and further declined by approximately 24 percent to $294.4 million in 1979. Crude oil and natural gas production in the State of Texas increased by approximately 2 percent from $5,598.7 million in 1970 to $5,732.5 million in 1973; but then declined by approximately 3 percent to $5,551.2

in 1974; and further declined by approximately 20 percent to $4,457.8 million in 1979. Crude oil and natural gas production in the State of Louisiana declined by approximately 39 percent from $4,237.7 million in 1970 to $2,579.5 million in 1973; then declined by approximately 15 percent to $2,200.7 million in 1974; and then by approximately 43 percent to $1,258.4 million in 1979.

Mineral Projections. Table 13 shows the projected value of crude oil and natural gas production, 1970 to 2050, for the Cypress Bayou Basin study area, the State of Texas and the State of Louisiana. Projections of crude oil and natural gas production value are based on OBERS Series "E" projections of crude oil and natural gas earnings for the BEA economic area 130, the State of Texas, and the State of Louisiana. OBERS projections of output to earnings factors were applied to the earnings projections to derive output projections of the respective economies (study area, Texas, and Louisiana). The resulting factors of growth were applied to the respective base year (1979) crude oil and natural gas production values. BEA economic area 130 growth factors were applied to the study area to compute projected value to 2000. Projections from 2010 to 2050 are by SWD and reflect a declining rate of growth beyond year 2000 consistent with expected depletion of crude oil and natural gas reserves in the area. State of Texas growth factors were applied to compute projected value for the State of Texas to the year 2050. State of Louisiana growth factors were applied to compute projected value for the State of Louisiana to 2050.

Though the value of oil and natural gas production in both Texas and Louisiana exhibited a general decline from 1970 to 1979, the value of production is projected to show an increase from 1979 to 2050. The rates of growth for value of oil and natural gas production in Texas and Louisiana during this 71 year period are expected to substantially exceed those of the study area. Such growth in value of production in the two states is expected due to larger areas available for exploratio compared to the study area.

TABLE 13

VALUE OF CRUDE OIL & NATURAL GAS PRODUCTION - 1970-2050
TEXAS, LOUISIANA, & CYPRESS BAYOU BASIN STUDY AREA

(MILLIONS OF 1967 DOLLARS)

	TEXAS		LOUISIANA		STUDY AREA	
YEAR	VALUE (Millions $)	AVERAGE ANNUAL % CHANGE	VALUE (Millions $)	AVERAGE ANNUAL % CHANGE	VALUE (Millions $)	AVERAGE ANNUAL % CHANGE
1970	5,598.7		4,237.7		375.1	
		0.79		-15.25		2.22
1973	5,732.5		2,579.5		400.7	
		-3.16		-14.69		-2.72
1974	5,551.2		2,200.7		389.8	
		-4.29		-10.58		-5.46
1979	4,457.8		1,258.4		294.4	
		1.80		2.07		-0.14
1980	4,538.0		1,284.4		294.8	
		1.44		1.97		0.13
1990	5,235.5		1,561.1		298.7	
		1.25		1.54		0.13
2000	5,928.0		1,818.9		302.6	
		1.05		1.22		0.07
2010	6,580.7		2,053.4		304.7	
		1.05		1.22		0.07
2020	7,305.3		2,318.1		306.8	
		0.53		0.61		0.04
2030	7,701.8		2,463.4		308.0	
		0.53		0.61		0.04
2040	8,119.9		2,617.9		309.2	
		0.53		0.61		0.04
2050	8,560.7		2,782.0		310.4	
1979-2050		0.92		1.12		0.07

FACTORS OF CHANGE FROM 1979

1979	1.00	1.00	1.00
1980	1.02	1.02	1.00
1990	1.17	1.24	1.01
2000	1.33	1.45	1.03
2010	1.48	1.63	1.03
2020	1.64	1.84	1.04
2030	1.73	1.96	1.05
2040	1.82	2.08	1.05
2050	1.92	2.21	1.05

SOURCES: Texas Railroad Commission Annual Reports, 1970, 1973, 1974, 1979.
Louisiana Department of Natural Resources.
OBERS Series "E", April 1974.

The value of crude oil and natural gas production for the Cypress Bayou Basin study area is projected to increase to $310.4 million by 2050, at an average annual rate of 0.07 percent from 1979. The value of crude oil and natural gas production for the State of Texas is projected to increase to $8,560.7 million by 2050 and an average annual rate of 0.92 percent from 1979. The value of crude oil and natural gas production in the State of Louisiana is expected to increase to $2,782.0 million by 2050, at an average annual rate of 1.12 percent.

Lignite coal is also present in the Cypress Bayou Basin study area as part of lignite coal deposits in south and east Texas and northwest Louisiana. Its value as a source of energy, under present technology and conditions, is mainly through its use in "mine-mouth" operations (burned at or near the lignite mine source). As an energy source, lignite coal has about one-half the heating value of anthracite coal.

Currently, the use of lignite coal in the study area is limited to use as a fuel source at the Texas Power and Light (TP&L) Monticello Power Plant located in Titus County, Texas. The plant currently consumes approximately 8 million tons of lignite annually at the three units (593.0 MW unit, 593.0 MW unit, and a 793.3 MW unit). Ample supplies of lignite from various deposits nearby are available to meet the needs of the expected 30 year life of the Monticello Plant.7/

The Pirkey Power Plant, located in Harrison County, Texas, is currently being developed by Southwestern Electric Power Co. (SWEPCO). The plant (719.0 MW unit), projected to be in operation in 1985, is expected to consume approximately 2.8 million tons of lignite annually. Adequate 25 year supply is available, and will be mined by the Sabine Mining Co. of Dallas, Texas.8/

7/ Texas Power & Light Co; telephone conversations, July 13,1981.
8/ Southwestern Electric Power Co., telephone conversation, July 7, 1981.

The future of lignite use in the study area appears favorable. In the near term, uses may be limited primarily to mine-mouth consumption for purposes of direct energy conversion. From 1980 to 2000 lignite will likely remain more attractive than coal. After the year 2000 western coal use may surpass lignite as the lignite reserves are depleted.[9/]

[9/] Lignite Development In Texas, "Texas Business Review", January-February, 1980.

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX B

AREA ECONOMIC AND WATER SUPPLY STUDIES

SECTION 2 - LITTLE CYPRESS WATER SUPPLY STUDY

LITTLE CYPRESS
WATER SUPPLY STUDY

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by

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July 1981

FOREWORD

The purpose of this report is to present forecasts of municipal and industrial (M&I) and power water requirements within the ten Texas counties and one Louisiana parish included in the study area for the Little Cypress Water Supply Study. These projected requirements are compared with current and anticipated supplies to determine any net water supply needs.

The municipal component of water use includes all water supplied by a municipal system excluding water supplied by the municipal systems for manufacturing and mining activities.

This study is divided into three sections. The first section delineates the study area and the larger cities which dominate the water supply picture. The second section measures net water supply needs without any additional conservation programs. The third section measures net M&I water supply needs for the five larger cities after allowing for additional conservation measures. Appendix A shows projections of average day use and maximum day use and water supply capacity for the five cities.

SUMMARY

This study determines future municipal, industrial, and power water requirements for the ten Texas counties and one Louisiana parish included in the Little Cypress Study Area, and the five larger cities in the study area.

For each county or parish and the five major cities, baseline projections were made with the assumption that no water conservation programs are implemented beyond those currently in effect. For the five larger cities, a second set of projections were made showing the effect of additional conservation programs, which amount to reductions of water use ranging from 2 percent to over 6 percent.

Table S-1 shows baseline projections of net water supply needs for the study area through 2040.

TABLE S-1

NET WATER SUPPLY NEEDS FOR THE LITTLE CYPRESS STUDY AREA

Millions of Gallons Per Day

YEAR	NET NEEDS - BASELINE
1980	----
1990	11.9
2000	28.2
2010	52.7
2020	103.4 (78.7)*
2030	179.6 (107.9)*
2040	295.6 (162.5)*

* NET NEEDS EXCLUDING INTERNATIONAL PAPER CO. IN CASS COUNTY WHICH OBTAINS WATER FROM LAKE WRIGHT PATMAN IN THE SULPHUR RIVER BASIN.

LITTLE CYPRESS WATER SUPPLY STUDY

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THE STUDY AREA

The study area includes Caddo Parish, Louisiana, and Camp, Cass, Franklin, Gregg, Harrison, Marion, Morris, Titus, Upshur, and Wood Counties, Texas. In addition to the one parish and ten counties, the water needs for the Cities of Shreveport, Marshall, Longview, Kilgore, and Mount Pleasant are also studied (Figure 1).

The City of Shreveport with a 1980 population of 204,943 in Caddo Parish and 872 in Bossier Parish, Louisiana, is located a few miles from the Texas-Louisiana line. Marshall is located about 20 miles from the Texas-Louisiana line in Harrison County and had a population of 24,921 in 1980. The City of Longview, with a population of 62,762 in 1980, is located mainly in Gregg County with a small area in Harrison County. Kilgore is located on the Gregg-Rusk County line southwest of Longview with 8,425 persons in Gregg County and 2,543 in Rusk County in 1980. Mount Pleasant, located about 55 miles north of Longview in Titus County, had a population of 11,003 in 1980.

Total population of the study area in 1980 was 549,367. Projected total population for 2040 is 913,300, an average annual increase of 0.85 percent for the period 1980-2040 (Table 1).

FIGURE 1 -
TO BE ADDED WHEN AVAILABLE

TABLE 1

POPULATION BY COUNTY AND SELECTED CITIES, 1980-2040
LITTLE CYPRESS STUDY AREA

COUNTY/PARISH	1980	1990	2000	2010	2020	2030	2040
CADDO - LOUISIANA	252,294	271,100	288,700	306,200	324,700	343,200	361,800
SHREVEPORT (part)	204,943	220,200	234,500	248,700	263,750	278,800	293,900
VIVIAN	4,146	4,450	4,700	5,000	5,300	5,600	5,900
CAMP - TEXAS	9,275	9,600	10,500	11,200	11,900	12,700	13,400
PITTSBURG	4,245	4,600	5,000	5,300	5,600	6,000	6,350
CASS	29,430	32,700	36,000	39,200	42,600	45,900	49,300
ATLANTA	6,272	7,300	8,400	9,500	10,600	11,700	12,800
FRANKLIN	6,893	8,700	10,300	11,500	12,800	14,200	15,600
GREGG	99,487	114,000	133,000	147,500	164,300	180,000	195,000
LONGVIEW (part)	61,085	68,500	79,000	86,500	96,300	104,000	114,400
KILGORE (part) also Rusk Co.	8,425	10,500	13,000	16,000	19,000	22,000	23,800
GLADEWATER (part)	4,311	5,600	6,400	7,200	8,300	9,400	10,800
HARRISON	52,265	59,500	68,000	72,000	78,000	82,000	86,000
MARSHALL	24,921	30,500	35,000	37,500	41,500	43,500	45,700
LONGVIEW (part)	1,677	3,000	3,500	4,000	4,500	5,000	5,300
MARION	10,360	11,700	12,400	13,300	14,200	15,200	16,300
JEFFERSON	2,643	3,000	3,200	3,400	3,600	3,900	4,200
MORRIS	14,629	17,300	20,600	23,100	25,400	27,500	29,500
DAINGERFIELD	3,030	3,400	3,800	4,200	4,600	5,000	5,400
TITUS	21,442	23,500	27,000	29,500	32,300	35,100	37,900
MOUNT PLEASANT	11,003	12,500	14,000	15,400	16,900	18,400	19,900
UPSHUR	28,595	33,500	40,000	44,400	49,700	54,000	58,000
GILMER	5,167	6,100	8,400	10,600	13,200	15,300	16,200
GLADEWATER (part)	2,237	2,400	2,600	2,800	3,000	3,200	3,400
WOOD	24,697	29,500	35,200	38,900	43,500	47,000	50,500
MINEOLA	4,346	6,000	7,600	8,900	10,600	12,000	13,800
STUDY AREA	549,367	611,100	681,700	736,800	799,400	856,800	913,300

MUNICIPAL AND INDUSTRIAL AND POWER REQUIREMENTS:
BASELINE PROJECTIONS
LITTLE CYPRESS STUDY AREA

In 1980 the ten counties and one parish in the study area used about 148.4 million gallons per day (mgd) of water for M&I and power purposes (Table 2). Municipal use was 55.1 mgd for a per capita use rate of 158 gallons per day. Industrial use in 1980 totaled 76.3 mgd. Water used for steam electric generation cooling accounted for 17.0 mgd.

Total water requirements are projected to reach 260.7 mgd by 2000, an increase of 76 percent over 1980. By the year 2040, total M&I and power requirements are projected to be 587.8 mgd. Water sources and quantities used in 1980 are shown in Table 3 for the cities and selected industries with self-supplied water.

Table 4 shows net needs for the study area and the individual counties. By 1990, net needs appear for Harrison, Morris, and Wood Counties. Net water needs are projected for Caddo Parish and Upshur County by 2000, Cass County by 2020, and Gregg County by 2030. No needs through 2040 are projected for Camp, Franklin, Marion, and Titus Counties.

<u>Caddo Parish</u>. Urban areas in the parish are Shreveport and Vivian.

Sources of water for Shreveport are Cross Lake and 12-Mile Bayou with dependable yields of 23 mgd and 20 mgd, respectively. Larger users of industrial water include Atlas Processing Co., General Motors Corp., Gould, Inc., Bird & Son, Western Electric, and Libbey Glass, Div. of Owens-Illinois, Incorporated. The city provides about 1 mgd of water to Barksdale Air Force Base in Bossier Parish. As shown in Table 5, the City of Shreveport is projected to have net needs by 2000 as population nears 235,000.

TABLE 2

BASELINE MUNICIPAL, INDUSTRIAL, AND POWER WATER REQUIREMENTS FOR THE LITTLE CYPRESS STUDY AREA, 1980-2040
MGD

YEAR	MUNICIPAL	INDUSTRIAL	POWER	TOTAL
1980	55.1	76.3	17.0	148.4
1990	64.4	117.0	22.0	203.4
2000	74.7	159.0	27.0	260.7
2010	82.4	207.8	27.0	317.2
2020	93.7	265.0	27.0	385.7
2030	101.0	342.4	27.0	470.4
2040	110.8	450.0	27.0	587.8

TABLE 3

WATER SOURCES AND WATER USES
LITTLE CYPRESS STUDY AREA

USER	WATER SOURCE SURFACE	GROUND	DEPENDABLE YIELD MGD	CURRENT ANNUAL WATER USE MGD 1/	ADDITIONAL INFORMATION
CADDO PARISH					
SHREVEPORT	CROSS LAKE	----	23.000	36.424	Will need additional water after 1990; quality good
	12-MILE BAYOU	----	20.000		
VIVIAN	----	5 WELLS	1.479	.720	Water quality good
CAMP COUNTY					
PITTSBURG	----	8 WELLS	1.540	.526	Sufficient water supply, water quality good
CASS COUNTY					
ATLANTA	LAKE WRIGHT PATMAN	----	4.937	.806	Water quality good; plan to use wells as backup
	----	4 WELLS	1.200		
BRECKENRIDGE GASOLINE CO.	----	3 WELLS	.105	.105	Near Lodi
SHELL OIL CO.	----	3 WELLS	.371	.371	Near Douglassville
INTERNATIONAL PAPER CO.	LAKE WRIGHT PATMAN	----	105.300	30.360	Near Texarkana (Sulphur River Basin) will need additional water after 2010
FRANKLIN COUNTY					
MOUNT VERNON	CITY LAKE	----	.170	.588	
	LAKE CYPRESS SPRINGS	----	.600		
GETTY OIL CO.	----	7 WELLS	.409	.409	Near Scroggins in SE Franklin County
GREGG COUNTY					
LONGVIEW	LAKE CHEROKEE	----	10.712		Water supply adequate past 2020; quality satisfactory
	LAKE FORK	----	5.900 2/	16.000	
	SABINE RIVER	----	22.100		
ARCO OIL & GAS CO.	----	3 WELLS	.126	.126	Gas plant
CITIES SERVICE CO.	----	1 WELL	.221	.221	Gas plant
KILGORE	----	9 WELLS	7.000	2.728	Water table dropping; quality deteriorating
PETROLITE CORP.	----	2 WELLS	.249	.249	
GLADEWATER	LAKE GLADEWATER	----	6.204	.866	Good quality water; never short
WARREN PETROLEUM CO.	----	2 WELLS	.052	.052	Gas plant
HARRISON COUNTY					
MARSHALL	BIG CYPRESS BAYOU	----	9.300	5.790	River flow not dependable; significant variation in quality; seeking alternative sources
TEXAS EASTMAN CO.	SABINE RIVER	----	.685	.685	Plastics mfg.
ARKANSAS LOUISIANA GAS CO.	----	2 WELLS	.246	.246	Near Waskom
THIOKOL CORP. (Longhorn Ordinance)	CYPRESS BAYOU (CADDO)	----	.425	.608	Near Karnack
MARION COUNTY					
JEFFERSON	LAKE O' THE PINES	----	1.000	.319	Water quality good
	----	1 WELL	.900		
MORRIS COUNTY					
DAINGERFIELD	LAKE O' THE PINES	----	1.200	.650	Expect water quality to improve with pumping from a different location on the lake
LONE STAR	ELLISON CREEK RESERVOIR	----	1.000	.250	Purchased from Lone Star Steel
LONE STAR STEEL	ELLISON CREEK RESERVOIR	----	17.700	17.700	
AIR PRODUCTS & CHEM. CO.	ELLISON CREEK RESERVOIR	----	.961	.961	Purchased from Lone Star Steel
TITUS COUNTY					
MOUNT PLEASANT	LAKE TANKERSLY	----	6.250	4.500	
	LAKE BOB SANDLIN	----	12.498		
UPSHUR COUNTY					
GILMER	----	6 WELLS	2.376	.816	
WOOD COUNTY					
MINEOLA	----	4 WELLS	1.479	.720	

1/ Data for 1980
2/ Dependable yield will be 17.855 MGD by 1990

TABLE 4

BASELINE TOTAL M&I AND POWER WATER REQUIREMENTS VS. SUPPLY FOR LITTLE CYPRESS STUDY AREA, BY COUNTY, 1980-2040

MGD

	1980	1990	2000	2010	2020	2030	2040
CAMP COUNTY							
REQUIREMENTS:							
MUNICIPAL	.4	.5	.6	.6	.7	.7	.8
INDUSTRIAL	.1	.2	.2	.2	.3	.3	.4
TOTAL	.5	.7	.8	.8	1.0	1.0	1.2
SUPPLY:							
M&I	1.5	1.5	1.5	1.5	1.5	1.5	1.5
NET NEEDS	----	----	----	----	----	----	----
CASS COUNTY							
REQUIREMENTS:							
MUNICIPAL	.8	1.0	1.2	1.4	1.6	1.8	2.0
INDUSTRIAL	30.9	53.9	78.5	102.5	135.0	181.8	242.9
TOTAL	31.7	54.9	79.7	103.9	136.6	183.6	244.9
SUPPLY:							
M&I	111.9	111.9	111.9	111.9	111.9	111.9	111.9
NET NEEDS	----	----	----	----	24.7	71.7	133.1
					*29.0	*75.8	*136.9
FRANKLIN COUNTY							
REQUIREMENTS:							
MUNICIPAL	.4	.6	.7	.8	.9	1.0	1.1
INDUSTRIAL	.4	.4	.4	.4	.4	.4	.4
TOTAL	.8	1.0	1.1	1.2	1.3	1.4	1.5
SUPPLY:							
M&I	1.2	1.2	1.2	1.2	1.3	1.4	1.5
NET NEEDS	----	----	----	----	----	----	----
GREGG COUNTY							
REQUIREMENTS:							
MUNICIPAL	13.5	16.6	20.7	24.0	27.7	30.6	36.2
INDUSTRIAL	10.6	12.9	16.3	19.8	24.5	30.7	39.0
POWER	3.0	2.0	2.0	2.0	2.0	2.0	2.0
TOTAL	27.1	31.5	39.0	45.8	54.2	63.3	77.2
SUPPLY:	----	----	----	----	----	----	----
M&I	47.6	59.7	59.7	59.7	59.7	59.7	59.7
POWER	3.0	2.0	2.0	2.0	2.0	2.0	2.0
TOTAL	50.6	61.7	61.7	61.7	61.7	61.7	61.7
NET NEEDS	----	----	----	----	----	1.6	15.5

* Net needs for International Paper - Source: Lake Wright Patman-Sulphur River Basin (incl. in county totals)

TABLE 4 (cont.)

HARRISON COUNTY							
REQUIREMENTS:							
MUNICIPAL	3.8	5.0	6.1	6.7	7.7	8.2	8.6
INDUSTRIAL	5.9	7.0	10.4	15.4	21.5	27.7	35.6
POWER	----	2.0	13.0	13.0	13.0	13.0	13.0
TOTAL	9.7	14.0	29.5	35.1	42.2	48.9	57.2
SUPPLY:							
M&I	10.6	10.6	10.6	10.6	10.6	10.6	10.6
POWER							
LITTLE CYPRESS CREEK		dependable yield not available					
CADDO LAKE		"	"	"	"		
TOTAL	10.6	10.6	10.6	10.6	10.6	10.6	10.6
NET NEEDS-							
excl power req.	----	1.4	5.9	11.5	18.6	25.3	33.6
MARION COUNTY							
REQUIREMENTS:							
MUNICIPAL	.3	.3	.4	.4	.5	.5	.6
INDUSTRIAL	1/	1/	1/	.1	.1	.1	.1
POWER	5.0	4.0	2.0	2.0	2.0	2.0	2.0
TOTAL	5.3	4.3	2.4	2.5	2.6	2.6	2.7
SUPPLY:							
M&I	2.9	2.9	2.9	2.9	2.9	2.9	2.9
POWER							
PLANT LAKE	5.0	4.0	2.0	2.0	2.0	2.0	2.0
TOTAL	7.9	6.9	4.9	4.9	4.9	4.9	4.9
NET NEEDS	----	----	----	----	----	----	----
MORRIS COUNTY							
REQUIREMENTS:							
MUNICIPAL	.5	.5	.6	.7	.8	.9	.9
INDUSTRIAL	18.9	30.3	38.1	51.5	62.2	76.3	101.0
POWER	2/	2/	----	----	----	----	----
TOTAL	19.4	30.8	38.7	52.2	63.0	77.2	101.9
SUPPLY:							
M&I	20.9	20.9	20.9	20.9	20.9	20.9	20.9
POWER							
ELLISON CREEK RESERVOIR	2/	2/	----	----	----	----	----
TOTAL	20.9	20.9	20.9	20.9	20.9	20.9	20.9
NET NEEDS	----	9.9	17.8	31.3	42.1	56.3	81.0
TITUS COUNTY							
REQUIREMENTS:							
MUNICIPAL	2.2	2.6	2.9	3.3	3.7	4.0	4.2
INDUSTRIAL	1.8	2.7	3.5	4.0	4.6	5.3	6.3
POWER	8.0	14.0	10.0	10.0	10.0	10.0	10.0
TOTAL	12.0	19.3	16.4	17.3	18.3	19.3	20.5
SUPPLY:							
M&I	9.3	18.8	18.8	18.8	18.8	18.8	18.8
POWER-							
2 PLANT LAKES	8.0	14.0	10.0	10.0	10.0	10.0	10.0
TOTAL	17.3	32.8	28.8	28.8	28.8	28.8	28.8
NET NEEDS	----	----	----	----	----	----	----

TABLE 4 (cont.)

UPSHUR COUNTY							
REQUIREMENTS:							
MUNICIPAL	1.2	1.5	2.0	2.4	3.0	3.4	3.6
INDUSTRIAL	.7	1.0	1.4	1.9	2.6	3.3	4.3
TOTAL	1.9	2.5	3.4	4.3	5.6	6.7	7.9
SUPPLY:							
M&I	2.7	2.7	2.7	2.7	2.7	2.7	2.7
NET NEEDS	----	----	.7	1.6	2.9	4.0	5.2
WOOD COUNTY							
REQUIREMENTS:							
MUNICIPAL	1.1	1.6	2.0	2.5	3.0	3.4	3.9
INDUSTRIAL	.8	.9	1.1	1.3	1.5	1.8	2.2
TOTAL	1.9	2.5	3.1	3.8	4.5	5.2	6.1
SUPPLY:							
M&I	1.9	1.9	1.9	1.9	1.9	1.9	1.9
NET NEEDS	----	.6	1.2	1.9	2.6	3.3	4.2
CADDO PARISH							
REQUIREMENTS:							
MUNICIPAL	31.2	34.6	38.0	40.2	44.7	47.2	49.7
INDUSTRIAL	6.2	7.7	9.1	10.7	12.3	14.7	17.8
POWER	1.0	2/	2/	2/	2/	2/	2/
TOTAL	38.4	42.3	47.1	50.9	57.0	61.9	67.5
SUPPLY:							
M&I	44.5	44.5	44.5	44.5	44.5	44.5	44.5
POWER							
PLANT LAKE	2/	2/	2/	2/	2/	2/	2/
CADDO LAKE	1.0	2/	2/	2/	2/	2/	2/
TOTAL	45.5	44.5	44.5	44.5	44.5	44.5	44.5
NET NEEDS	----	----	2.6	6.4	12.5	17.4	23.0
TOTAL STUDY AREA							
NEEDS	----	11.9	28.2	52.7	103.4	179.6	295.6

1/ Less than 50,000 GPD

2/ Less than .5 MGD

TABLE 5

BASELINE TOTAL M&I WATER REQUIREMENTS VS. SUPPLY FOR SELECTED CITIES, LITTLE CYPRESS STUDY AREA, 1980-2040

MGD

CITY	1980	1990	2000	2010	2020	2030	2040
SHREVEPORT							
M&I Requirements	36.3	41.0	45.6	49.3	55.1	59.8	65.0
Supply	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Net Needs	----	----	2.6	6.3	12.1	15.8	22.0
MARSHALL							
M&I Requirements	7.3	9.0	12.6	17.1	22.5	27.0	32.4
Supply	9.3	9.3	9.3	9.3	9.3	9.3	9.3
Net Needs	----	----	3.3	7.8	13.2	17.7	23.1
LONGVIEW							
M&I Requirements	19.0	22.8	28.0	32.6	38.5	44.8	53.1
Supply	39.0	51.1	51.1	51.1	51.1	51.1	51.1
Net Needs	----	----	----	----	----	----	2.0
KILGORE							
M&I Requirements	2.4	4.2	5.6	7.1	8.7	10.5	12.5
Supply	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Net Needs	----	----	----	----	1.5	3.3	5.3
MOUNT PLEASANT							
M&I Requirements	4.0	5.3	6.4	7.3	8.3	9.3	10.5
Supply	9.3	18.8	18.8	18.8	18.8	18.8	18.8
Net Needs	----	----	----	----	----	----	----

Ground water for Vivian is obtained from five wells. The estimated safe yield is 1.5 mgd. No water needs are projected for Vivian.

At Blanchard, UOP, Inc., Process Division, operates its chemical plant, using about .36 mgd of water in 1980.

In 1979, Southwestern Electric Power operated the Arsenal Hill and Lieberman thermal electric generating plants in Caddo Parish. Sources of cooling water were, respectively, a plant lake and Caddo Lake (Table 6), according to the Federal Energy Regulatory Commission.

Net needs for M&I and power water are projected to reach 23 mgd by 2040 in the parish.

Camp County. The City of Pittsburg comprises the urban area of the county. Pittsburg obtains its water from eight wells with a dependable yield estimated at 1.5 mgd. Industrial water users includes an iron foundry and a steel foundry.

The county is not projected to have water needs for the period of this study.

Cass County. The urban area in Cass County is the City of Atlanta. Sources of water for the city are four wells with a safe yield of 1.2 mgd and Lake Wright Patman (4.9 mgd). Atlanta will not have net water needs through the year 2040.

Gas processing plants were operated by Breckenridge Gasoline Co. near Lodi and Shell Oil Co. near Douglassville using self-supplied ground water. International Paper Co. manufactured paper pulp and products at its plant near Texarkana. The company has contracted with the City of Texarkana, Texas to purchase up to 105.3 mgd for operation of its mill near the Sulphur River downstream from Lake Wright Patman dam. This includes water required for operation of the plant's waste treatment facilities. As shown in Table 4, the projected net needs for this plant more

TABLE 6

THERMAL ELECTRIC GENERATING PLANTS, 1979-2000
LITTLE CYPRESS STUDY AREA

ANT	INSTALLED CAPACITY (MW)	GENERATION (GWH)	TYPE COOLING	WATER SOURCE	WITHDRAWAL (MGD)	ESTIMATED CONSUMPTION (MGD)
			GREGG COUNTY, TEXAS			
			1979			
KNOX LEE	537	2,634	CP	LITTLE CHEROKEE	5	3
			1985			
KNOX LEE	537	1,910	CP	LITTLE CHEROKEE	4	2
			2000			
KNOX LEE	1,046	1,830	CP	LITTLE CHEROKEE	4	2
			HARRISON COUNTY, TEXAS			
			1979			
NONE						
			1985			
PIRKEY	640	1,505	CP	LITTLE CYPRESS CREEK	3	2
			2000			
PIRKEY	1,280	6,167	CP & WT	LITTLE CYPRESS CREEK	13	8
KARNACK	640	3,083	WT	CADDO LAKE	8	5
			MARION COUNTY, TEXAS			
			1979			
WILKES	882	4,701	CP	PLANT LAKE	7	5
			1985			
WILKES	882	3,860	CP	PLANT LAKE	6	4
			2000			
LKES	882	1,550	CP	PLANT LAKE	3	2
			MORRIS COUNTY, TEXAS			
			1979			
LONE STAR	50	1	CP	LONE STAR	2/	2/
			1985			
LONE STAR	50	30	CP	LONE STAR	2/	2/
			2000			
NONE						
			TITUS COUNTY, TEXAS			
			1979			
MONTICELLO	990	4,838	CP	PLANT LAKE	7	5
WELSH	558	2.865	CP	PLANT LAKE	4	3
			1985			
MONTICELLO	990	5,203	CP	PLANT LAKE	8	5
WELSH	1,614	9,190	CP	PLANT LAKE	13	9
			2000			
MONTICELLO	990	3,470	CP	PLANT LAKE	5	3
WELSH	1,614	6,780	CP	PLANT LAKE	10	7
			CADDO PARISH, LOUISIANA			
			1979			
ARSENAL HILL	125	157	CP	PLANT LAKE	2/	2/
LIEBERMAN	277	998	CP	CADDO LAKE	2	1
			1985			
ARSENAL HILL	63	90	CP	PLANT LAKE	2/	2/
LIEBERMAN	277	180	CP	CADDO LAKE	2/	2/
			2000			
ARSENAL HILL	63	50	CP	PLANT LAKE	2/	2/
LIEBERMAN	277	200	CP	CADDO LAKE	2/	2/

1/ CP = Cooling Pond
WT = Wet Tower

2/ Less than .5 MGD

SOURCE: Federal Energy Regulatory Commission than account for the projected net needs for Cass County from 2020 through 2040. The county has no projected water needs if the International Paper Co. is excluded.

Franklin County. Mount Vernon obtains water from a city lake and purchases Lake Cypress Springs water. Dependable yield of the city lake is .17 mgd; the city has a contract to "pay or take" at least 350 acre feet (.312 mgd) annually from Lake Cypress Springs and is expected to be able to obtain sufficient water through 2040.

Getty Oil Co. uses self-supplied ground water from seven wells in the operation of its gas plant near Scroggins in the southeast corner of the county.

No net water needs have been projected for Franklin County.

Gregg County. Urban areas studied in the county were Longview, Kilgore, and Gladewater.

Sources of water for Longview are Lake Cherokee, Lake Fork Reservoir, and the Sabine River. The city has contracted for over 15 mgd from Lake Cherokee, with a dependable yield of 10.7 mgd, and for 17.855 mgd from Lake Fork Reservoir, with the full amount available by 1990. Industrial users purchasing over 50 million gallons per year include Texas Eastman Co., Jos. Schlitz Brewing Co., Southwest Stell Castings, Marathon-LaTourneau, and Jos. Schlitz Container Division. Arco Oil and Gas CO. operates its gas plant using about .126 mgd of self-supplied water from 3 wells; Cities Service Co. uses .221 mgd of self-supplied water from 1 well. Municipalities and systems purchasing water from Longview are White Oak (raw water), and Elderville Water Supply Corp., Gum Springs Water Supply Corp., Tryon Water System, and Spring Hill Utilities District. The City of Longview is projected to have net needs by 2040 (Table 4).

Ground water for Kilgore is obtained from a nearby well field, pumping from nine wells. According to city estimates, the safe annual withdrawal rate from the wells is 7.000 mgd. The City of Kilgore has constructed pumps, pipelines, and storage for the diversion of water from Longview. Negotiations for the eventual purchase (pay or take) of up to 7.5 mgd are currently under way. Industrial users include Kilgore Ceramics Corporation and Petrolite Corporation. Petrolite Corp. also uses about .249 mgd of self-supplied water from two wells. Other entities purchasing water from Kilgore are Crossroads Water Corp., City of Liberty, and Liberty, Danville Water Corporation. The City of Kilgore is projected to have net water needs by 2020.

The City of Gladewater obtains its water from Lake Gladewater which has sufficient dependable yield to supply future water requirements to 2040. Water is sold to Clarksville City and Starrville Friendship Water Co. (in Smith County).

According to the Federal Energy Regulatory Commission, the thermal electric power plant of Southwestern Electric Power Co. consumed an estimated 3 mgd of water in 1979. Source of the water is Lake Cherokee. The plant is projected to consume 2 mgd in 1985 and 2000 (Table 5).

Net needs for M&I and power water are not projected for Gregg County until 2030.

Harrison County. The City of Marshall is the only urban area in the county, except for a small part of the City of Longview. Marshall obtains its water from Big Cypress Bayou. If available, Marshall has a permit to pump water from the Bayou at a rate of 31.2 mgd; however, the dependable yield is estimated at 9.3 mgd in times of severe drought. The City is currently studying alternatives to provide additional water supplies. Significant users of industrial water include ICI Americas, Inc. and ALCOA Conductor Products Co. (Scottsville). Net water needs are projected for Marshall by 2000.

Texas Eastman Co., in addition to purchasing raw and processed water from Longview in Gregg County, also obtains surface water from the Sabine River in Harrison County (.685 mgd). Near Waskom in Harrison County, Arkansas Louisiana Chemical Corp. used .246 mgd of self-supplied ground water. At Karnack, Thiokol Corp. obtained over .60 mgd of surface water from Cypress Bayou (Caddo Lake) for use in the operation of the Longhorn Ordnance Plant.

According to the Federal Energy Regulatory Commission, two thermal electric power plants are projected in the county, using surface water from Little Cypress Creek and Caddo Lake (Table 5).

Net needs for M&I and power water are expected by 1990.

Marion County. The City of Jefferson comprises the urban area of the county. Sources of water include ground water (1 well) and a no-limit contract for surface water from Lake O' the Pines by stream diversion on Big Cypress Bayou.

According to the Federal Energy Regulatory Commission, Southwestern Electric Power operated its Wilkes thermal electric generating plant in Marion County in 1979, and consumed 5 mgd of water obtained from the plant lake.

Marion County is not projected to have net water needs through the year 2040.

Morris County. The City of Daingerfield obtains water from Lake O' the Pines. The current contract extends throught 1981. Beginning in 1982, the city has contracted to obtain Lake O' the Pines water from a different location on the lake which will provide a better quality water with very little variations in quality during the year.

Lone Star Steel Co., owner of Ellison Creek Reservoir, currently provides water for its steel mill plus selling water to the City of Lone Star and to Air Products and Chemicals Co.

In 1979, Southwestern Electric Power operated its Lone Star thermal electric generating plant in Morris County, according to the Federal Energy Regulatory Commission. Water consumption was less than .5 mgd.

On the basis of projected industry employment and employee productivity, net water needs are projected by 1990, increasing to nearly 102 mgd by 2040. However, technological advances could enable the industries (mainly Lone Star Steel) to adjust the mix of total water available to provide for substantially more make-up water.

Titus County. The City of Mount Pleasant comprises the urban area in Titus County. Sources of water for the city are Lake Tankersly and Lake Bob Sandlin. By 1990, dependable yield from the two lakes will exceed 18 mgd (Table 3). Leading industrial water users include Dorchester Refining Co., Pilgrim Industries, Inc., and Golden Feast Poultry, Incorporated. No net needs for Mount Pleasant are projected.

According to the Federal Energy Regulatory Commission, two thermal electric generating plants were operating in the county in 1979.

Texas Utilities Generating Co.'s Monticello plant consumed an estimated 5 mgd of water in 1979; source of the water is Lake Monticello. Southwestern Electric Power Co.'s Welsh plant consumed an estimated 3 mgd of water from Lake Welsh.

Titus County is projectd to have sufficient sources of water for M&I and power through 2040.

Upshur County. The City of Gilmer is the only urban area in the county. Water supply source is from six wells with a dependable yield of 1.2 mgd. No high-volume industrial water users purchase water from the city. Robroy Industries uses about .283 mgd of self-supplied water from one well. The city sells no water to other entities. Net water needs are projected by 2000 in the county.

Wood County. Mineola was the urban area studied in Wood County. Water is obtained from four wells with a dependable yield estimated to be 16 mgd. There are no high volume water using industries in the city. Mineola does not supply water to other entities.

At Hawkins, Exxon Company, USA operates its gasoline plant, using about .233 mgd of self supplied ground water from seven wells.

Amoco Production Co. uses approximately .133 mgd of self-supplied ground water from three wells in the operation of its gas processing plant at Yantis.

Net water needs are projected by 1990 in Wood County.

Thermal Electric Power. According to the Federal Energy Regulatory Commission, thermal electric generating plants operating in 1979 in the study area were the Arsenal Hill and Lieberman plants in Caddo Parish, Knox Lee plant in Gregg County, Wilkes plant in Marion County, Lone Star plants in Titus County (Table 6). In Harrison County, the Pinkey plant is expected to be in operation by 1985 and the Karnack plant by 2000.

Estimated water consumption by these plants in 1979 was 17 mgd. By 2000, estimated consumption is projected to be 27 mgd.

III

WATER NEEDS WITH CONSERVATION

Introduction. Conservation has been established as a cornerstone of federal water resources policy. Factors accounting for the growing emphasis on water conservation include: rising demand, scarcity of new reservoir sites, declining ground water levels, rising costs of water resources development, and increasing concern for environmental quality.

Several measures can be used to encourage or implement water conservation. Public education through the use of television, radio, and newspapers can be used to communicate the need to the public of conserving water and describe methods to achieve this objective. The use of water conservation devices such as shower flow controls, toilet inserts, and modified lawn sprinkling devices are relatively inexpensive and may be effective in reducing demand. Plumbing codes can be revised to require low flow showerheads and faucets and water-saving toilets for new construction or replacements plumbing. Pricing and metering techniques can be employed to encourage conservation.

The purpose of this section is to measure the effects of conservation programs on municipal water requirements of selected cities in the study area.

Baseline industrial water use projections have not been modified because the projections reflect increasing recirculation of water used in the industrial processes. Thus these projections automatically reflect conservation.

Conservation projections of municipal water needs include both interior and exterior residential conservation estimates. For interior residential use it was assumed that water saving toilets, faucets, and shower heads would be required in all new construction and that replacement of these items in existing residences would occur gradually over a period of 50 years. For exterior conservation savings the seasonal component (extra water used in the months of June through October) for landscape irrigation, swimming pools, etc. was estimated for the year 1980 and this ratio applied to projected water use data. The seasonal component was reduced by 10 percent to obtain the projected savings through conservation for exterior water use.

Projections of Net Needs with Conservation. Projected M&I water requirements with conservation are shown in Table 7 for the cities of Shreveport, Marshall, Longview, Kilgore, and Mount Pleasant.

With projected conservation measures, M&I requirements for Shreveport will be reduced by 2.4 percent in 1990, increasing to 6.6 percent savings by 2040. For the City of Longview, conservation savings will reach nearly 2 percent by 1990, increasing to 3.6 percent by 2040. For Kilgore and Mount Pleasant, the savings due to conservation measures range from 2 percent in 1990 to 3 percent in 2040.

TABLE 7

TOTAL M&I WATER REQUIREMENTS WITH CONSERVATION VS. SUPPLY FOR SELECTED CITIES, LITTLE CYPRESS STUDY AREA, 1980-2040

CITY	1980	1990	2000	2010	2020	2030	2040
SHREVEPORT							
M&I Requirements	36.3	40.0	43.9	46.9	51.9	55.9	60.7
Supply	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Net Needs	----	----	.9	3.9	8.9	12.9	17.7
MARSHALL							
M&I Requirements	7.3	8.8	12.3	16.7	22.0	26.4	31.7
Supply	9.3	9.3	9.3	9.3	9.3	9.3	9.3
Net Needs	----	----	3.0	7.4	12.7	17.1	22.4
LONGVIEW							
M&I Requirements	19.0	22.4	27.2	31.5	37.1	43.2	51.2
Supply	39.0	51.1	51.1	51.1	51.1	51.1	51.1
Net Needs	----	----	----	----	----	----	.1
KILGORE							
M&I Requirements	2.4	4.1	5.4	6.9	8.4	10.1	12.1
Supply	7.2	7.2	7.2	7.2	7.2	7.2	7.2
Net Needs	----	----	----	----	1.2	2.9	4.9
MOUNT PLEASANT							
M&I Requirements	4.0	5.2	6.3	7.1	8.1	9.0	10.2
Supply	9.3	18.8	18.8	18.8	18.8	18.8	18.8
Net Needs	----	----	----	----	----	----	----

APPENDIX A:

AVERAGE DAY USE AND MAXIMUM DAY USE-SELECTED CITIES

Projections of average day water use and maximum day water use were made for the cities of Shreveport, Louisiana, and Marshall, Longview, Kilgore, and Mount Pleasant, Texas. Water used for public services plus losses have been included in the total.

Tables A-1 through A-10 show average day use and maximum day use for the five cities for 1980 through 2040, and the differences between projected use and water supply capacity.

TABLE A-1

M&I WATER SUPPLIES, WITHOUT-PROJECT CONDITION, AVERAGE DAY USE AND CAPACITY SHREVEPORT, LOUISIANA

	MILLIONS OF GALLONS PER DAY						
	1980	1990	2000	2010	2020	2030	2040
PROJECTED AVERAGE DAY WATER USE:							
RESIDENTIAL	17.5	19.4	21.3	22.6	25.1	26.6	27.9
COMMERCIAL	9.9	11.0	12.1	12.8	14.2	15.0	15.8
INDUSTRIAL	5.8	7.2	8.5	10.0	11.4	13.6	16.4
ADDITIONAL [1]	3.1	3.4	3.7	3.9	4.4	4.6	4.9
TOTAL	36.6	41.0	45.6	49.3	55.1	59.8	65.0
AVERAGE DAY WATER SUPPLY CAPACITY:							
CROSS LAKE	23.0	23.0	23.0	23.0	23.0	23.0	23.0
12-MILE BAYOU	20.0	20.0	20.0	20.0	20.0	20.0	20.0
TOTAL	43.0	43.0	43.0	43.0	43.0	43.0	43.0
DIFFERENCE BETWEEN PROJECTED AVERAGE DAY WATER USE AND SUPPLY WITHOUT A PLAN:	----	----	2.6	6.3	12.1	15.8	22.0

1/ Includes public services and unaccounted for losses.

TABLE A-2

M&I WATER SUPPLIES, WITHOUT-PROJECT CONDITION, MAXIMUM DAY USE AND CAPACITY SHREVEPORT, LOUISIANA

	MILLIONS OF GALLONS PER DAY						
	1980	1990	2000	2010	2020	2030	2040
PROJECTED MAXIMUM DAY WATER USE:							
RESIDENTIAL	30.5	34.0	37.3	39.5	44.1	46.6	49.4
COMMERCIAL	17.4	19.3	21.2	22.4	25.0	26.7	27.9
INDUSTRIAL	10.7	12.6	14.9	17.5	20.0	23.8	28.7
ADDITIONAL 1/	5.4	5.9	6.5	6.9	7.4	7.5	7.6
TOTAL	64.0	71.8	79.9	86.3	96.5	104.6	113.6
MAXIMUM DAY WATER SUPPLY CAPACITY:							
CROSS LAKE	23.0	23.0	23.0	23.0	23.0	23.0	23.0
12-MILE BAYOU	20.0	20.0	20.0	20.0	20.0	20.0	20.0
TOTAL	43.0	43.0	43.0	43.0	43.0	43.0	43.0
DIFFERENCE BETWEEN PROJECTED MAXIMUM DAY WATER USE AND SUPPLY WITHOUT A PLAN:	21.0	28.8	36.9	43.3	53.5	61.6	70.6

1/ Includes public services and unaccounted for losses

TABLE A-3

M&I WATER SUPPLIES, WITHOUT-PROJECT CONDITION, AVERAGE DAY USE AND CAPACITY
MARSHALL, TEXAS

	MILLIONS OF GALLONS PER DAY						
	1980	1990	2000	2010	2020	2030	2040
PROJECTED AVERAGE DAY WATER USE:							
RESIDENTIAL	3.0	2.9	3.6	3.9	4.5	4.8	5.0
COMMERCIAL	1.5	1.5	1.8	2.0	2.3	2.4	2.5
INDUSTRIAL	2.8	4.6	7.2	11.2	15.7	19.8	24.9
ADDITIONAL 1/	.7	1.0	1.4	1.9	2.5	3.0	3.6
TOTAL	8.0	10.0	14.0	19.0	25.0	30.0	36.0
AVERAGE DAY WATER SUPPLY CAPACITY:							
BIG CYPRESS BAYOU	9.3	9.3	9.3	9.3	9.3	9.3	9.3
DIFFERENCE BETWEEN PROJECTED AVERAGE DAY WATER USE AND SUPPLY WITHOUT A PLAN	---	.7	4.7	9.7	15.7	20.7	26.7

1/ Includes public servaices and unaccounted for losses

TABLE A-4

M&I WATER SUPPLIES, WITHOUT-PROJECT CONDITION, MAXIMUM DAY USE AND CAPACITY
MARSHALL, TEXAS

	MILLIONS OF GALLONS PER DAY						
	1980	1990	2000	2010	2020	2030	2040
PROJECTED MAXIMUM DAY WATER USE:							
RESIDENTIAL	4.0	5.1	6.3	6.9	7.9	8.4	8.8
COMMERCIAL	2.2	2.6	3.2	3.5	4.0	4.2	4.4
INDUSTRIAL	4.9	8.1	12.6	19.6	27.5	34.7	43.6
ADDITIONAL 1/	1.2	1.7	2.4	3.3	4.4	5.2	6.2
TOTAL	12.3	17.5	24.5	33.3	43.8	52.5	63.0
MAXIMUM DAY WATER SUPPLY CAPACITY:							
BIG CYPRESS BAYOU	9.3	9.3	9.3	9.3	9.3	9.3	9.3
DIFFERENCE BETWEEN PROJECTED MAXIMUM DAY WATER USE AND SUPPLY WITHOUT A PLAN	3.0	8.2	15.2	24.0	34.5	43.2	53.7

1/ Includes public services and unaccounted for losses

TABLE A-5

M&I WATER SUPPLIES, WITHOUT-PROJECT CONDITION, AVERAGE DAY USE AND CAPACITY
LONGVIEW, TEXAS

	MILLIONS OF GALLONS PER DAY						
	1980	1990	2000	2010	2020	2030	2040
PROJECTED AVERAGE DAY WATER USE:							
RESIDENTIAL	7.0	8.5	10.3	11.6	13.3	14.4	15.8
COMMERCIAL	3.6	4.2	5.2	5.9	6.7	7.2	7.9
INDUSTRIAL	8.4	10.1	12.5	15.1	18.6	23.2	29.4
ADDITIONAL 1/	3.5	3.5	3.4	3.4	3.4	3.3	3.3
TOTAL	22.5	26.3	31.4	36.0	42.0	48.1	56.4
AVERAGE DAY WATER SUPPLY CAPACITY:							
LAKE CHEROKEE	10.7	10.7	10.7	10.7	10.7	10.7	10.7
LAKE FORK RESERVOIR	5.9	17.0	17.0	17.0	17.0	17.0	17.0
SABINE RIVER	22.1	22.1	22.1	22.1	22.1	22.1	22.1
TOTAL	38.7	50.8	50.8	50.8	50.8	50.8	50.8
DIFFERENCE BETWEEN PROJECTED AVERAGE DAY WATER USE AND SUPPLY WITHOUT A PLAN	---	---	---	---	---	---	5.6

1/ Includes public services and unaccounted for losses

TABLE A-6

M&I WATER SUPPLIES, WITHOUT-PROJECT CONDITION, MAXIMUM DAY USE AND CAPACITY
LONGVIEW, TEXAS

	MILLIONS OF GALLONS PER DAY						
	1980	1990	2000	2010	2020	2030	2040
PROJECTED MAXIMUM DAY WATER USE:							
RESIDENTIAL	12.8	15.3	18.3	20.5	23.3	25.1	27.4
COMMERCIAL	6.6	7.6	9.2	10.4	11.8	12.6	13.7
INDUSTRIAL	15.4	18.2	22.3	26.6	32.6	40.4	51.1
ADDITIONAL 1/	3.5	3.6	3.6	3.7	3.7	3.7	3.7
TOTAL	38.3	44.7	53.4	61.2	71.4	81.8	95.5
MAXIMUM DAY WATER SUPPLY CAPACITY:							
LAKE CHEROKEE	10.7	10.7	10.7	10.7	10.7	10.7	10.7
LAKE FORK RESERVOIR	5.9	17.0	17.0	17.0	17.0	17.0	17.0
SABINE RIVER	22.1	22.1	22.1	22.1	22.1	22.1	22.1
TOTAL	38.7	50.8	50.8	50.8	50.8	50.8	50.8
DIFFERENCE BETWEEN PROJECTED MAXIMUM DAY WATER USE AND SUPPLY WITHOUT A PLAN	---	---	2.6	10.4	20.6	31.0	45.1

1/ Includes public services and unaccountable losses

TABLE A-7

M&I WATER SUPPLIES, WITHOUT-PROJECT CONDITION, AVERAGE DAY USE AND CAPACITY
KILGORE, TEXAS

	MILLIONS OF GALLONS PER DAY						
	1980	1990	2000	2010	2020	2030	2040
PROJECTED AVERAGE DAY WATER USE:							
RESIDENTIAL	.6	1.5	2.0	2.5	2.9	3.4	3.7
COMMERCIAL	.3	.8	1.0	1.3	1.5	1.7	1.8
INDUSTRIAL	1.5	1.9	2.6	3.3	4.3	5.4	7.0
ADDITIONAL 1/	.5	.5	.5	.5	.5	.5	.5
TOTAL	2.9	4.7	6.1	7.6	9.2	11.0	13.0
AVERAGE DAY WATER SUPPLY CAPACITY:							
WELLS (CITY)	7.0	7.0	7.0	7.0	7.0	7.0	7.0
WELLS (PRIVATE)	.2	.2	.2	.2	.2	.2	.2
TOTAL	7.2	7.2	7.2	7.2	7.2	7.2	7.2
DIFFERENCE BETWEEN PROJECTED AVERAGE DAY WATER USE AND SUPPLY WITHOUT A PLAN	---	---	---	.4	2.0	3.8	5.8

1/ Includes public services and unaccountable losses

TABLE A-8

M&I WATER SUPPLIES, WITHOUT-PROJECT CONDITION, MAXIMUM DAY USE AND CAPACITY
KILGORE, TEXAS

	MILLIONS OF GALLONS PER DAY						
	1980	1990	2000	2010	2020	2030	2040
PROJECTED MAXIMUM DAY WATER USE:							
RESIDENTIAL	1.3	3.0	4.0	5.0	5.8	6.8	7.4
COMMERCIAL	.7	1.6	2.0	2.6	3.0	3.4	3.6
INDUSTRIAL	3.2	3.8	5.2	6.6	8.6	10.8	13.0
ADDITIONAL 1/	.6	.6	.6	.6	.6	.6	.6
TOTAL	5.8	9.0	11.8	14.8	18.0	21.6	24.6
AVERAGE DAY WATER SUPPLY CAPACITY:							
WELLS (CITY)	7.0	7.0	7.0	7.0	7.0	7.0	7.0
WELLS (PRIVATE)	.2	.2	.2	.2	.2	.2	.2
TOTAL	7.2	7.2	7.2	7.2	7.2	7.2	7.2
DIFFERENCE BETWEEN PROJECTED MAXIMUM DAY WATER USE AND SUPPLY WITHOUT A PLAN	---	1.8	4.6	7.6	10.8	14.4	17.4

1/ Includes public services and unaccountable losses

TABLE A-9

M&I WATER SUPPLIES, WITHOUT-PROJECT CONDITION, AVERAGE DAY USE AND CAPACITY
MOUNT PLEASANT, TEXAS

	MILLIONS OF GALLONS PER DAY						
	1980	1990	2000	2010	2020	2030	2040
PROJECTED AVERAGE DAY WATER USE:							
RESIDENTIAL	1.5	1.7	1.9	2.2	2.5	2.7	2.8
COMMERCIAL	.7	.9	1.0	1.1	1.2	1.3	1.4
INDUSTRIAL	1.8	2.7	3.5	4.0	4.6	5.3	6.3
ADDITIONAL 1/	.5	.5	.5	.5	.5	.5	.5
TOTAL	4.5	5.8	6.9	7.8	8.8	9.8	11.0
AVERAGE DAY WATER SUPPLY CAPACITY:							
LAKE TANKERSLY	6.2	6.2	6.2	6.2	6.2	6.2	6.2
LAKE BOB SANDLIN	12.5	12.5	12.5	12.5	12.5	12.5	12.5
TOTAL	18.7	18.7	18.7	18.7	18.7	18.7	18.7
DIFFERENCE BETWEEN PROJECTED AVERAGE DAY USE AND SUPPLY WITHOUT A PLAN	---	---	---	---	---	---	---

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1/ Includes public services and unaccounted for losses .

TABLE A-10

M&I WATER SUPPLIES, WITHOUT-PROJECT CONDITION, MAXIMUM DAY USE AND CAPACITY
MOUNT PLEASANT, TEXAS

	MILLIONS OF GALLONS PER DAY						
	1980	1990	2000	2010	2020	2030	2040
PROJECTED MAXIMUM DAY WATER USE:							
RESIDENTIAL	2.4	3.2	3.8	4.4	5.0	5.6	5.7
COMMERCIAL	1.1	1.5	1.8	2.0	2.3	2.6	2.6
INDUSTRIAL	2.9	3.8	4.6	5.3	6.0	6.7	6.9
ADDITIONAL 1/	.6	.6	.6	.6	.6	.6	.6
TOTAL	7.0	9.1	10.8	12.3	13.9	15.5	15.8
MAXIMUM DAY WATER SUPPLY CAPACITY:							
LAKE TANKERSLY	6.2	6.2	6.2	6.2	6.2	6.2	6.2
LAKE BOB SANDLIN	12.5	12.5	12.5	12.5	12.5	12.5	12.5
TOTAL	18.7	18.7	18.7	18.7	18.7	18.7	18.7
DIFFERENCE BETWEEN PROJECTED MAXIMUM DAY WATER USE AND SUPPLY WITHOUT A PLAN	---	---	---	---	---	---	---

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1/ Includes public services and unaccounted for losses

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX C - HYDROLOGY AND HYDRAULICS

CYPRESS BAYOU BASIN STUDY
FEASIBILITY REPORT

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HYDROLOGY AND HYDRAULICS

CHAPTER 1 - HYDROLOGY

BASIN DESCRIPTION

The Cypress Bayou Basin is located in northeast Texas and northwest Louisiana. It is the watershed upstream of Caddo Dam. The basin is bound on the north by the Sulphur River Basin, on the west and south by the Sabine River Basin, and on the east by the Twelvemile Bayou Basin (to which it contributes).

DRAINAGE AREA

The Cypress Bayou Basin has a length of about 88 miles, a maximum width of 48 miles, and a drainage area of about 2,780 square miles, embracing all or portions of 10 Texas counties and one Louisiana parish. Subbasin drainage areas in square miles are shown below.

Lake O' The Pines	880
Little Cypress Bayou	730
Black Cypress Bayou	390
Big Cypress Bayou above confluence with Little Cypress and Black Cypress Bayous and below Lake O' The Pines	70
Caddo Lake below confluence of Big Cypress, Little Cypress, and Black Cypress Bayous	710
Total Cypress Bayou Basin	2,780
Texas	(2,680)
Louisiana	(100)

Plate C-1 is a watershed map of Big Cypress Bayou.

STREAM CHARACTERISTICS

Big Cypress Bayou originates in southeastern Hopkins County, Texas and flows southeast, a distance of about 80 miles to enter Caddo Lake near the Texas-Louisiana border. The major tributary to Big Cypress Bayou is Little Cypress Bayou. Other significant tributaries are Black Cypress Bayou, Frazier Creek, and James Bayou. Downstream from Caddo Lake, the name of Big Cypress Bayou changes to Twelvemile Bayou. Black Bayou enters Twelvemile Bayou about a mile downstream from Caddo Lake Dam.

Steambed elevations of Big Cypress Bayou vary from about 550 feet NGVD near Highway 43 (Karnack stream gage).

HYDROLOGIC MODEL

A hydrologic model was developed using the HEC-5 program, "Simulation of Flood Control and conservation Systems." Thirteen years of record (1945, 1958, and 1964 through 1974) were used in calibrating the model. The floods of 1945, 1958, and 1966 are the largest in the period of record, which began in 1938.

The regulation scheme adopted for Lake O' The Pines regulates to specified discharges at downstream locations as long as less than 50 percent of the flood control pool is projected to be utilized. Once an elevation of 236 (fee line) is forecast, operation under the original regulation scheme is initiated to limit adverse effects within the reservoir area. Under the original regulations scheme, releases are made at a rate of 3,000 cfs without regard for downstream flood conditions. The downstream control point is the gage at Karnack, Texas, where the control discharge is 7,000 cfs. Other controls utilized include a channel capacity of 3,000 cfs below Lake O' The Pines and 2,000 cfs each below the investigated Marshall and Black Cypress Lakes.

INVESTIGATED LAKES

General

Two lakes were investigated for multiple purposes including flood control, water supply, recreation, and hydropower. The lakes and their locations are Marshall Lake, river mile (RM) 21.3 on Little Cypress Bayou, and Black Cypress Lake, RM 17.0 on Black Cypress Bayou. The locations of these lakes are shown on Plate 9 of the main report.

Pertinent Data and Area Capacity

Preliminary pertinent data for Black Cypress and Marshall Lakes were developed for numerous lake alternatives. These alternatives included single and multiple purpose lakes of different sizes. Tables 30 and 31 from the main report contain pertinent data for the array of Marshall and Black Cypress Lakes evaluated. Area capacity tabulations for Marshall Lake are shown in Table C-1. Plate C-2 presents a yield curve for Marshall Lake. Black Cypress Lake area capacity tabulations are shown in Table C-2. The yield curve for Black Cypress Lake is presented in plate C-3.

DISCHARGE FREQUENCY

A period of record analysis was performed for the Little Cypress Bayou near Jefferson gage and the Black Cypress Bayou near Jefferson gage using Program No. 723-X6-17550, "Flood Flow Frequency Analysis," deve- loped by HEC and WRC. The period of record used was 1939 through 1978 and 1944 through 1982 for Black Cypress Bayou and Little Cypress Bayou, respectively. Adopted skew coefficients are 0.05 and -0.24 for Black Cypress Bayou and Little Cypress Bayou, respectively. Tables C-3 and C-4 present the results of these frequency analyses for Black Cypress Bayou and Little Cypress Bayou, respectively. To determine the effects of the proposed lakes on the flood flows in the Cypress Bayou Basin, a synthetic unit hydrograph, modified PULS routing model, was developed and analyzed using the JREWING computer program developed by the Fort Worth District. For existing conditions, this model was approximately calibrated to the analytical frequency mentioned above. Also considered in the calibration process for existing conditions were historic stages and discharges for Big Cypress Bayou near Jefferson, Big Cypress Bayou at Karnack, Caddo Lake at Caddo Dam, Twelvemile Bayou near Mooringsport, Twelvemile Bayou near Dixie, and Black Bayou near Gilliam. Existing conditions discharge frequency results are presented in Table C-5. The synthetic unit hydrograph model was used, along with the HEC-5 analyses and judgement, to determine modified discharge frequency curves throughout the Cypress Bayou Basin for 10-, 25-, and 50-year flood control projects with a yield of 180 cfs for Marshall Lake and Black Cypress Lake.

LAKE STORAGE CAPACITIES

Three alternatives for flood control storage for Marshall and Black Cypress Lakes were analyzed. Storage was based on one of the following: 10-year storage plus a 21-day reserve (i.e., assumption that channel capacity downstream from the project would be utilized by local flows and not available for flood control releases), 25-year storage plus a 21-day reserve, or 50-year storage plus a 21-day reserve. Determination of the storage values was accomplished by analyzing the daily period of record (1939-1979) and calculating the maximum flood control storage required in inches for each year. During flood period, the assumption of a constant release rate of 2,000 cfs was made. A storage depth versus frequency curve was established and the 10-year, 25-year, and 50-year storages were adopted from this curve. The 21-day reserve of 2,000 cfs per day was added to the frequency storages to obtain the total flood control storage. The following are the flood control storages for Marshall and Black Cypress Lakes.

	Marshall Lake Flood Control Storage		Black Cypress Lake Flood Control Storage	
	Inches	Acre-Feet	Inches	Acre-Feet
10-year Storage	8.25	271,500	8.22	149,900
25-year Storage	10.95	360,300	10.87	198,300
50-year Storage	12.55	413,000	12.57	229,300

These storages closely relate to storages published in "Review of Reports -- White Oak, Cypress, and Little Cypress Creeks, Texas," published by the New Orleans District in 1968. In that document, the Little Cypress Grayston site had a 25-year storage of 11.43 inches, and the Cypress Creek Harvard site had a 30-year storage of 11.79 inches.

SPILLWAY

The spillways for Marshall and Black Cypress Lakes were designed as ogee overflow type with vertical upstream faces. Spillway crest was at the top of the flood control pool or conservation pool for projects without flood control storage, and for preliminary plan formulation the spillway crest length sized at was 600 feet.

SPILLWAY DESIGN FLOOD

The HEC-5 model was used to develop the spillway design flood for existing and modified conditions. Inflows were determined from the "Watershed Runoff Computer Model for Historical and Hypothetical Storm Events" developed by the Southwestern Division. The spillway design flood is one-half of the probable maximum flood followed in 4 days by the probable maximum flood.

FREEBOARD

Freeboard was determined using program number 723-X6-M0074, "Wave Runup and Wind Setup Computational Model" by B. R. Bodine of the Southwestern Division. Assumptions made for the dams were riprap slopes and an embankment slope of 1 on 3. Total increase in water computed level for Marshall lake was 4.5 feet and for Black Cypress Lake was 3.7 feet.

DETAILED PLAN EVALUATION

Marshall Lake

As shown on Table 30 of the main report preliminary pertinent data were developed for several Marshall Lake scenarios. However, none of the preliminary lake yields evaluated was sized to yield the projected future water supply needs of the study area. Consequently, as part of the overall detailed plan evaluations, pertinent data were developed for a Marshall Lake scaled to yield the projected 200cfs water supply need in the study area. Additional analyses were also performed to determine the sensitivity different length spillways would have on downstream expected probability discharge - frequency. Pertinent data for Marshall lake having a 200 cfs water supply yield with spillway lengths of 400, 600 and 1000 feet are shown in Table C-6. The surcharge storage impacts on downstream probability discharge-frequency, for the three spillway sizes, is shown on Table C-7.

LAKE O' THE PINES STORAGE REALLOCATION

The increased water supply yield which would be available in Lake O' The Pines as a result of reallocating flood control storage was evaluated by the consulting engineering firm of Freese and Nichols for the Northeast

Texas Municipal Water District, local sponsors for the lakes' conservation storage. Freese and Nichols determined the change in yield from reservoir operation studies of Lake O' The Pines with inflow and evaporation based on historical hydrologic conditions. The following assumptions were used by Freese and Nichols in developing Lake O' The Pines inflow:

a. Lake Cypress Springs releases inflow for Lake O' The Pines as specified in the Cypress Basin Operating Agreement.

b. Lake Bob Sandlin passes through releases from Lake Cypress Springs but has no obligation to release other inflow.

c. Monticello Reservoir is in operation.

d. Ellison Creek Reservoir is in operation and is drawn down 10 feet at the end of critical periods of low flow.

e. Specific operation studies were not made for Welsh Reservoir and Johnson Creek Reservoir, which have contractual rights to intercept water that would otherwise flow into Lake O' The Pines. Thus, the calculated yields for Lake O' The Pines include the water that those two reservoirs on tributary streams would use under the existing contracts.

The results of the Freese and Nichols analysis is presented on Table C-8 and Plate C-4.

Since detailed reallocation studies were not performed, impacts of storage reallocations were based on the maximum 50,000 ac-ft storage reallocation allowed at the discretion of the Commander, USACE. Based on the findings of the Freese and Nichols study, reallocating 50,000 acre-ft of flood control storage to water supply storage, water supply yields at Lake O' The Pines could be expected to increase by about 15,700 ac-ft/yr (21 cfs). This increase in water supply yield, however, would be at the expense of increased lake levels and foregone flood control storage. As shown on Plate C-5, a 50,000 ac-ft reduction in flood control storage at Lake O' The Pines would reduce the frequency of the existing 50-year flood control storage to about the 40-year flood control storage.

CHAPTER 2 HYDRAULICS

WATER SURFACE PROFILES

General

Hydraulic characteristics of the Big Cypress Bayou were studied for existing conditions and conditions as modified by Marshall lake on the Little Cypress Bayou at RM 21.3. The Big Cypress Bayou was studied from Louisiana State Highway 1, RM 21.34, about 1.6 river miles above the spillway for Caddo Lake, upstream to Ferrell's Bridge Dam for Lake O' The Pines, RM 81.6 which is about 2,700 feet upstream from USGS Streamgage 07346000 Big Cypress Creek near Jefferson, Texas. The Little Cypress Bayou has its mouth at Big Creek Bayou RM 56.8 about 8.3 river miles above USGS Streamgage 07346085 Big Cypress Creek near Karnack, Texas. The Black Cypress Bayou was studied from its confluence with Big Cypress Bayou, RM 60.7, to Black Cypress Damsite RM 17.0. The backwater profiles were computed by HEC2 from data acquired from cross sections obtained by sonar at and above Caddo Lake, by degradation ranges, by surveyed cross-sections, bridge plans for highway and railroad crossings. Surveyed channel cross-sections were extended with the use of USGS quadranges sheets, scale 1:24000. The coefficient of roughness, n, varied for the channel from 0.040 to 0.100 and for the overbank from 0.070 to 0.300 based on field investigations, photograph inspection and correlation with recorded gage data.

Existing Conditions

Water surface profiles for existing conditions were computed for the 1-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year floods and the standard project flood using the stream discharges shown on Table C-9. The water surface profiles for Big Cypress Bayou are shown on Plate C-6; for Little Cypress Bayou on Plate C-7; and Black Cypress Bayou on Plate C-8.

Modified Conditions

Discharge frequency data downstream of the proposed Marshall Lake on Little Cypress Bayou was developed for the lake with a water supply yield of 200 cfs without flood control storage. As part of the detailed plan evaluation three different length spillways were investigated at Marshall Lake. Backwater was computed for each of the spillway lengths evaluated utilizing the existing conditions model with modified discharges. The resulting computed water surface information was furnished in numerical form for use in planning and economic evaluations. The comparative water surface elevations for existing conditions and with the 400-ft, 600-ft and 1,000 ft spillways in place at Marshall lake are shown in Table C-10 for selected river miles on the Big Cypress, Little Cypress and Black Cypress Bayous.

Spillway

The spillway for Marshall Lake studies would consist of an uncontrolled rectangular ogee weir, chute and stilling basin complete with downstream riprap. The weir widths studied were 400-ft, 600-ft and 1,000-ft. The spillway would be in the main embankment with short channel changes from and to the Little Cypress Bayou. Since these weirs have a ratio of depth from the bottom of approach channel to weir crest divided by the maximum weir head less than unity the ogee weir shape would be based on the maximum weir head. The spillway rating curves are based on design criteria set forth in EM 1110-2-1603.

Outlet Works

The outlet works would be located in the main embankment near the right abutment. It would consist of a 10-foot diameter conduit controlled by two 4.5 by 10-foot gates. Low-flow gated intakes at various levels would be provided to permit releases from selected lake levels. Trash beams, stop log slots, service and emergency gates would be located in the intake structure. The conduit, including the gate passages and trash rack, would be about 500 feet long. The intake and outfall inverts would be at about elevations 203.0 and 200.0, respectively. The outlet works would be used for diversion during construction, for the passage of flood releases, and for low flow discharges. For the range of discharges with the conduit flowing full, the effective head would be measured from the pressure gradient at the outfall as determined by USAEWES HDC 225-1. Friction loss in the conduit would be computed by the Darcy-Weisbach formula with $k = 0.002$ ft. An intake loss of 44 percent of the velocity head in the gate passages would also be used based on USAEWES HDC 221-1/2.

Low-Flow Outlets

Selector gates for intakes into a wet well would be provided to permit low-flow releases from selected lake levels. The wet well would be in the outlet works intake. Releases would be made through a conduit in the gate pier between the two 4.5 by 10-foot outlet works gate passages. This conduit would be controlled at the wet well by a sluice gate. The selector gate sills are to be evenly distributed between the conservation pool level, elevation 233.1 and a minimum level, about elevation 220, determined by the structural features of the flood control intake.

Tailwater Rating Curve

The tailwater rating curve at the damsite is shown on Plate C-9. The tailwater rating curve was developed by backwater methods.

Care of Water During Construction

The plan for care of water during construction would be set forth in detail as part of detailed design studies.

Gages

A water level recording gage would be installed in the outlet works intake tower to measure lake levels. Due to the importance of maintaining an accurate record of all releases made for downstream use, it would be necessary to establish a recording streamgaging station below the dam. A tile gage would be placed on a side wall in the spillway approach channel and on the outlet works intake tower to measure reservoir levels. Tile gages would be located on the spillway and outlet works stilling basin training wall to measure tailwater levels.

TABLE C-1
MARSHALL LAKE
R.M. 21.3 D.A. =617 SQ. MI.
1985 AREA-CAPACITY

AREA IN ACRES

ELEV	0	1	2	3	4	5	6	7	8	9
190									0	15
200	60	187	385	653	991	1400	1757	2154	2591	3069
210	3587	3761	3940	4122	4309	4500	5114	5767	6459	7191
220	7962	8442	8935	9443	9964	10500	11079	11674	12284	12910
230	13551	14246	14958	15688	16435	17200	17602	18010	18421	18838
240	19259	19793	20334	20882	21437	22000	22793	23600	24421	25256
250	26105	26672	27245	27824	28409	29000	29984	30984	32000	33376
260	34780	35629	36487	37356	38236	39125	39987	40858	41738	42628
270	43527	44653	45793	46948	48117	49300	50002	50710	51422	52139
280	52861	53579	54302	55030	55763	56500	57283	58072	58866	59665
290	60470	61557	62653	63759	64875	66000	67415	68844	70289	71748
300	73223									

CAPACITY IN ACRE-FEET

ELEV	0	1	2	3	4	5	6	7	8	9
190									0	5
200	40	158	438	951	1767	2956	4531	6483	8852	11678
210	15003	18677	22527	26558	30773	35177	39981	45418	51528	58350
220	65924	74124	82811	91999	101701	111933	122721	134096	146073	158669
230	171898	185795	200396	215718	231778	248595	265995	283801	302016	320645
240	339694	359219	379281	399888	421047	442765	465160	488356	512365	537202
250	562881	589269	616227	643761	671877	700580	730071	760553	792044	824729
260	858804	894008	930065	966986	1004781	1043460	1083015	1123437	1164734	1206916
270	1249992	1294081	1339303	1385672	1433203	1481910	1531561	1581916	1632982	1684761
280	1737261	1790481	1844421	1899086	1954482	2010613	2067504	2125181	2183650	2242915
290	2302982	2363994	2426098	2489304	2553620	2619056	2685762	2753890	2823456	2894473
300	2966957									

TABLE C-2
BLACK CYPRESS RESERVOIR
R.M. 17.0 D.A. = 342 SQ. MI.
1985 AREA-CAPACITY

ELEV	0	1	2	3	4	5	6	7	8	9
					AREA IN ACRES					
190	0	9	35	79	141	220	232	244	256	268
200	281	402	544	708	893	1100	1204	1312	1426	1543
210	1666	1902	2153	2420	2702	3000	3275	3562	3861	4172
220	4495	4884	5289	5710	6147	6600	7061	7537	8029	8536
230	9059	9451	9851	10259	10675	11100	11482	11871	12266	12667
240	13075	13783	14509	15254	16018	16800	17367	17943	18528	19123
250	19727	20455	21197	21951	22719	23500	24277	25067	25870	26685
260	27513	28312	29123	29946	30780	31625	32399	33183	34607	36060
270	37544	38415	39296	40188	41089	42000	42894	43798	44711	45633
280	46565	47647	48742	49849	50968	52100	53303	54520	55750	56994
290	58252	59610	60984	62374	63779	65200	65913	66629	67350	68074
300	68802									
					CAPACITY IN ACRE-FEET					
190	0	3	23	79	188	367	592	830	1080	1341
200	1616	1956	2427	3051	3850	4844	5996	7254	8622	10106
210	11711	13493	15519	17804	20364	23213	26350	29767	33477	37493
220	41825	46513	51598	57096	63023	69395	76224	83521	91303	99584
230	108380	117635	127284	137338	147805	158692	169982	181658	193725	206191
240	219062	232489	246633	261513	277148	293555	310637	328291	346526	365350
250	384775	404865	425689	447262	469596	492705	516592	541263	566731	593007
260	620105	648017	676734	706268	736630	767831	799842	832633	866525	901856
270	938656	976635	1015490	1055231	1095868	1137412	1179858	1223203	1267457	1312628
280	1358726	1405831	1454025	1503319	1553726	1605259	1657960	1711870	1767004	1823374
290	1880996	1939926	2000222	2061900	2124975	2189463	2255019	2321290	2388279	2455990
300	2524428									

TABLE C-3
-BLACK CYPRESS BAYOU
NEAR JEFFERSON
-FREQUENCY ANALYSIS
USING PROGRAM
723-X6-17550

```
 FINAL RESULTS
-ANNUAL PEAKS   - BLACK CYPRESS BAYOU NEAR JEFFERSON, DA_365 SQ
*************************************************************
*......DATA ANALYZED........*..............ORDERED DATA............*
*
                              *        WATER                 MEDIAN   *
* MON DAY  YEAR        FLOW   *   RANK  YEAR       FLOW     PLOT POS *
*------------------------------*--------------------------------------*
*   3   3  1939       2080.   *     1   1958      17500.     .0173    *
*  12  31  1940       2400.   *     2   1944      10620.     .0421    *
*   1   1  1941       2670.   *     3   1966      10210.     .0668    *
*   4  12  1942       4820.   *     4   1950       9600.     .0916    *
*   1   8  1943        492.   *     5   1945       8560.     .1163    *
*   5   5  1944      10620.   *     6   1974       6950.     .1411    *
*   4   2  1945       8560.   *     7   1957       6380.     .1658    *
*  11  11  1946       3640.   *     8   1975       6290.     .1906    *
*  12  14  1947       1560.   *     9   1973       5810.     .2153    *
*   3   6  1948       3400.   *    10   1953       5632.     .2401    *
*  10  29  1949       3400.   *    11   1960       5630.     .2649    *
*   9  19  1950       9600.   *    12   1942       4820.     .2896    *
*   2  23  1951       1712.   *    13   1946       3640.     .3144    *
*   4  17  1952       3312.   *    14   1965       3471.     .3391    *
*   5  19  1953       5632.   *    15   1948       3400.     .3639    *
*   6   5  1954        988.   *    16   1949       3400.     .3886    *
*   3  27  1955       1905.   *    17   1976       3390.     .4134    *
*   5   6  1956       1125.   *    18   1952       3312.     .4381    *
*   4  28  1957       6380.   *    19   1961       3149.     .4629    *
*   5   1  1958      17500.   *    20   1969       3090.     .4876    *
*   2  20  1959       1656.   *    21   1941       2670.     .5124    *
*  12  12  1960       5630.   *    22   1940       2400.     .5371    *
*   4   3  1961       3149.   *    23   1962       2223.     .5619    *
*   1  31  1962       2223.   *    24   1939       2080.     .5866    *
*   4  29  1963        927.   *    25   1968       1910.     .6114    *
*   4  30  1964       1497.   *    26   1955       1905.     .6361    *
*   2  16  1965       3471.   *    27   1977       1860.     .6609    *
*   4  26  1966      10210.   *    28   1967       1831.     .6856    *
*   5   9  1967       1831.   *    29   1970       1760.     .7104    *
*   5  18  1968       1910.   *    30   1951       1712.     .7351    *
*   4  17  1969       3090.   *    31   1959       1656.     .7599    *
*   1   4  1970       1760.   *    32   1947       1560.     .7847    *
*  12  18  1971        460.   *    33   1964       1497.     .8094    *
*   1   7  1972       1360.   *    34   1972       1360.     .8342    *
*   4  28  1973       5810.   *    35   1956       1125.     .8589    *
*   6  12  1974       6950.   *    36   1954        988.     .8837    *
*   2   5  1975       6290.   *    37   1978        954.     .9084    *
*   3  12  1976       3390.   *    38   1963        927.     .9332    *
*   1  24  1977       1860.   *    39   1943        492.     .9579    *
*   3  16  1978        954.   *    40   1971        460.     .9827    *
*************************************************************
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TABLE C-3
(CONT'D)

```
 FINAL RESULTS
-FREQUENCY CURVE- BLACK CYPRESS BAYOU NEAR JEFFERSON, DA_365 SQ
*****************************************************************
*.......PEAK FLOWS........*                *...CONFIDENCE LIMITS...*
*              EXPECTED    * EXCEEDANCE    *                        *
*  COMPUTED  PROBABILITY * PROBABILITY *  .05 LIMIT   .95 LIMIT *
*-------------------------*---------------*------------------------*
*    29500.     35100.    *     .002      *    53200.     19400.   *
*    23200.     26400.    *     .005      *    39700.     15700.   *
*    19000.     21000.    *     .010      *    31200.     13200.   *
*    15200.     16500.    *     .020      *    24000.     10900.   *
*    11900.     12600.    *     .040      *    17900.      8790.   *
*     8140.      8350.    *     .100      *    11400.      6250.   *
*     5670.      5760.    *     .200      *     7540.      4490.   *
*     2820.      2820.    *     .500      *     3520.      2260.   *
*     1390.      1370.    *     .800      *     1760.      1050.   *
*      957.       926.    *     .900      *     1250.       680.   *
*      701.       666.    *     .950      *      944.       472.   *
*      390.       348.    *     .550      *      564.       234.   *
*****************************************************************
*   FREQUENCY CURVE STATISTICS   *     STATISTICS BASED ON        *
*--------------------------------*--------------------------------*
*  MEAN LOGARITHM        3.4475  *  HISTORIC EVENTS          0    *
*  STANDARD DEVIATION     .3627  *  HIGH OUTLIERS        0        *
*  COMPUTED SKEW         -.0053  *  LOW OUTLIERS         0        *
*  GENERALIZED SKEW      -.1000  *  ZERO OR MISSING      0        *
*  ADOPTED SKEW          -.0455  *  SYSTEMATIC YEARS         40    *
*                                *  TOTAL PERIOD, YEARS      40    *
```

TABLE C-4
-LITTLE CYPRESS CREEK
NEAR JEFFERSON
-FREQUENCY ANALYSIS
USING PROGRAM
723-X6-17550

```
 FINAL RESULTS
-PLOTTING POSITIONS- LITTLE CYPRESS CR NR JEFFERSON, TX
*********************************************************************
*.....EVENTS ANALYZED.............*..............ORDERED EVENTS...........*
*                                                   WATER                          MEDIAN    *
*  MON DAY  YEAR   FLOW,CFS  *     RANK   YEAR    FLOW,CFS   PLOT POS *
*--------------------------------*-----------------------------------------------*
*    5   7  1944    26000.   *      1    1966    35500.    0.0182    *
*    6   4  1945     9500.   *      2    1944    26000.    0.0443    *
*   11  15  1946     3100.   *      3    1958    23900.    0.0703    *
*    5  17  1948     5400.   *      4    1957    18400.    0.0964    *
*    5   7  1949     2260.   *      5    1961    12000.    0.1224    *
*    2  16  1950    10200.   *      6    1953    11800.    0.1484    *
*    2  20  1951     2260.   *      7    1973    11800.    0.1745    *
*    4  21  1952     2900.   *      8    1974    10400.    0.2005    *
*    5  19  1953    11800.   *      9    1950    10200.    0.2265    *
*    5  13  1954     1490.   *     10    1979     9730.    0.2526    *
*    3  25  1955     3810.   *     11    1945     9500.    0.2786    *
*    5   6  1956     2080.   *     12    1968     8240.    0.3047    *
*    4  27  1957    18400.   *     13    1975     7550.    0.3307    *
*    4  30  1958    23900.   *     14    1980     5960.    0.3568    *
*    4  26  1959     3420.   *     15    1969     5480.    0.3828    *
*    1  20  1960     4500.   *     16    1948     5400.    0.4088    *
*   12  11  1960    12000.   *     17    1977     4780.    0.4349    *
*   12  23  1961     3940.   *     18    1960     4500.    0.4609    *
*    5   3  1963     3680.   *     19    1967     4350.    0.4870    *
*    5   3  1964      568.   *     20    1962     3940.    0.5130    *
*    2  14  1965     1760.   *     21    1955     3810.    0.5391    *
*    4  26  1966    35500.   *     22    1963     3680.    0.5651    *
*    6   6  1967     4350.   *     23    1959     3420.    0.5911    *
*    5  15  1968     8240.   *     24    1947     3100.    0.6172    *
*    3  24  1969     5480.   *     25    1970     3090.    0.6432    *
*    5   3  1970     3090.   *     26    1952     2900.    0.6693    *
*    2  22  1971      279.   *     27    1981     2400.    0.6953    *
*    1  11  1972     2290.   *     28    1972     2290.    0.7214    *
*    4  27  1973    11800.   *     29    1951     2260.    0.7474    *
*    6  10  1974    10400.   *     30    1949     2260.    0.7734    *
*    2   5  1975     7550.   *     31    1956     2080.    0.7995    *
*    7   6  1976     1710.   *     32    1965     1760.    0.8255    *
*    2  17  1977     4780.   *     33    1976     1710.    0.8516    *
*    3  18  1978     1170.   *     34    1954     1490.    0.8776    *
*    5   7  1979     9730.   *     35    1978     1170.    0.9036    *
*    1  27  1980     5960.   *     36    1982      594.    0.9297    *
*    5  25  1981     2400.   *     37    1964      568.    0.9557    *
*    2  11  1982      594.   *     38    1971      279.    0.9818    *
*********************************************************************
```

TABLE C-4
(CONT'D)

```
FINAL RESULTS
-FREQUENCY CURVE- LITTLE CYPRESS CR NR JEFFERSON, TX
*******************************************************************
*.........FLOW,CFS..........*                   *....CONFIDENCE LIMITS....*
*              EXPECTED     *  EXCEEDANCE   *                          *
*   COMPUTED  PROBABILITY   *  PROBABILITY  *  0.05 LIMIT  0.95 LIMIT  *
*---------------------------*---------------*--------------------------*
*    68300.      82600.     *     0.002     *   141000.      40700.    *
*    52900.      61300.     *     0.005     *   104000.      32700.    *
*    42600.      47900.     *     0.010     *    79800.      27100.    *
*    33400.      36500.     *     0.020     *    59600.      21900.    *
*    25400.      27100.     *     0.040     *    42900.      17200.    *
*    16300.      17000.     *     0.100     *    25500.      11600.    *
*    10500.      10900.     *     0.200     *    15500.       7820.    *
*     4470.       4470.     *     0.500     *     5980.       3350.    *
*     1770.       1730.     *     0.800     *     2400.       1220.    *
*     1070.       1020.     *     0.900     *     1510.        677.    *
*      591.        539.     *     0.950     *     1030.        406.    *
*      293.        250.     *     0.990     *      492.        147.    *
************************************************************************
*    FREQUENCY CURVE STATISTICS     *     STATISTICS BASED ON         *
*-----------------------------------*---------------------------------*
*   MEAN LOGARITHM          3.6320  *  HISTORIC EVENTS           0    *
*   STANDARD DEVIATION      0.4636  *  HIGH OUTLIERS         0        *
*   COMPUTED SKEW          -0.3072  *  LOW OUTLIERS          0        *
*   GENERALIZED SKEW       -0.1000  *  ZERO OR MISSING       0        *
*   ADOPTED SKEW           -0.2363  *  SYSTEMATIC EVENTS        38    *
************************************************************************
```

TABLE C-5

EXISTING CONDITIONS EXPECTED PROBABILITY DISCHARGE-FREQUENCY DISCHARGES IN CFS

LOCATIONS	1-YR	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	500-YR	SPF
Caddo Lake Dam (Elevation-Feet NGVD)	4,500 170.1	8,500 171.1	13,700 173.1	18,000 175.5	24,300 179.3	30,000 182.7	37,000 185.0	65 100 185.2	153.800 185.7
Karnack Gage, Big Cypress	4,500	9,000	17,700	25 500	38 300	50 900	67,500	129,900	148,600
Big Cypress Below Little Cypress	4,500	9,000	18,000	26,200	40,000	54,000	72,000	141,300	156,600
Little Cypress Above Big Cypress	3,000	6,300	10,500	14,000	20,300	27,500	38,500	102,800	114,000
Marshall Damsite (Little Cypress)	3,000	6,600	11,500	17,300	27,000	36,500	48,000	88,000	110,500
Big Cypress Below Black Cypres	3,000	4,500	7,000	9,500	14,200	18,900	24,700	47,500	65,500
Black Cypress Above Big Cypress	2,000	4,000	6,100	8,400	12,400	16,500	21,100	38,500	50,900
Black Cypress Damsite	2,000	4.000	6,400	8,800	13,000	17,100	22,000	40,500	49,100
Big Cypress Above Black Cypress	3,000	3,000	4,300	5,600	7,600	9,500	11,400	31,000	42,000
Lake O' The Pines Outflows	3,000	3,000	3,000	3,000	3,000	3,000	5,000	31,000	42 000

TABLE C-6

MARSHALL LAKE (200 cfs Yield)

	MARSHALL LAKE 200 CFS YIELD WITH SPILLWAY LENGTHS OF		
	400'	600'	1000'
Top of Dam (Elevation)	256.5	253.4	249.9
Maximum Design Water Surface (Elevation)	252.0	248.9	245.4
Fee Acquisition Line (Elevation)	241.7	241.0	240.1
Fee Acquisition Line (Acres)	20,172	19,793	19,312
Top Conservation Pool (Elevation)	233.1	233.1	233.1
Top Conservation Pool (Acres)	15,763	15,763	15,763
Top Conservation Pool (AC-FT)	217,324	217,324	217,324
50-Year Flood Level (Elevation)	238.7	238.0	237.1

TABLE C-7

MARSHALL LAKE 200 CFS WATER SUPPLY YIELD

EXPECTED PROBABILITY DISCHARGE - FREQUENCY

DISCHARGES IN 1000'S CFS

LOCATION SPILLWAY LENGTH (FT)	1-YR	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	500-YR	SPF
Caddo Lake Dam									
1000'	3.5	8.5	15.0	18.4	25.8	30.0	38.0	65.0	125.0
600'	3.5	7.5	13.6	16.4	22.8	28.0	34.0	60.0	120.0
400'	3.5	7.0	12.6	14.7	20.5	25.0	30.0	55.0	110.0
Karnack Gage, Big Cypress									
1000'	3.5	8.5	15.8	23.5	36.0	49.0	57.0	120.0	130.0
600'	3.5	7.5	14.4	21.5	33.0	44.0	54.5	105.0	122.0
400'	3.5	7.0	13.2	19.8	30.5	41.0	50.0	82.0	112.0
Big Cypress Below Little Cypress									
1000'	3.5	8.5	16.0	24.2	37.0	50.0	65.6	135.0	142.0
600'	3.5	7.5	14.5	22.2	34.0	45.0	62.0	116.0	130.0
400'	3.5	7.0	13.4	20.5	31.5	42.0	58.0	93.0	120.0
Little Cypress Above Big Cypress									
1000'	2.0	4.0	7.2	10.2	14.9	22.6	31.9	74.8	89.6
600'	2.0	3.2	5.9	8.6	12.5	18.9	28.8	57.6	76.2
400'	2.0	2.6	4.9	7.2	10.6	16.3	25.4	36.7	64.3
Little Cypress (Marshall Damsite)									
1000'	2.0	4.8	9.0	13.2	19.4	28.4	42.2	68.6	89.1
600'	2.0	3.8	7.0	10.6	15.8	23.4	35.4	58.5	76.3
400'	2.0	3.0	5.7	8.5	12.9	19.4	29.5	49.4	64.8
Big Cypress Below Black Cypress									
1000'	3.0	4.5	7.0	9.5	14.2	18.9	24.7	47.5	65.5
600'	3.0	4.5	7.0	9.5	14.2	18.9	24.7	47.5	65.5
400'	3.0	4.5	7.0	9.5	14.2	18.9	24.7	47.5	65.5
Black Cypress Above Big Cypress									
1000'	2.0	4.0	6.1	8.4	12.4	16.5	21.1	38.5	50.9
600'	2.0	4.0	6.1	8.4	12.4	16.5	21.1	38.5	50.9
400'	2.0	4.0	6.1	8.4	12.4	16.5	21.1	38.5	50.9

TABLE C-7 - CONTINUED

MARSHALL LAKE 200 CFS WATER SUPPLY YIELD

EXPECTED PROBABILITY DISCHARGE - FREQUENCY

DISCHARGES IN 1000'S CFS

LOCATION SPILLWAY LENGTH (FT)	1-YR	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	500-YR	SPF
Big Cypress Above Black Cypress									
1000'	3.0	3.0	4.3	5.6	7.6	9.5	11.4	31.0	42.0
600'	3.0	3.0	4.3	5.6	7.6	9.5	11.4	31.0	42.0
400'	3.0	3.0	4.3	5.6	7.6	9.5	11.4	31.0	42.0
Lake O' The Pines Outflows									
1000'	3.0	3.0	3.0	3.0	3.0	3.0	3.0	31.0	42.0
600'	3.0	3.0	3.0	3.0	3.0	3.0	3.0	31.0	42.0
400'	3.0	3.0	3.0	3.0	3.0	3.0	3.0	31.0	42.0

TABLE C-8

LAKE O' THE PINES YIELD*

5-31-76 TRS

Elevation(ft-msl)	Capacity	Increased Capacity(AF)	Yield(AF/YR)	Increased Yield(AF/YR)
228.5	254,900	-	146,900	-
229.5	274,000	19,100	153,200	6,300
230.5	293,800	38,900	159,700	12,800
231.5	314,300	59,400	165,500	18,600
232.5	335,600	80,700	171,100	24,200
233.5	357,800	102,900	176,600	29,700
234.5	380,900	126,000	181,800	34,900
235.5	404,900	150,000	187,100	40,200
236.5	429,800	174,900	192,700	45,800
237.5	455,600	200,700	198,600	51,700
238.5	482,300	227,400	204,500	57,600
239.5	509,900	255,000	210,700	63,800
240.5	538,600	283,700	217,200	70,300
241.5	568,300	313,400	224,000	77,100
242.5	599,100	344,200	231,000	84,100
243.5	630,800	375,900	238,200	91,300
244.5	663,700	408,300	245,700	98,800
245.5	697,500	442,600	253,400	106,500
246.5	732,200	477,300	261,400	114,500
247.5	767,900	513,000	269,700	122,800
248.5	804,500	549,600	277,700	130,800
249.5	842,100	587,200	283,300	136,400

* Estimates only, based on initial area/capacity data,
No reserve, with Lake Cypress Springs releases.

SOURCE: FREESE AND NICHOLS CONSULTING ENGINEERS

TABLE C-9

BIG CYPRESS BAYOU
EXISTING CONDITIONS

FILENAME: LDBCB

SECTION	DISCHARGES *								
	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR	500 YR	SPF
21.34	4500	8500	13700	18000	24300	30000	37000	65100	153800
22.29	4500	8550	14060	18680	25570	31900	39770	70990	153300
24.50	4500	8600	14420	19360	26840	33800	42540	76880	152830
31.88	4500	8650	14780	20040	28110	35700	45310	82770	152360
32.00	4500	8700	15140	20720	29380	37600	48080	88660	151890
34.25	4500	8750	15500	21400	30650	39500	50850	94550	151420
40.43	4500	8800	15860	22080	31920	41400	53620	100440	150950
43.17	4500	8850	16220	22760	33190	43300	56390	106330	150480
44.00	4500	8900	16580	23440	34460	45200	59160	112220	150010
45.32	4500	8950	16940	24120	35730	47100	61930	118110	149540
46.28	4500	8950	17300	24800	37000	49000	64700	124000	149070
47.77	4500	9000	17700	25500	38300	50900	67500	129900	148600
58.13	4500	9000	18000	26200	40000	54000	72000	141300	156600
59.30	3000	4500	7000	9500	14200	18900	24700	47500	65500
61.92	3000	3000	4300	5600	7600	9500	11400	31000	42000
74.35	3000	3000	3000	3000	3000	3000	5000	31000	42000

* These discharges were used to plot the water surface profiles dated June 1984.

TABLE C-9(cont)

BLACK CYPRESS BAYOU
EXISTING CONDITIONS

FILENAME: LDBLCYP

SECTION	DISCHARGES *								
	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR	500 YR	SPF
4594	2000	4000	6100	8400	12400	16500	21100	38500	50900
32097	2000	4000	6400	8800	13000	17100	22000	40500	49100

LITTLE CYPRESS BAYOU
EXISTING CONDITIONS

FILENAME: LDLCYP

SECTION	DISCHARGES *								
	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR	500 YR	SPF
3.61	3000	6300	10500	14000	20300	27500	38500	102800	114000
9.34	3000	6400	10800	15100	22500	30500	41600	97900	112900
13.45	3000	6500	11100	16200	24700	33500	44700	93000	111800

* These discharges were used to plot the water surface profiles dated June 1984.

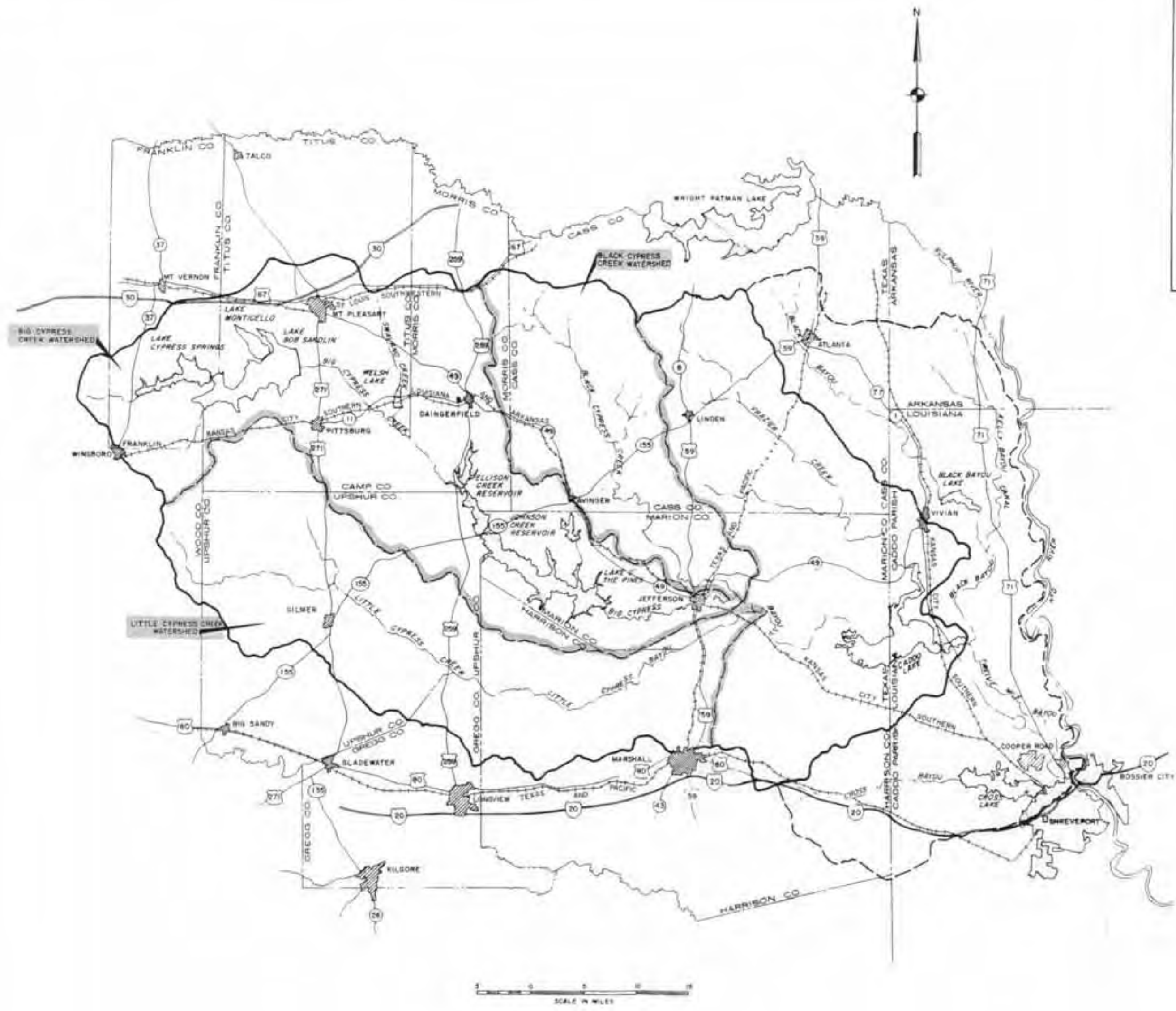
TABLE C-10

MARSHALL LAKE 200 CFS WATER SUPPLY YIELD
COMPARISON OF WATER SURFACE ELEVATIONS
SPILLWAY LENGTHS OF 400-FT, 600-FT AND 1000-FT

SECTION NO. (RIVER MILE)	MARSHALL LAKE WEIR WIDTH-FT	WATER SURFACE ELEVATION IN FEET NGVD								
		1-YR	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	500-YR	SPF
				BLACK CYPRESS BAYOU						
37540	Existing Cond.	184.45	186.44	187.97	189.23	190.99	192.48	194.06	198.63	199.59
	400'	184.46	186.44	187.90	189.17	190.91	192.36	193.87	197.24	198.97
	600'	184.46	186.44	187.90	189.17	190.92	192.39	193.94	197.52	199.24
	1000'	184.45	186.44	187.90	189.17	190.92	192.39	193.94	197.52	199.24
				LITTLE CYPRESS BAYOU						
9.83	Existing Cond.	186.71	189.31	190.96	192.29	194.15	195.88	198.01	206.27	207.65
	400'	185.51	186.46	188.56	190.06	191.22	193.08	195.46	198.15	201.99
	600'	185.51	187.14	189.30	190.41	192.01	193.94	196.31	201.03	203.51
	1000'	185.51	187.85	190.15	191.14	192.77	194.87	197.07	203.11	205.04
				BIG CYPRESS BAYOU						
31.88	Existing Cond.	170.22	171.39	173.50	175.88	179.64	183.02	185.37	186.30	190.08
	400'	169.79	170.92	173.32	174.89	178.75	182.02	185.02	185.88	187.87
	600'	169.79	170.95	173.38	174.97	178.82	182.09	185.09	186.07	188.28
	1000'	169.79	171.02	173.45	175.05	178.89	182.12	185.15	186.15	189.49
32.00	Existing Cond.	170.23	171.39	173.50	175.88	179.64	183.02	185.37	186.30	190.08
	400'	169.79	170.93	173.34	174.91	178.77	182.04	185.03	185.91	187.94
	600'	169.79	170.97	173.39	174.99	178.84	182.11	185.11	186.11	188.36
	1000'	169.79	171.04	173.47	175.07	178.91	182.14	185.16	186.20	188.57

TABLE 10 (continued)

SECTION NO. (RIVER MILE)	MARSHALL LAKE WEIR WIDTH (FT)	1-YR	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	500-YR	SPF
34.25	Existing Cond.	170.25	171.43	173.55	175.92	179.67	183.04	185.39	186.38	190.20
	400'	169.81	170.96	173.37	174.94	178.79	182.06	185.05	185.96	188.03
	600'	169.81	171.00	173.43	175.03	178.87	182.13	185.13	186.16	188.45
	1000'	169.81	171.08	173.52	175.12	178.95	182.17	185.19	186.27	188.67
44.00	Existing Cond.	170.79	172.22	174.34	176.50	180.04	183.32	185.68	187.17	191.07
	400'	170.31	171.67	173.97	175.51	179.13	182.31	185.25	186.41	188.71
	600'	170.31	171.77	174.09	175.50	179.23	182.39	185.34	186.76	189.20
	1000'	170.31	171.98	174.28	175.86	179.41	182.52	185.45	187.10	189.47
46.28	Existing Cond.	170.95	172.59	174.82	176.90	180.32	183.52	185.89	187.74	191.55
	400'	170.43	171.96	174.32	175.89	179.38	182.49	185.38	186.71	189.11
	600'	170.43	172.09	174.48	175.94	179.50	182.59	185.49	187.17	189.63
	1000'	170.43	172.35	174.71	176.32	179.73	182.76	185.62	187.62	189.95
48.50	Existing Cond.	171.03	172.81	175.38	177.59	180.89	183.92	186.27	188.61	192.13
	400'	170.47	172.11	174.67	176.44	179.85	182.84	185.62	187.16	189.63
	600'	170.47	172.26	174.88	176.58	180.05	182.98	185.77	187.84	190.19
	1000'	170.47	172.55	175.17	177.01	180.32	183.21	185.91	188.38	190.54
50.03	Existing	171.11	173.02	175.80	178.04	181.29	184.23	186.59	189.28	192.60
	400'	170.53	172.26	174.96	176.82	180.19	183.10	185.82	187.55	190.05
	600'	170.53	172.43	175.21	177.02	180.43	183.28	186.02	188.40	190.65
	1000'	170.53	172.76	175.53	177.46	180.73	183.55	186.16	188.98	191.02
51.85	Existing	171.40	173.45	176.29	178.43	181.57	184.45	186.80	189.71	192.92
	400'	170.75	172.65	175.36	177.22	180.46	183.29	185.97	187.81	190.34
	600'	170.84	172.84	175.64	177.45	180.71	183.49	186.20	188.79	190.97
	1000'	170.75	173.20	175.97	177.88	181.03	183.79	186.33	189.40	191.35
54.32	Existing	171.40	173.45	176.29	178.43	181.57	184.45	186.80	189.71	192.92
	400'	171.07	173.09	175.72	177.54	180.68	183.46	186.12	188.06	190.62
	600'	171.07	173.29	176.01	177.80	180.95	183.68	186.34	189.14	191.26
	1000'	171.07	173.68	176.35	178.22	181.29	184.00	186.50	189.79	191.66



VICINITY MAP
NOT TO SCALE

LEGEND

EXISTING RESERVOIR
RIVER
20 INTERSTATE HIGHWAY
71 U.S. HIGHWAY
155 1 STATE HIGHWAY
RAILROAD
▨ WATERSHED BOUNDARY

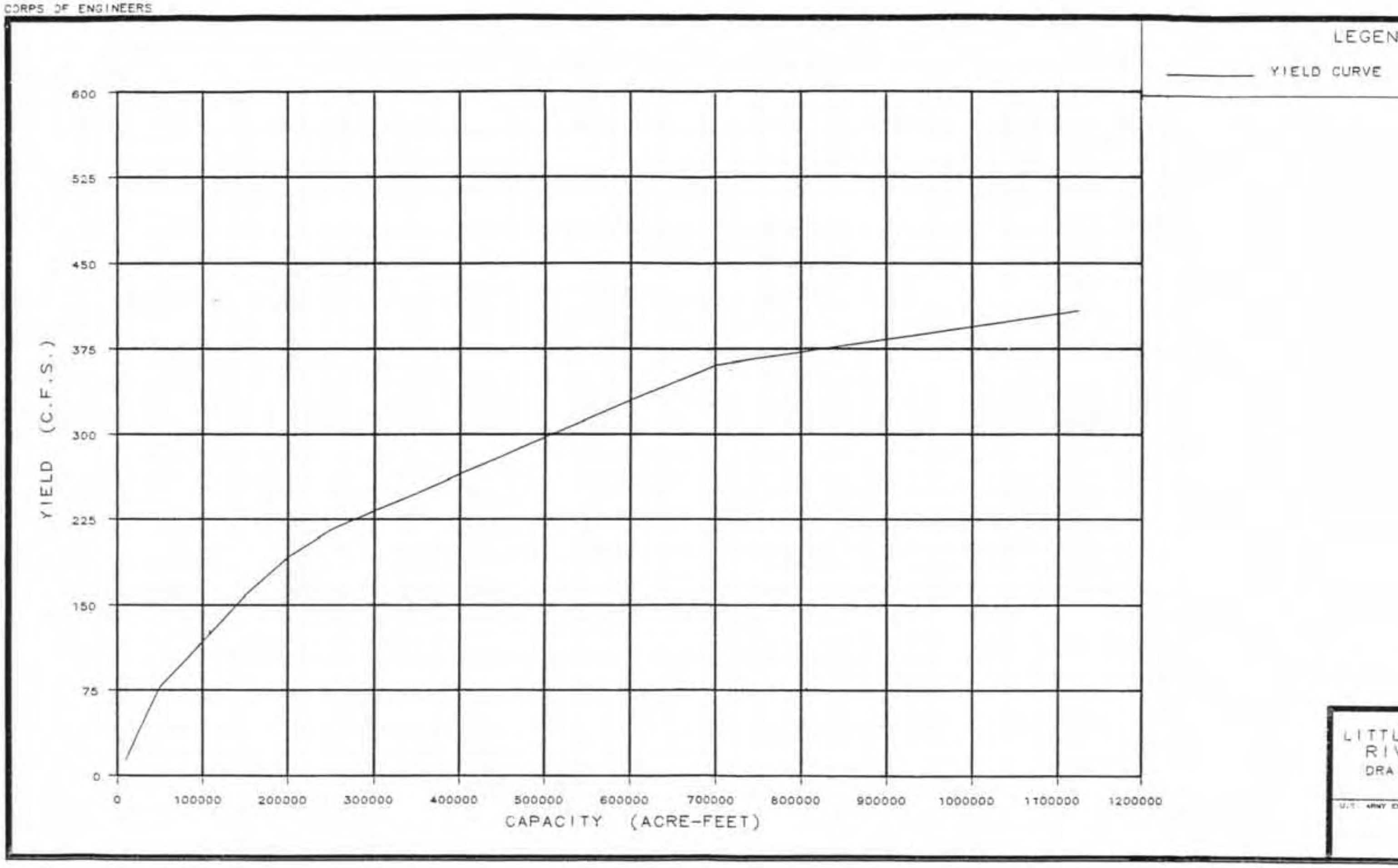
CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

WATERSHED BOUNDARIES

U.S. ARMY ENGINEER DISTRICT, FORT WORTH JULY 1981

FILE NO **PLATE C-1**

CORPS OF ENGINEERS U.S. ARMY



3 JUL 84

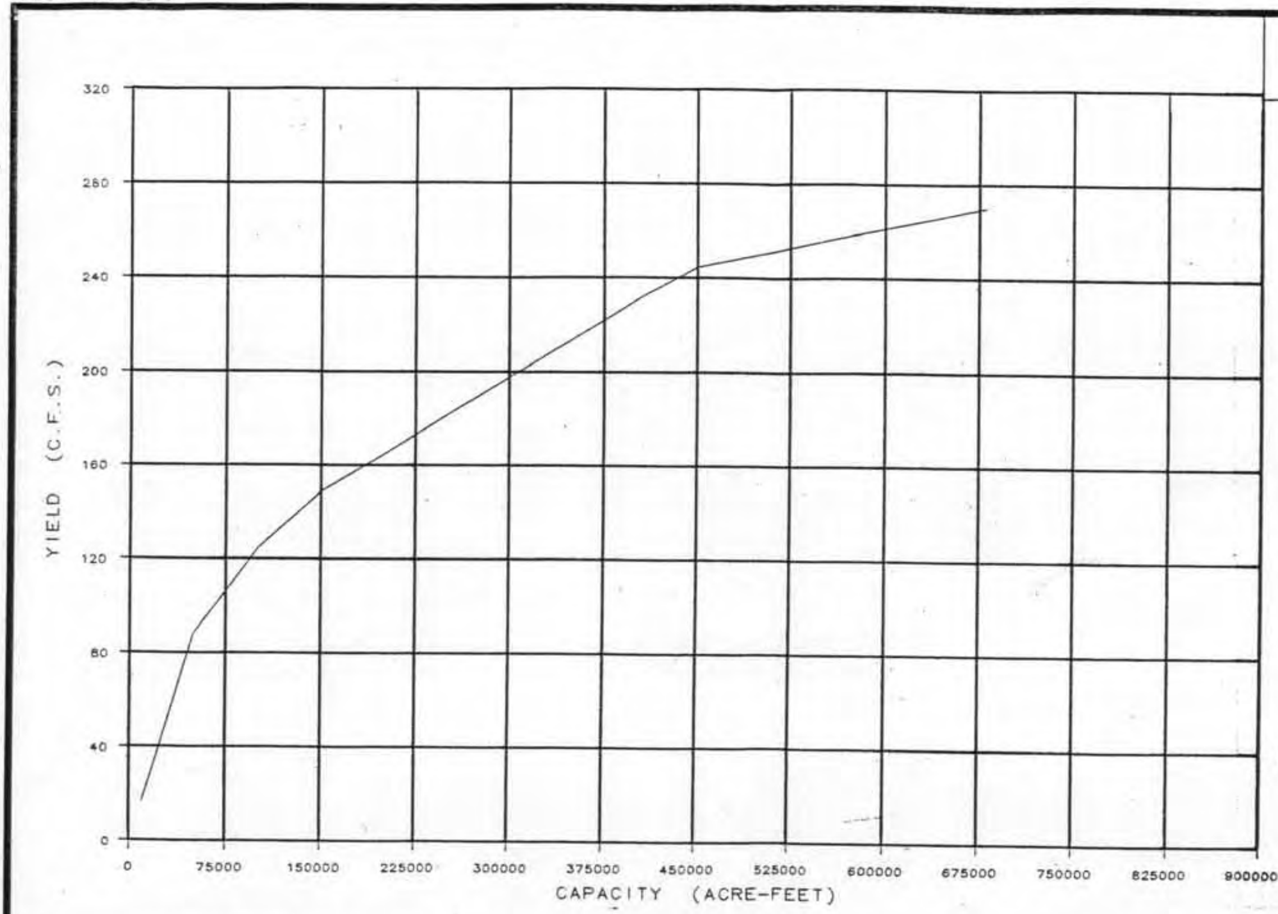
MARSHALL RESERVOIR
LITTLE CYPRESS CREEK
RIVER MILE 21.3
DRAINAGE AREA 617 SM
YIELD CURVE

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE C-2

CORPS OF ENGINEERS

U.S. ARMY

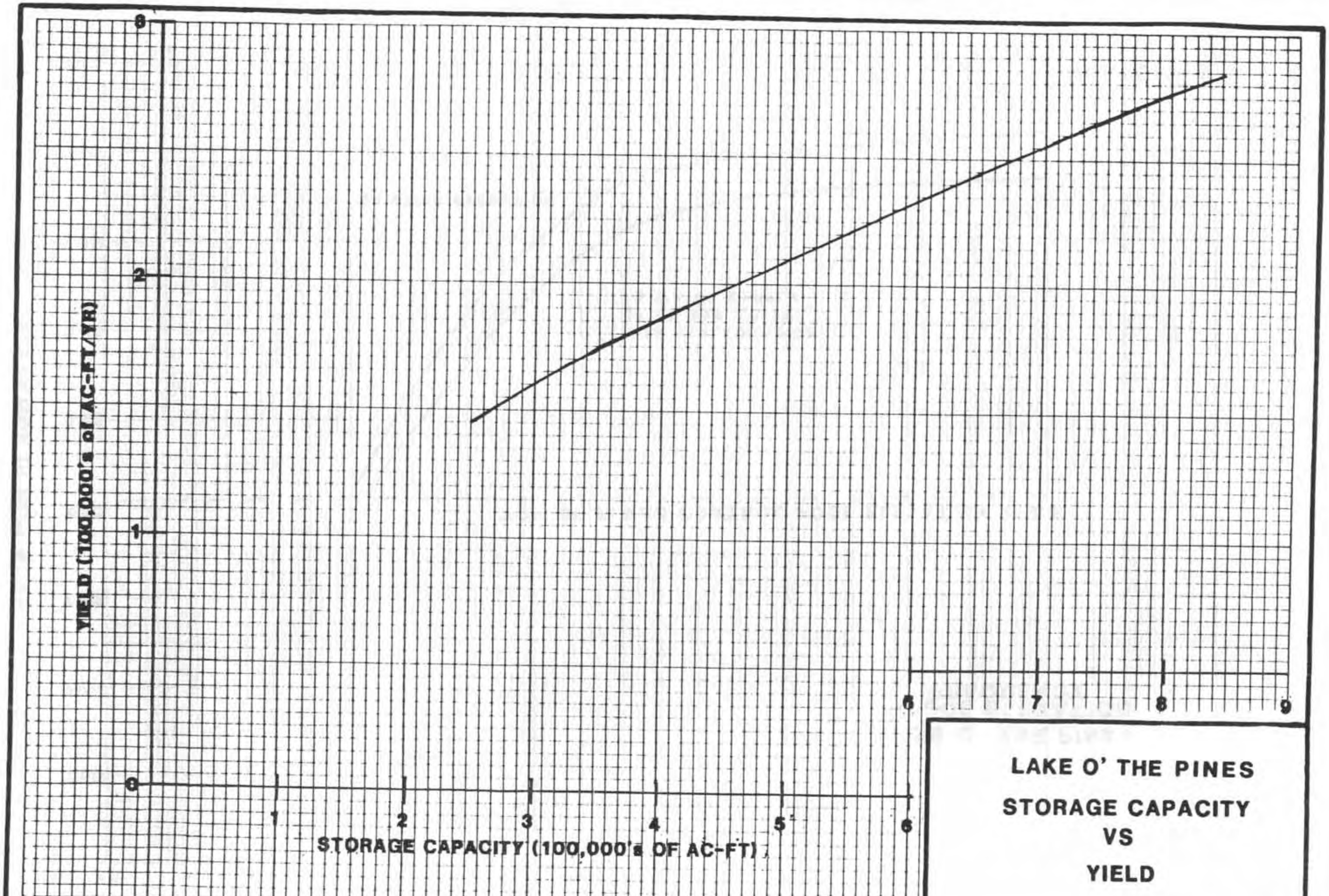


3 JUL 84

BLACK CYPRESS RESERVOIR
BLACK CYPRESS CREEK
RIVER MILE 17.0
DRAINAGE AREA 342 S.M.
YIELD CURVE

U.T. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE C-3



SOURCE: FREESE AND NICHOLS 5-31-86

LAKE O' THE PINES
STORAGE CAPACITY
VS
YIELD

PLATE C-4

K+E PROBABILITY X 90 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 8003

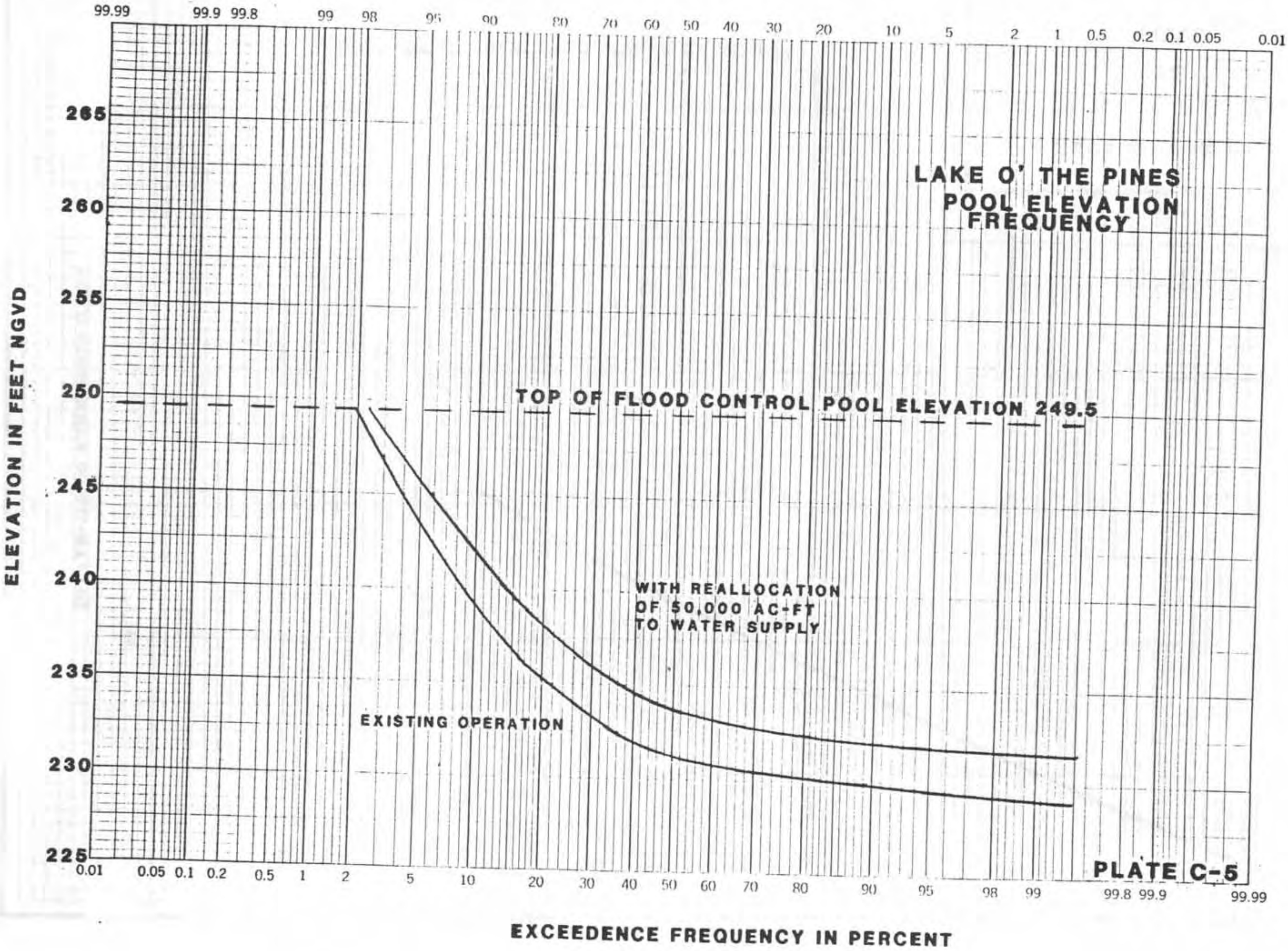
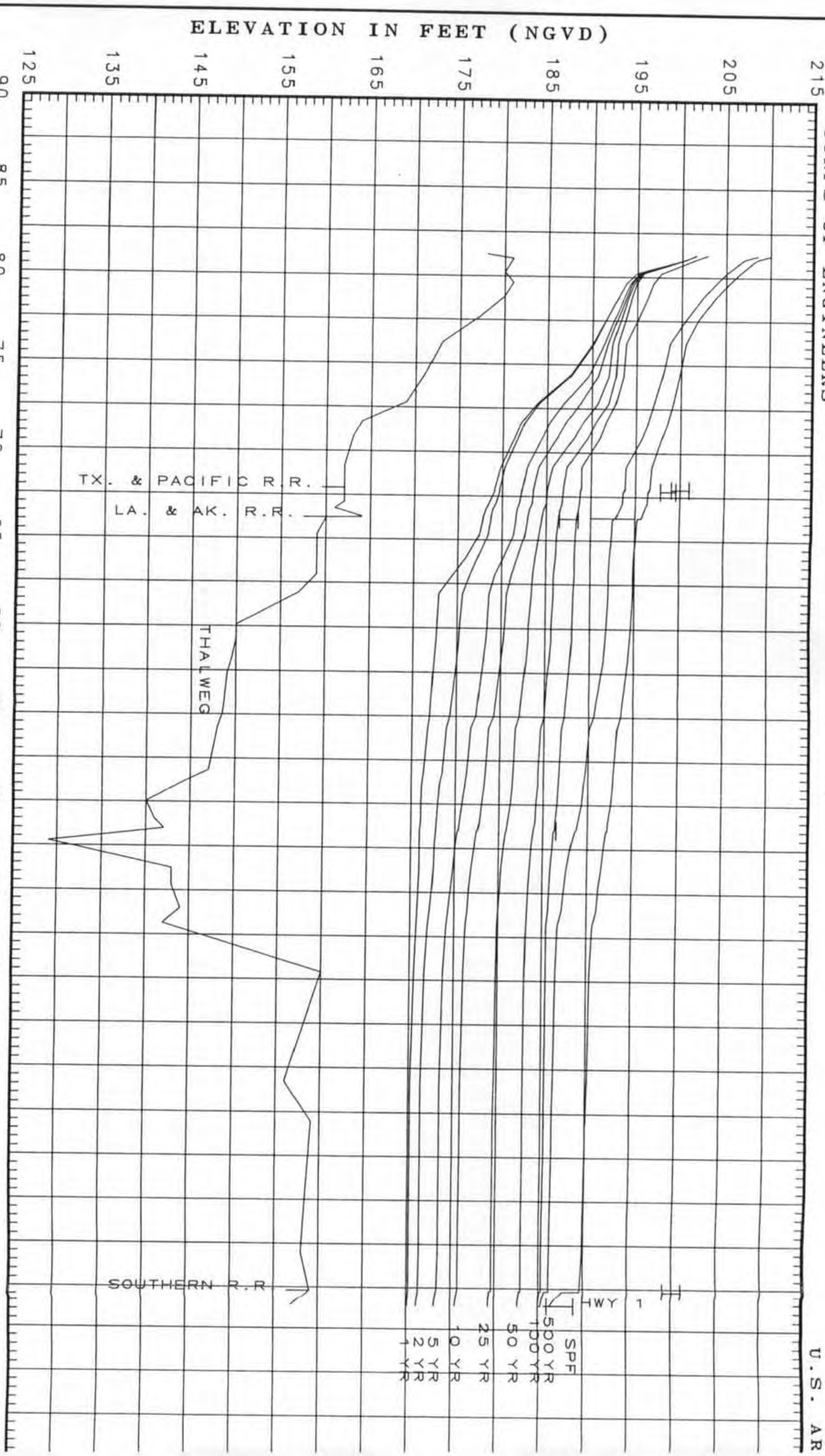
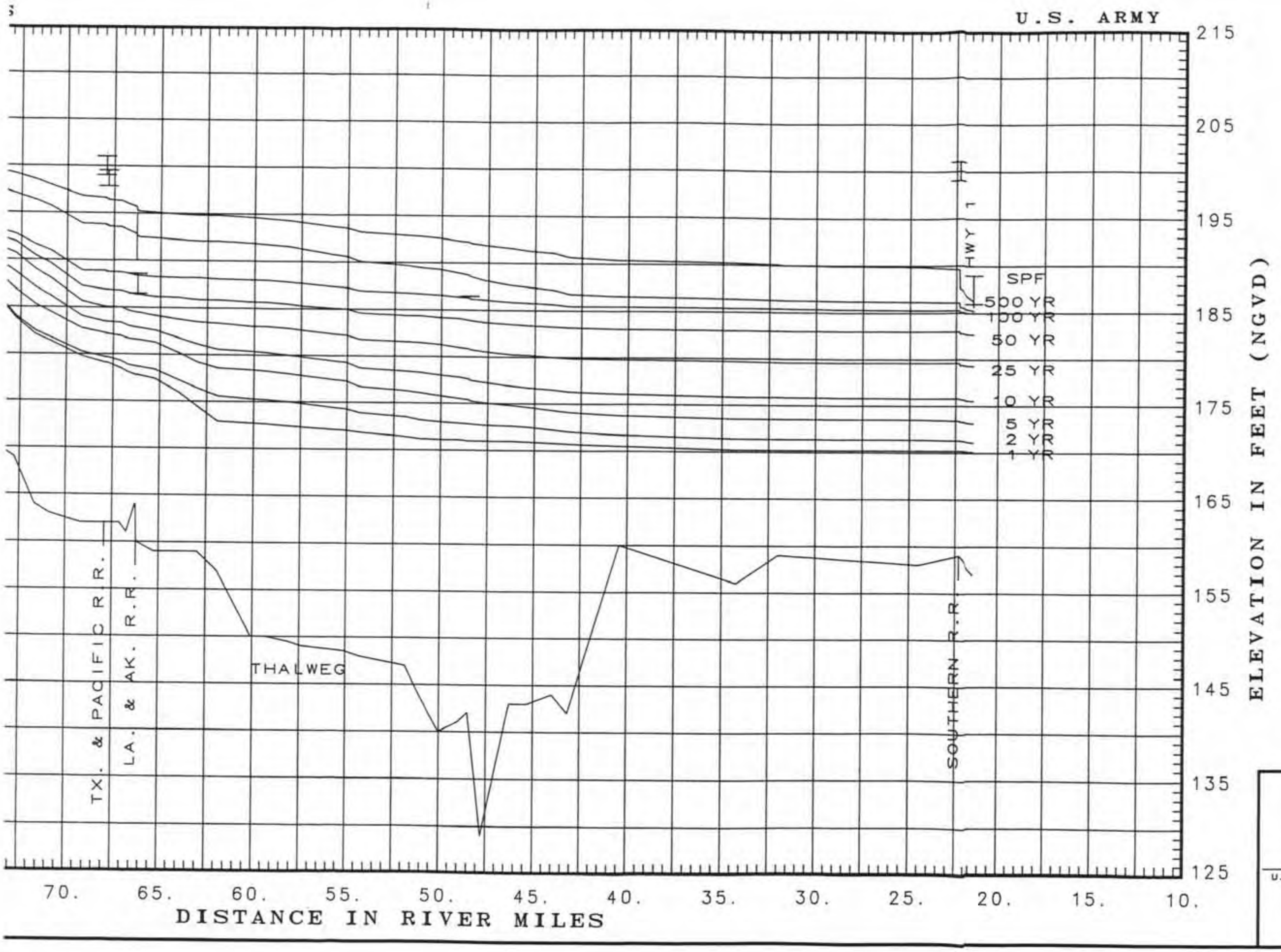


PLATE C-5



CORPS OF ENGINEERS

U.S. AR

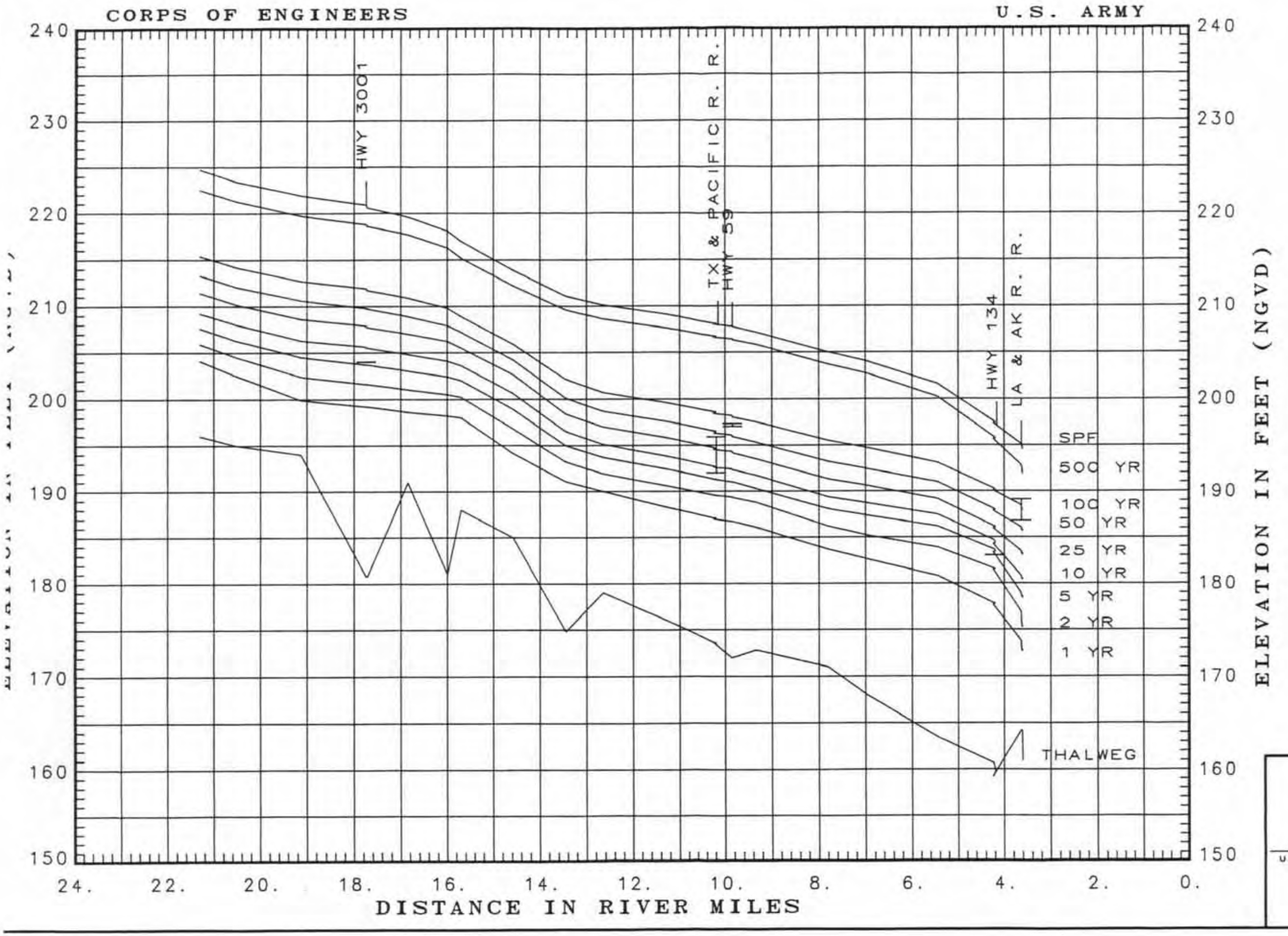


EXISTING CONDITIONS

BIG CYPRESS BAYOU
CADDO LAKE TO
LAKE O THE PINES
WATER SURFACE PROFILES
JUNE 1984

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

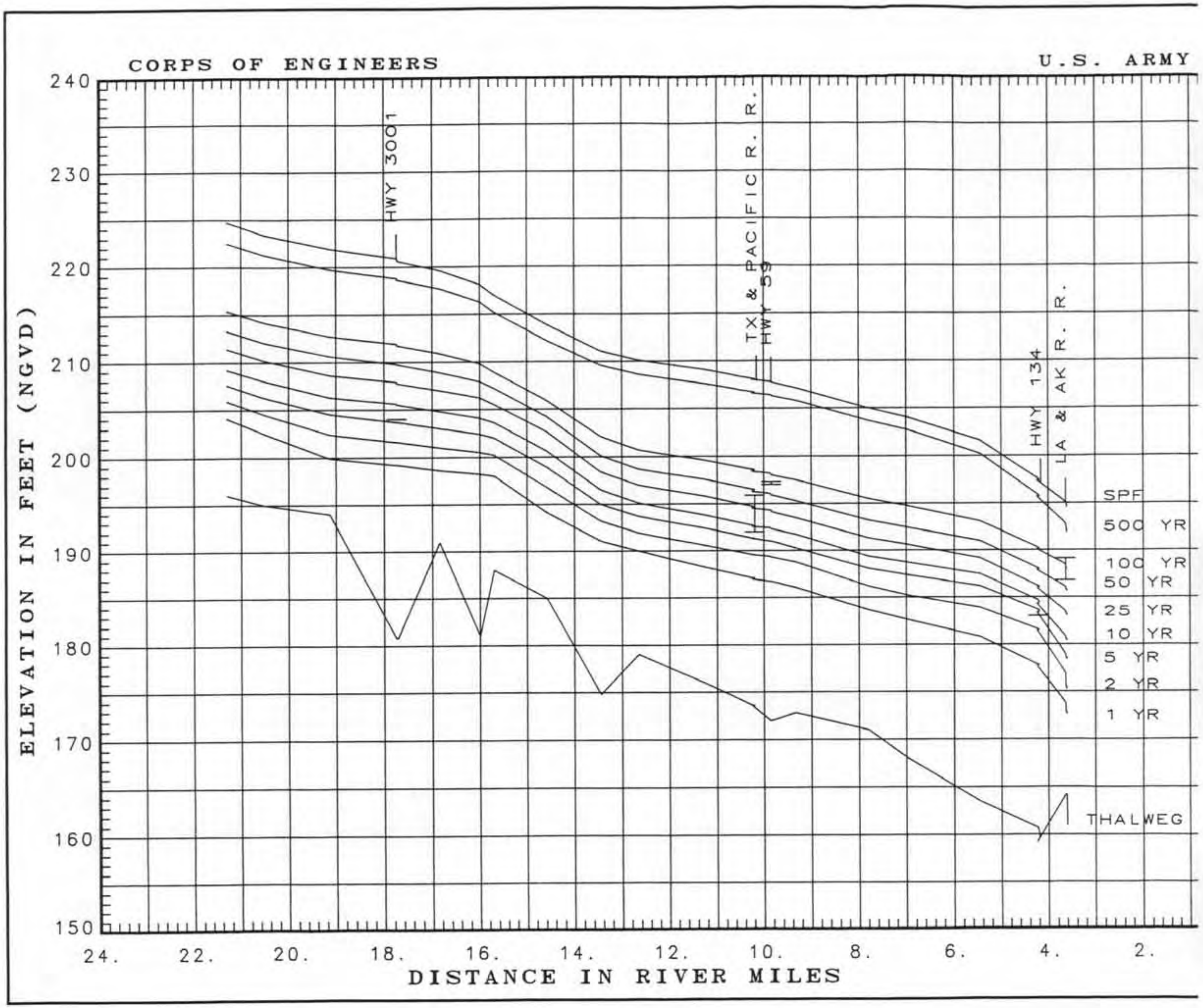
PLATE C-6

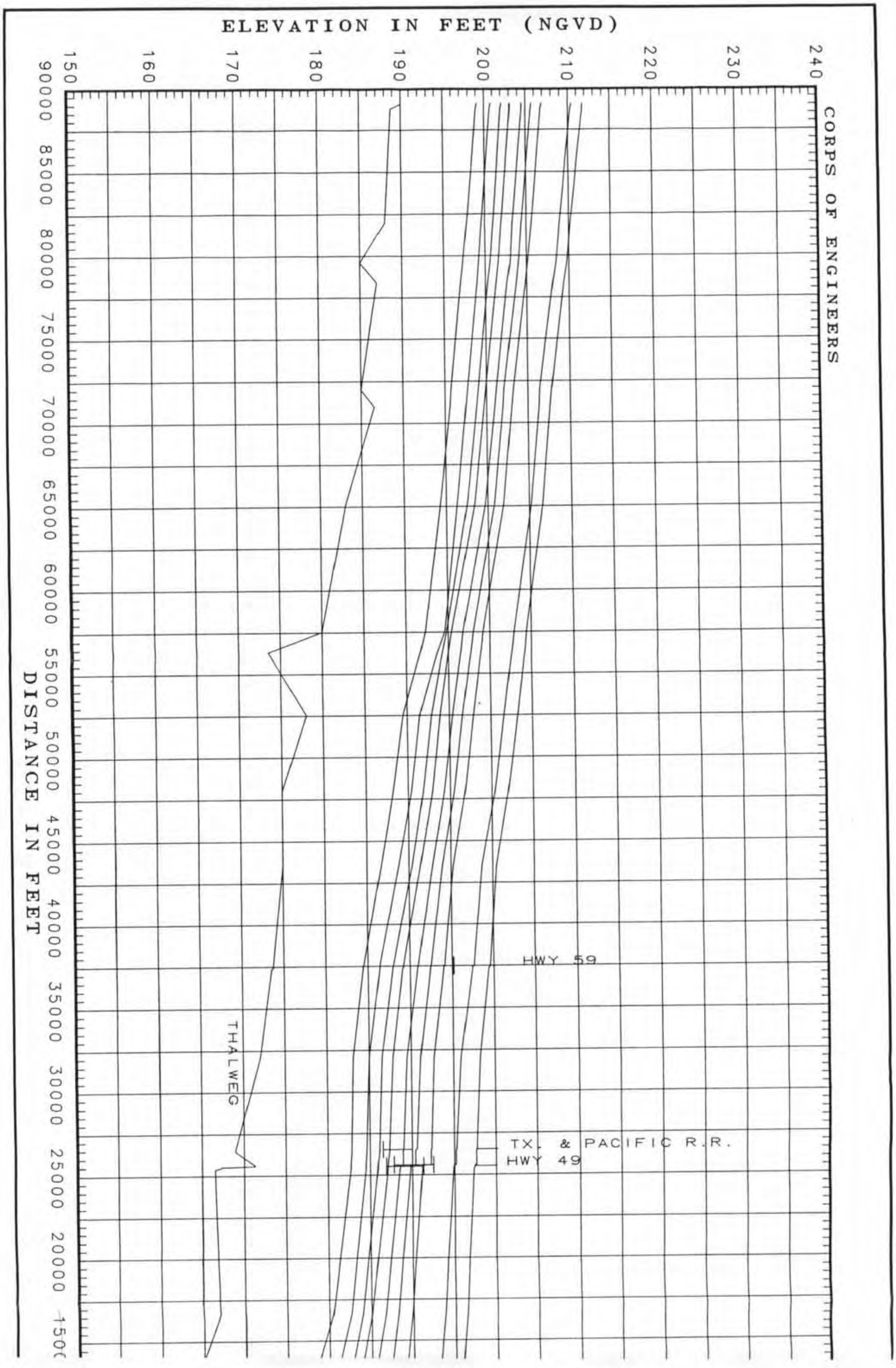


LITTLE CYPRESS BAYOU
MOUTH TO DAMSITE
WATER SURFACE PROFILES
JUNE 1984
EXISTING CONDITIONS

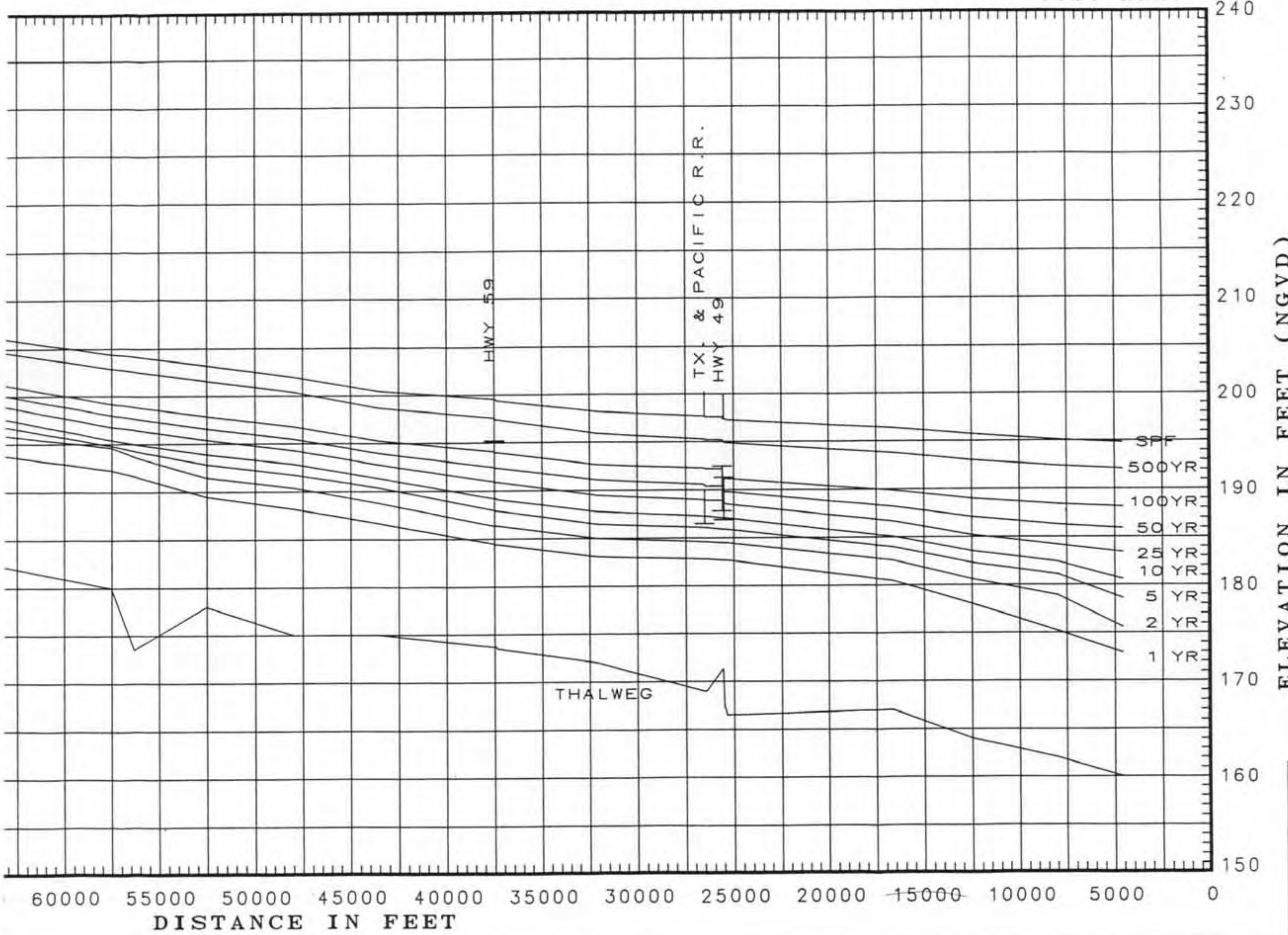
U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE C-7


CORPS OF ENGINEERS
U.S. ARMY
ELEVATION IN FEET (NGVD)
240
230
220
210
200
190
180
170
160
150
DISTANCE IN RIVER MILES
24.
22.
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
HWY 3001
TX & PACIFIC R. R.
HWY 59
HWY 134
LA & AK R. R.
SPF
500 YR
100 YR
50 YR
25 YR
10 YR
5 YR
2 YR
1 YR
THALWEG


ELEVATION IN FEET (NGVD)
150
160
170
180
190
200
210
220
230
240
CORPS OF ENGINEERS
90000
85000
80000
75000
70000
65000
60000
55000
50000
45000
40000
35000
30000
25000
20000
150
DISTANCE IN FEET
THALWEG
HWY 59
TX. & PACIFIC R.R.
HWY 49

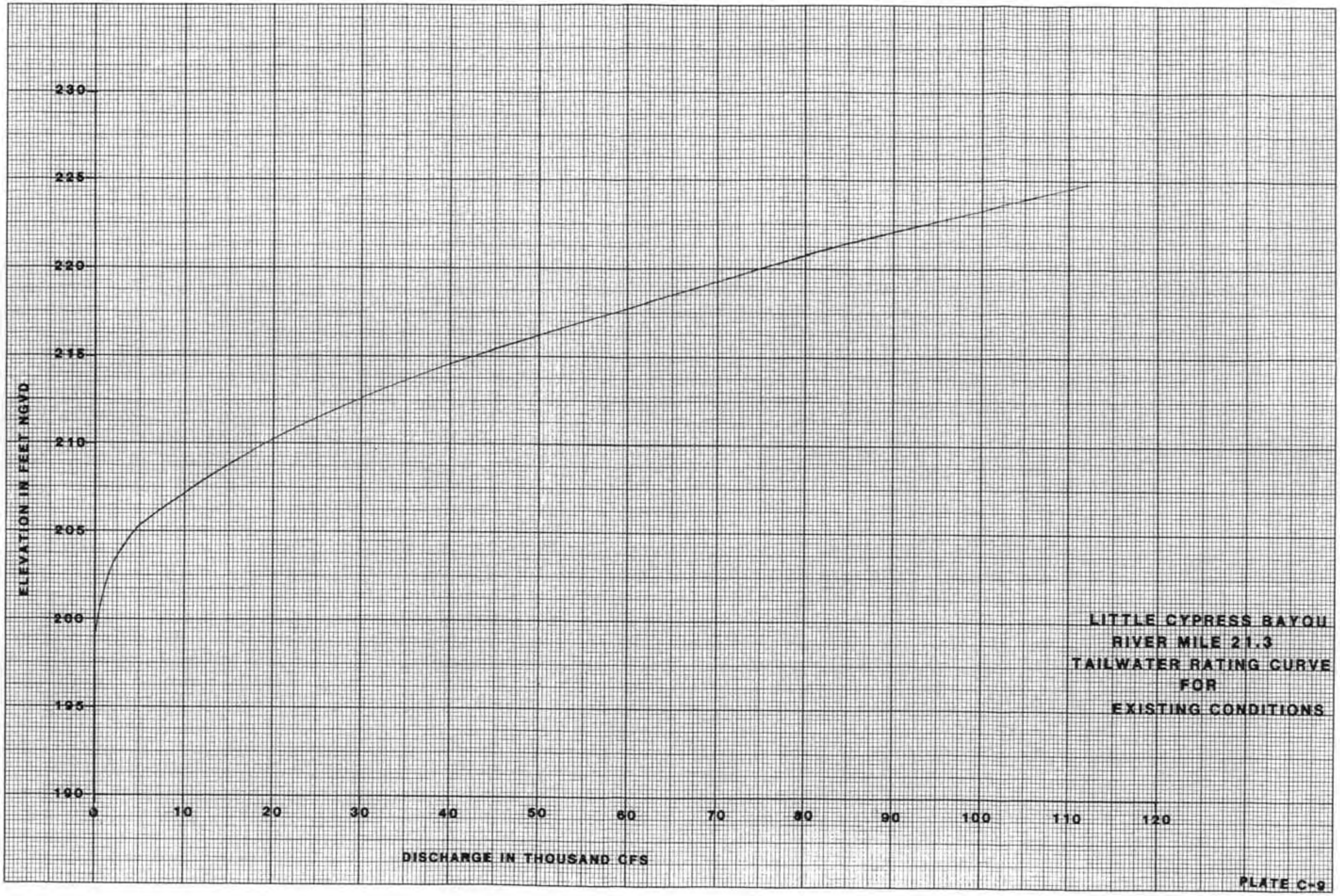
U.S. ARMY



BLACK CYPRESS BAYOU
MOUTH TO DAMSITE
WATER SURFACE PROFILES
JUNE 1984
EXISTING CONDITIONS

U.S. ARMY ENGINEER DISTRICT, FT. WORTH

PLATE C-8



LITTLE CYPRESS BAYOU
RIVER MILE 21.3
TAILWATER RATING CURVE
FOR
EXISTING CONDITIONS

PLATE C-9

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX D - RECREATION

CYPRESS BAYOU BASIN STUDY

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RECREATION

INTRODUCTION

In recent years the demand for outdoor recreation opportunities has rapidly increased throughout Texas, Louisiana, and Arkansas. Changes in factors such as population, urbanization, leisure time, buying power, and recreational preferences have created tremendous pressure on public agencies and private entities to provide more outdoor recreation opportunities. Under the provisions of the Land and Water Conservation Fund Act, each State must develop, maintain, and keep up-to-date a statewide comprehensive outdoor recreation plan. In response to the requirement, the Texas Outdoor Recreation Plan (TORP) of 1980, and the Louisiana State Comprehensive Outdoor Recreation Plan (SCORP) of 1977, and the Arkansas State Comprehensive Outdoor Recreation Plan (SCORP) of 1979 have been prepared and provide the guide for outdoor recreation development in Texas, Louisiana, and Arkansas.

RECREATION NEEDS

The recreation market area analysis of the proposed project locations include the counties, parishes, and State planning regions listed in Tables D-1 and D-2.

The Texas counties listed in Table D-1 cover all of TORP planning regions 5 and 6, and overlap regions 4 and 22. The Louisiana parishes overlap SCORP region 7, and the Arkansas counties overlap SCORP southwest planning region.

The Texas counties listed in Table D-2 cover all of TORP planning regions 5 and 6 and overlap regions 4, 16, and 22. The Louisiana parishes overlap SCORP region 7, and the Arkansas counties overlap SCORP southwest planning region.

Corps of Engineers studies, the TORP, and the Louisiana and Arkansas SCORP reports indicate that a wide deficit exists between the projected recreational needs in the recreation market area and output capacities of all existing and proposed recreational outlets. All studies recognize that there is a shortage of recreational facilities for all activities in the primary study regions overlapping the recreation market area. Access to recreation water is in many cases the limiting factor in utilizing the existing water based resources to their capacity.

Tables D-3 depicts existing and future rural and urban resource requirements identified in the TORP for State planning regions 5 and 6 which encompass the Cypress Bayou Basin.

Texas, Arkansas, and Louisiana recreation studies all show an unsatisfied demand for the traditional recreation facilities, such as camping, picnicking, boat lanes and docks, trails, etc. The creation of an additional lake in the region would satisfy a portion of those overall needs, but would not be able to meet the total resource requirements for recreation.

Demands for hunting lands are expected to increase in the Cypress Bayou Basin. A number of special problems exist with regard to providing adequate hunting opportunities in Texas. According to the TORP, the foremost amoung these problems is the lack of access to private lands suitable for hunting. Other problems are high cost, restrictive leasing practices of private landowners, crowded conditions on public hunting lands, less than optimum distribution of wildlife and land available for hunting, low harvest rates, and the critical loss of high quality wildlife habitat from competing land uses. The alleviation of these problems would make the most effective contributions toward providing more adequate hunting opportunities for Texas.

According to the TORP and SCORP reports, there is a need to acquire areas that are unique or that have particular value for wilderness preservation. Special attention should be given to preserving the critical bottomland hardwood and coastal marsh areas that still exist in a relatively undisturbed state. Recreation in these areas should revolve around low impact, low density use with emphasis on interpretive programs. Special consideration should be given to acquisition of wilderness areas close to urban centers.

POPULATION

The population within the market areas was projected from 1990 through 2040 based on OBERS Series E population projections. A summary of the projections by decade are shown in Table D-4.

PLAN OF RECREATION DEVELOPMENT

Demand for recreational lands and facilities within the Cypress Bayou Basin market area is among the highest in the State of Texas. Unmet demands for both urban and rural facilities have placed a strain on the existing recreational facilities within the region. Population growth, urbanization, and ever increasing pressure by the public for additional outdoor recreation resources will continue to create pressures on public agencies and commercial enterprise to provide new outdoor recreation opportunities. For these reasons, a recreational plan of development should be included in any water resource plan of development.

Recreational visitation, cost, and benefits would be dependent on the level of development agreed upon by the Corps of Engineers and a local sponsor. A listing of the types of recreational opportunities which should be considered in any reservoir type recreation feature for the Cypress Bayou Basin area should include the following:

- Access to water for boat launching, bank fishing, and swimming.
- A full line of camping, picnic, and support facilities.
- A system of trails for water access, nature study, hiking and sight-seeing.
- Marina facilities for long haul pleasure craft as well as smaller craft needing fuel, shelter, and other related services.
- Undisturbed lands for low density recreational use.

Recreational facility development at the two reservoir site alternatives (Marshall and Black Cypress) have the potential for a full line of recreational facilities. Unmet recreation demands for the market area are far greater than the ability of any one project alternative to satisfy. For this reason, either project site should include a highly developed, well balanced plan of recreational development.

LAKE FISHING

Fishing is expected to be a major attraction at either site alternative, especially during the initial 5 years of project life. Any recreation plan should include adequate boat launching facilities situated around the reservoir. Boat lanes should be sited in close proximity to camping and picnic facilities wherever possible. Fishing piers should be located in areas likely to have good fish populations.

STREAM FISHING

Due to the need of adequate stream fishing access, either project alternative should include the acquisition of lands below the embankment for park development. A park and trail system could effectively provide canoe and small boat launching facilities and fishing access to either Black Cypress or Little Cypress Bayous, depending on project location. Land acquisition could be accomplished by means of mitigation, environmental quality, or specific recreation land purchase. Fishing access along the stilling basin should also be included in any structural plan of development.

PICNIC AND CAMPING AREAS

Park development at either project site alternative would receive a high degree of visitor usage. These areas should be intensively developed and should give primary emphasis to providing sufficient recreation facilities for the continued enjoyment and maximum sustained use by the visiting public, consistent with carrying capacity and aesthetic and biological values. This requires a balanced approach to facility development which must take into consideration both recreational and environmental goals in order to achieve an equilibrium between conservation and the natural environment and development for public use. These areas will have a mix of day use and overnight facilities. Campsites should be multi-use and should be designed for visitors with travel trailers, pop-up trailers, campers on pickups, or tent camps. Each site should consist of a parking area of sufficient dimensions to accommodate an automobile with a typical recreational trailer in tow. Adjacent to each parking area will be the campsite consisting of a table with benches, an electrical outlet, a water faucet, a trash receptacle, and a cooking grill. Picnic units would consist of a parking area, a table with benches, a trash receptacle, and a cooking grill. Boat launching ramps, waterborne toilets, camper service buildings, and potable water should also be provided.

Other areas should be developed as low density use parks and would be designed to protect, maintain, and enhance existing environmental and recreational values. The primary objective would be to provide opportunities for outdoor recreation activities such as hiking, bird watching, nature study, photography, natural environment camping, and other recreation activities which require limited development and which will leave the area natural in appearance.

Land requirements for park development are based on the optimum recreational facility development with allowances for undevelopable park lands to serve as buffer areas, open space, and preservation of the park-like atmosphere to assure the enhancement of the recreational experience. Participation rates are combined with space standards and associated planning decisions to derive the most accurate estimate of land requirements for the two project alternatives. The final result is the gross acreage requirement necessary to accommodate the design day load. The acreage is used as a basis for choosing the size and number of public use land parcels to be required and developed. The land requirements thus determined are shown in Table D-5.

TRAILS

Many areas are well suited for nature study and plant and animal photography. Development should include the location of special nature trails leading through unique areas. Viewing blinds would be placed along trails near openings, bogs, swamps, or at other places where wildlife can be studied and photographed. Special interpretive facilities generally part of the development of a nature area will be placed at key ecological areas throughout the project. Trails should also be established starting from each park and access area and proceeding into the more scenic areas. These trails will be designed to provide hiking, nature experiences, and access.

Interpretation would be made at intervals along the main trail and various spur trails. Trailside rest shelters, bike camping, and picnicking areas should be provided for some trails. Other trails should be designed to accommodate horseback riding. Provisions should be made for nondeveloped camping areas. These areas could be reached only through the network of trails. Interpretive facilities would include self guiding nature trails providing access to scenic natural areas and wildlife interpretive areas.

ENVIRONMENTALLY SENSITIVE AREAS

There are no identified areas within the Marshall and Black Cypress project locations which are considered environmentally sensitive. There are, however, areas which should be given special consideration in any recreational plan of development. Both Black and Little Cypress Bayous have the potential for a high degree of recreational use. Canoeing, fishing, and hiking activities could place a great deal of stress on the area if allowed to be overused. Activity design should consider the proper carrying capacity of the resource to avoid possible deterioration of a unique environment.

RECREATION COST

The recreation cost presented in this plan is based on development by the Corps of Engineers. The cost estimates are based on July 1984 price levels. A summary of the recreation costs are shown in Tables D-6 and D-7. The cost of facilities required to achieve this level of recreation use and development will be subject to cost sharing by a non-Federal local sponsor under the provisions of Public Law 89-72.

VISITATION AND BENEFITS CALCULATIONS

Projected visitation and the estimated benefits accruing to such visitation were calculated following the instructions presented in "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies" dated March 10, 1983. The Travel Cost method was selected as the most appropriate of the procedures listed.

In this procedure, visitation is estimated using population projections for the counties in the market area and per capita use rates observed at some existing, similar, project elsewhere. Benefits for this visitation are then estimated, using the travel cost method. The first step in this method is to calculate the cost per person per trip for each county of the market area for the project at which the per capita use rates were observed. The cost measures both the variable cost of operating a vehicle to the project and the opportunity cost of an individual's time in traveling to each particular project rather than some other place. In order to derive these costs, some basic assumptions were made. The variable cost of operating a passenger sedan was assumed to be 7 cents per mile, and each car was assumed to carry three persons and average 50 mph. The opportunity cost for time spent in traveling was assumed to be 1/3 the median per capita income for that county as identified in the 1980 census.

The "similar projects" chosen for use in this study were B. A. Steinhagen reservoir in the Fort Worth Disirct and Beaver Reservoir in the Little Rock District. These projects were chosen for their similarity to the proposed project in terms of size, relative distance from major population centers, and number of competing reservoirs. The observed per capita use rates for these projects were taken from Technical Report No. 2, Estimating Initial Reservoir Recreation Use, published in October 1969 by the U. S. Army Engineer District, Sacramento. Projected visitation based on the market area for the Marshall and Black Cypress reservoir sites are shown below.

PROJECTED VISITATION

	MARHSALL	BLACK CYPRESS
1990 Visitation (Visitor days)	2,938,646	1,655,366
2040 Visitation (Visitor days)	4,618,796	2,572,893

A simple, bivariate regression equation is then developed, relating the cost per person per trip to the per capita use. The regression parameters are then used to estimate the drop in expected visitation with each dollar increase in travel cost. These numbers, in effect, generate a demand curve for recreation with the cost per trip on one axis and the estimated visitation on the other. The consumer surplus, or the amount visitors would be willing to pay (but do not have to), can be estimated from the area under the derived demand curve and is assumed to be equivalent to the project's recreation benefits.

Projected benefits, however, can be limited by the lake's maximum capacity which is a measure of the project's capability to support recreation use. It is based on many of the physical and environmental factors affecting the project, but also takes into account the market area, access to the project and user needs and perferences. For lake projects, standards of maximum crowding are keyed to a maximum boat density desirable for the project, an example is as follows:

(MARSHALL SITE)

13,690 water acres[1] ÷ 5 acres/boat = 2738 boats on the lake at one time
2,738 X 2 (1/2 boats active) = 5,476 total boats
5,476 X 3 persons/boat = 16,428 persons
16,428 X 2 (1:1 ratio of boat users to non-users) = 32,856 (design day load)
32,856 X 26 weekend days = 854,256 summer weekend users
854,256 ÷ .6 weekend use rate = 1,423,760 summer visitation
1,423,760 ÷ .5 summer visitation rate = 2,847,520 maximum annual use

[1] Average acreage at the top of the conservation pool.

It should be noted that when maximum capacity for a site is lower than the projected visitation, this indicates that the market area demand for recreation is greater than the project can meet. Accordingly, the visitation and benefits must be reduced. Table D-8 gives benefits for the alternatives investigated. Plate D-1 presents recreation benefit curves used in the evaluation of the remaining array of Marshall and Black Cypress Lake alternatives.

TABLE D-1

BLACK CYPRESS LAKE SITE
RECREATION MARKET AREA - COUNTIES AND PARISHES

Texas Counties	Louisiana Parishes	Arkansas Counties
Bowie	Bossier	Hempstead
Camp	Caddo	Lafayette
Delta	Red River	Little River
Franklin		Miller
Greg		
Harrison		
Hopkins		
Lamar		
Marion		
Morris		
Panola		
Rains		
Shelby		
Smith		
Titus		
Upshur		
Wood		

TABLE D-3

RESOURCE REQUIREMENT FOR RECREATION FACILITIES
ON TORP REGIONS 5 AND 6

		Urban			Rural		
	Unit of	Existing	Required		Existing	Required	
Recreation Resource	Measure	1980	1985	2000	1980	1985	2000
Recreation Land	Acres	2,490	3,471	6,634	49,172	6,418	12,404
Camping	Sites	---	0	0	2,480	7,834	15,923
Playgrounds	Acres	28	60	87	9	31	60
Picnicking	Tables	776	11	52	1,681	4,704	8,200
Boat Ramps	Lanes	5	28	50	244	283	523
Fishing Facilities	Lin Yds	245	89	183	2,580	10,278	17,183
Bicycle Trails	Miles	---	---	---	---	7	14
Horseback Riding Trails	Miles	0	2	4	0	48	100
Combined Trails (walk, hike nature study)	Miles	---	---	---	23	201	378
Combined Trails (walk, hike nature study, bicycle)	Miles	18	41	79	---	---	---
Recreation Water	Surface Acres	0	953	1,630	142,494	0	0
Swimming Beaches	Sq Yds	0	97	173	242	3,093	5,862

NOTE: Dashes indicate needs have not been projected

TABLE D-5
SPECIFIC RECREATION LAND REQUIREMENTS

MARSHAL SITE

Area	Acres
Park Site 1	375
Park Site 1	600
Park Site 3	500
Access Area 1	25

BLACK CYPRESS SITE

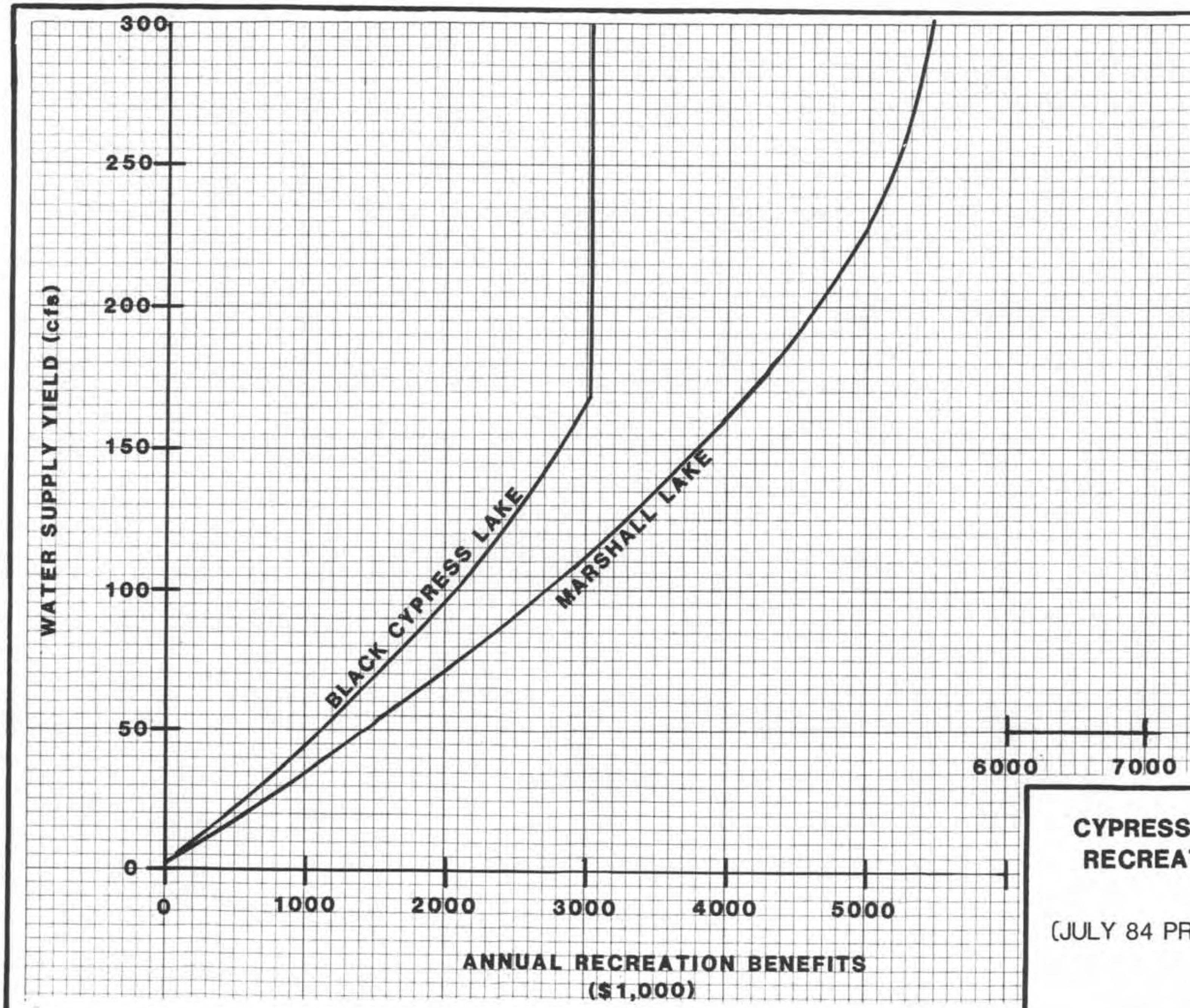
Area	Acres
Park Site 1	300
Park Site 2	500
Park Site 3	275
Access Area 1	25

TABLE D-8
RECREATION BENEFITS

Recreation Pool Size (Acres)	Maximum Capacity Annual (Visitor-Days)	1990 Visitation Annual (Visitor-Days)	2040 Visitation Annual (Visitor-Days)	1990 Benefits ($1000)	2040 Benefits ($1000)	Annual Benefits (1) ($1000)
13690	2,847,500	2,847,500 (2)	2,847,500 (2)	$4,302.5 (2)	$4,302.5 (2)	$4,302.5
19312	4,016,900	2,938,600 (3)	4,016,900 (2)	4,439.5 (3)	6,060.7 (2)	5,222.9
28527	5,933,600	2,938,600 (3)	4,618,800 (3)	4,439.5 (3)	6,965.9 (3)	5,452.8
BLACK CYPRESS SITE						
8130	1,691,000	1,655,400 (3)	1,691,000 (2)	2,467.5 (3)	2,492.5 (2)	2,473.4
13641	2,837,300	1,655,400 (3)	2,572,900 (3)	2,467.5 (3)	3,868.1 (3)	3,029.8
21049	4,378,200	1,655,400 (3)	2,572,900 (3)	2,467.5 (3)	3,868.1 (3)	3,029.8

NOTES:

(1) Benefits were annualized at 8 3/8% interest rate
(2) Visitation and benefits limited by maximum capacity
(3) Visitation and benefits limited by projected visitation



CYPRESS BAYOU BASIN
RECREATION BENEFITS

(JULY 84 PRICE LEVELS,
8 3/8% INTEREST)

PLATE D-1

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX E - COST ESTIMATE

TABLE D-2

MARSHALL LAKE SITE
RECREATION MARKET AREA - COUNTIES AND PARISHES

Texas Counties	Louisiana Parishes	Arkansas Counties
Anderson	Bossier	Miller
Bowie	Caddo	
Cass	DeSoto	
Camp	Red River	
Cherokee		
Delta		
Franklin		
Greg		
Harrison		
Hopkins		
Marion		
Morris		
Nacogdoches		
Panola		
Rains		
Rusk		
San Augustine		
Shelby		
Smith		
Titus		
Upshur		
Van Zandt		

TABLE D-4

PROJECTED POPULATION IN THE MARSHALL MARKET AREA

Decade	Population
1990	1,395,700
2000	1,567,100
2010	1,724,600
2020	1,971,500
2030	2,053,300
2040	2,209,300

PROJECTED POPULATION IN THE BLACK CYPRESS MARKET AREA

Decade	Population
1900	1,174,100
2000	1,314,700
2010	1,434,500
2020	1,565,800
2030	1,689,300
2040	1,815,901

TABLE D-6

RECREATION COST - OPTIMUM DEVELOPMENT
All Alternatives at the Marshall Site

($1,000)

Facilities (initial)	16,516.1
Future facilities	1,649.8
Subtotal	18,165.9
Contingencies (25%)	4,541.5
Total	22,707.4

NOTE: 1500 acres of specific recreation lands will also be acquired.

TABLE D-7

RECREATION COST - OPTIMUM DEVELOPMENT
All Alternatives at the Black Cypress Site

($1,000)

Facilities (initial)	7,586.8
Future facilities	1,565.0
Subtotal	9,151.8
Contingencies (25%)	2,288.0
Total	11,439.8

NOTE: 1100 acres of specific recreation lands will also be acquired.

CYPRESS BAYOU BASIN STUDY

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COST ESTIMATES

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APPENDIX E - COST ESTIMATES

GENERAL

This appendix presents the data used to prepare cost estimates for the array of preliminary and detailed lake alternatives.

COST CURVES

To facilitate the investigation and evaluation of the numerous lake alternatives identified, cost curves were developed for both the Marshall and Black Cypress Lake sites. The curves were developed for each of the following project features:

COST ACCOUNT NO.	PROJECT FEATURE
01	Lands and Damages
02	Relocations
03	Reservoir
04	Dams
08	Roads, Railroads, and Bridges
14	Recreation Facilities
18	Cultural Resource Preservation
19	Building, Grounds and Utilities
20	Permanent Operating Equipment

The cost curves for each of the above features are based on detailed estimates of several scales of development at each of the lake sites. The price level basis of all cost curves is July 1984 dollars. The following briefly discusses each of the items presented in the cost analysis tables included as part of the main report.

LANDS

Land costs were based on a gross appraisal report prepared for planning purposes in 1982 with costs updated to July 1984 price levels. The land cost cost curves shown on Plate E-1, is comprised of three categories: (1) Project Lands; (2) Mitigation lands; and (3) Specific recreation lands. To compute land acquisition cost, determine total project land requirement, and from curve find associated per-acre land costs. This per-acre cost is then used for each of the three categories identified.

PROJECT LANDS

Project land requirements are based on acquisition acres indicated on pertinent data tables.

MITIGATION LANDS

Plate E-2 was developed to estimate the amount of mitigation lands needed to mitigate for endured project losses. For water supply only projects, mitigation acreage is based on the conservation pool elevation. If flood control storage is considered as a purpose, mitigation land requirements are reduced to reflect increase in lands acquired above the conservation pool. For flood control only lakes, mitigation lands were based on using 10-percent of the lands indicated as necessary for mitigation at top of flood control pool.

SPECIFIC RECREATION LANDS

Preliminary estimates of recreation land requirements for Marshall and Black Cypress lakes were measured at 1,500 acres and 1,100 acres, respectively, regardless of project scale.

RELOCATIONS

Relocation costs presented on Plate E-3 are based on elevating, altering or relocating roads, cemeteries, pipelines, rural electric lines, telephone lines and transmission lines three feet above the 50-year pool elevation as noted on the pertinent data tables. Also included on this plate are curves reflecting estimated costs for above in kind replacement. For Marshall Lake, there is also an additional relocations cost associated with raising oil and gas wells. Plate E-4, presents these costs based on the conservation pool elevation plus three feet.

RESERVOIR COSTS

Reservoir costs are comprised of two items; clearing which includes clearing trees, brush and debris based on the conservation pool elevation and boundary line survey and marketing based on the fee acquisition line. Plate E-5 presents these costs.

DAM COSTS

Dam costs include costs associated with embankment, spillway, and outlet works. Plate E-6 presents dam costs based on top of dam elevation.

Plate E-7 presents cost adjustments for Marshall Lake dam, Plate E-6 to reflect impacts to overall dam costs resulting in changes of the spillway length.

ROADS, RAILROADS, AND BRIDGES

Costs associated with modifications to roads, railroads, and bridges are based on top of dam elevation. These costs are presented on Plate E-8.

RECREATION COSTS

Recreation facilties costs, exclusive of land costs, were estimated to be the same for any size Marshall or Black Cypress Lakes. Based on developing potential recreational opportunities at each site costs of $22,707,400.00 and $11,439,800.00 were used for Marshall and Black Cypress Lakes, respectively.

CULTURAL RESOURCE PRESERVATION

Public Law 93-291 limits cultural resource preservation cost to not more than one percent of construction costs.

BUILDINGS, GROUNDS AND UTILITIES

Cost for buildings, grounds and utilities were estimated to be the same for all projects, $378,000.00, Plate E-9.

PERMANENT OPERATING EQUIPMENT

Plate E-9, presents costs for permanent operating equipment based on top of dam elevation.

CONSTRUCTION PERIOD

The construction period indicated was used to compute interest during construction costs. The period indicated was based on total construction cost:

Less Than $250,000,000 = 48 months

250,000,000 to 350,000,000 = 60 months

351,000,000 to 550,000,000 = 72 months

551,000,000 to 650,000,000 = 84 months

651,000,000 to 750,000,000 = 96 months

PROJECT OPERATION AND MAINTENANCE

Project operation and maintenance costs were developed for the full array of lake alternatives considered. The costs indicated on Plate E-10 are based on conservation pool acres for alternatives which include water supply and acres at top of flood control pool for flood control only lakes.

MITIGATION OPERATION AND MAINTENANCE

Operation and maintenance costs for mitigation lands were based on a unit cost of $5.00 per acre of mitigation lands acquired.

FIRST COSTS

FINANCIAL COST

Financial costs are the initial and recurring outlays of monies, lands, materials, goods and services that will be incurred over the life of the project in its construction, operation, and maintenance. Financial costs also include cost of contingencies, engineering, design, supervision and administration.

ECONOMIC COST

Economic costs are equal to financial costs minus the costs for relocation replacements above in kind.

ENGINEERING AND DESIGN

The engineering and design cost includes all engineering, design and survey for detailed design studies, plans and specifications and related work for the construction of the project. This cost was estimated by adding 8-percent of the construction cost and was based on previous projects of relative complexity of design.

SUPERVISION AND ADMINISTRATION

The cost of supervision and administration is included into the estimate to provide such anticipated items as salaries of the resident engineer, his staff of engineers, surveyment, etc; construction cost or rental for field office, operation, maintenance and fixed charges for transportation and for other field equipment; field supplies; construction management; project office administration and general overhead charged to the project. This cost was estimated by adding 7-percent of the construction cost and was based on previous projects of relative complexity.

INTEREST DURING CONSTRUCTION

This is the cost of construction money invested in a project before the beginning of the period of economic analysis and before the accumulation of benefits by the project. Interest during construction (IDC) costs are added to the project cost to determine investment costs. Average annual costs are determined based on investment costs which include IDC.

Planning Guidance Notebook (EP1105-2-45) states that costs incurred during the construction period should be increased by adding compound interest at the applicable project discount rate from the date the expenditures are made to the beginning of the period of analysis.

The total construction period for either Marshall and Black Cypress Lakes was estimated to be 48 months. Therefore, IDC was computed for 48 months based on average monthly expenditures of the first cost of the project.

PERIOD OF ANALYSIS

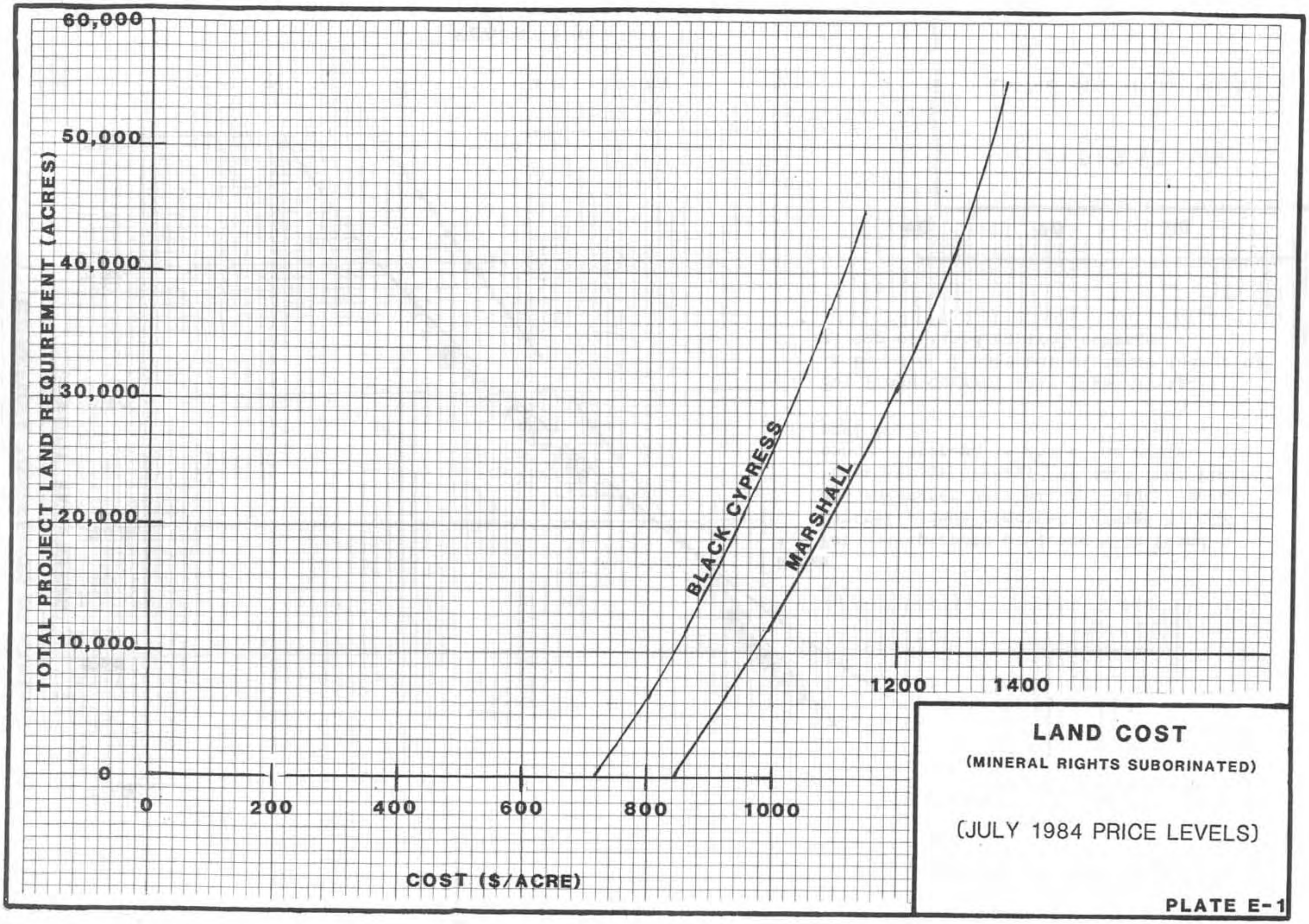
It is estimated that major features of the plan such as spillway and embankment will have useful life expectancies of at least 100 years, provided a consistent program of maintenance is adhered to by the operating agency.

INTEREST AND AMORTIZATION

The interest rate used to convert investment costs to equivalent annual cost is the rate set by the Water Resources Council for the evaluation of Federal Government Water Resources Projects. This rate is set at 8.625 percent for fiscal year 1986. Amortization is the financial or economic process of recovering an investment in a project. The amortization period is the period of time assumed or selected for economic recovery of the net investment in a project by the process of amortization. The definition of amortization can more readily be explained by stating it is the equivalent annual amount which, with compound interest, will accumulate to provide one dollar at the end of the amortization period. When combined, interest and amortization become the capital recovery factor which, when applied to project costs, will result in the annual cost of the project investment. The interest and amortization factor based on a 100-year period of analysis and 8.625 percent interest rate is 0.086273.

OPERATION AND MAINTENANCE

The operation and maintenance costs are estimated to represent the anticipated average annual economic costs necessary to maintain the project at full operating efficiency throughout the project life. After completion of the project, operation and maintenance of project facilities and related mitigation measures would be performed by the local cooperating agency in accordance with government regulation.

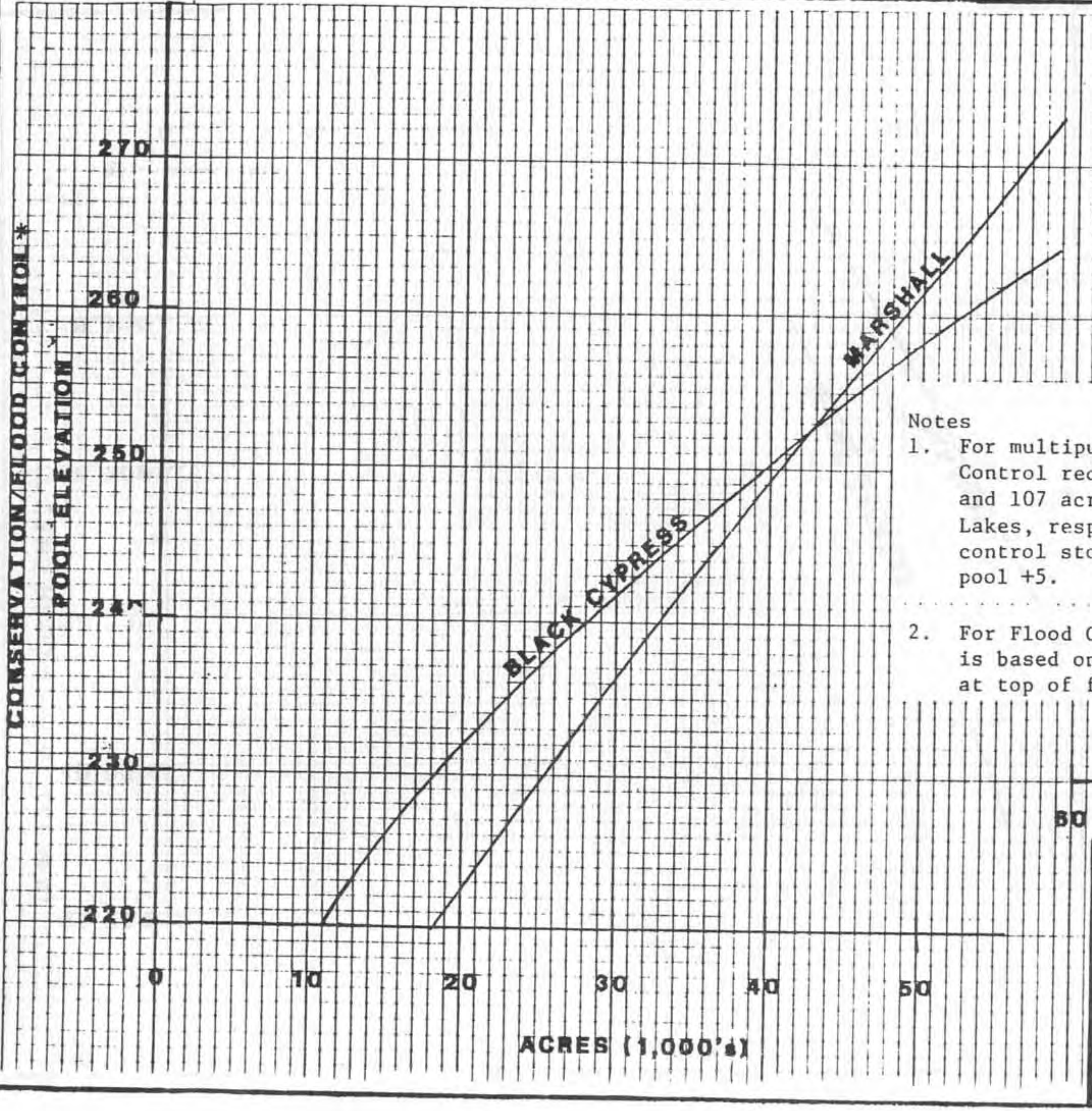


LAND COST

(MINERAL RIGHTS SUBORINATED)

(JULY 1984 PRICE LEVELS)

PLATE E-1



Notes

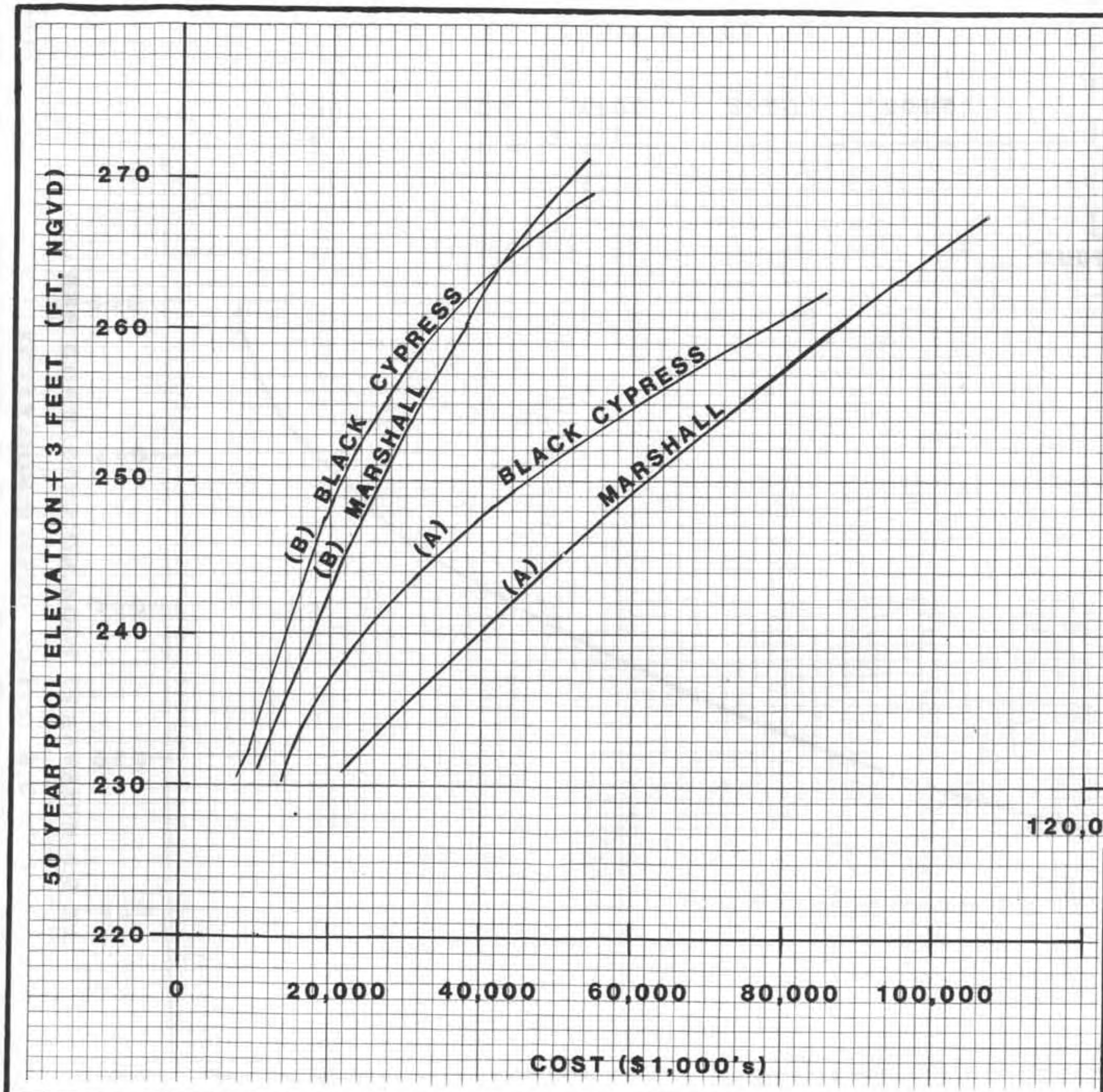
1. For multipurpose projects with Flood Control reduce required acreage by 465 and 107 acres Marshall and Black Cypress Lakes, respectively, for each foot flood control storage is above the conservation pool +5.

2. For Flood Control only lakes mitigation is based on 10-percent of lands indicated at top of flood control storage.

MITIGATION

LAND REQUIREMENTS

PLATE E-2

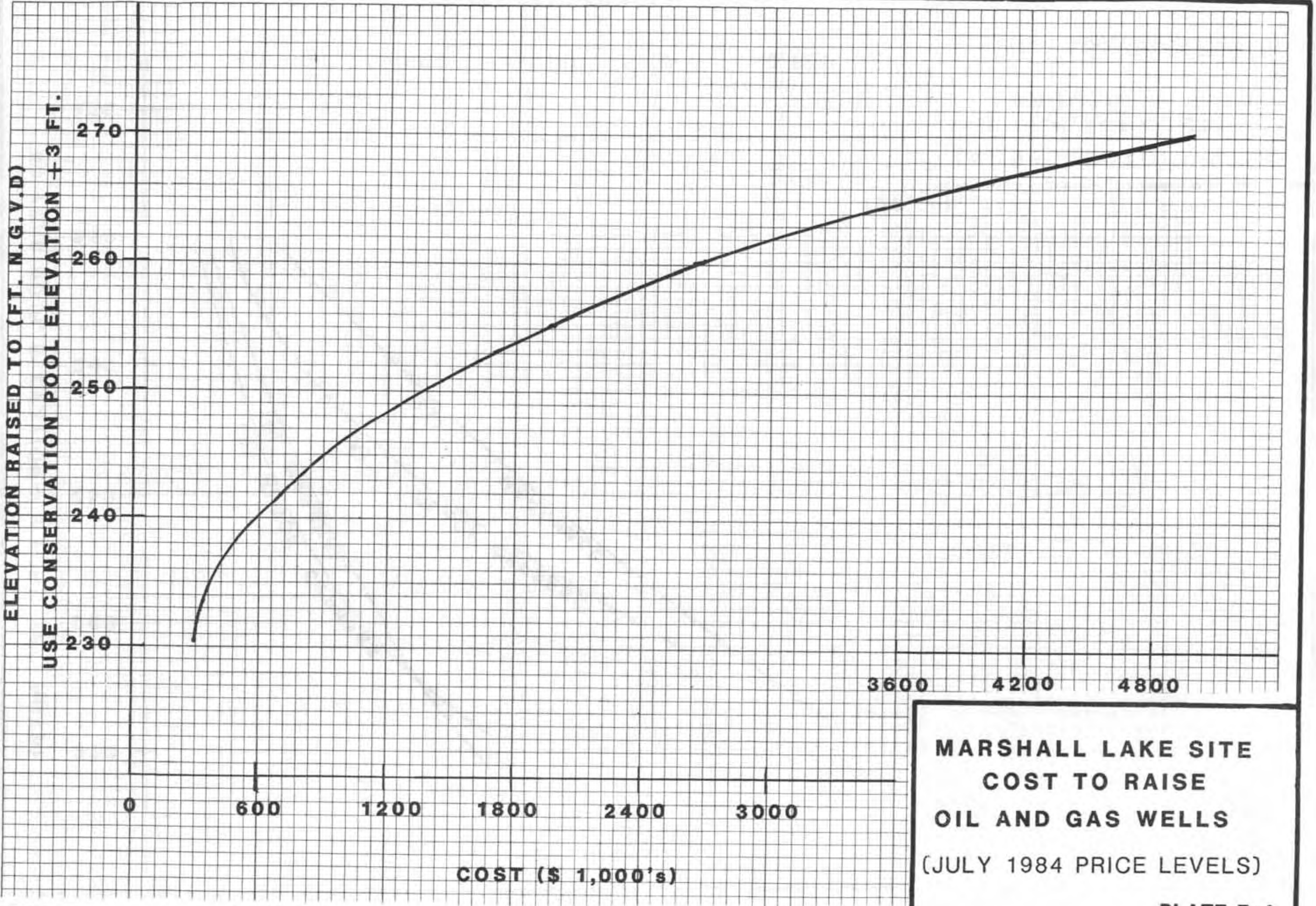


(A) RELOCATION COST

(B) REPLACEMENTS ABOVE IN - KIND

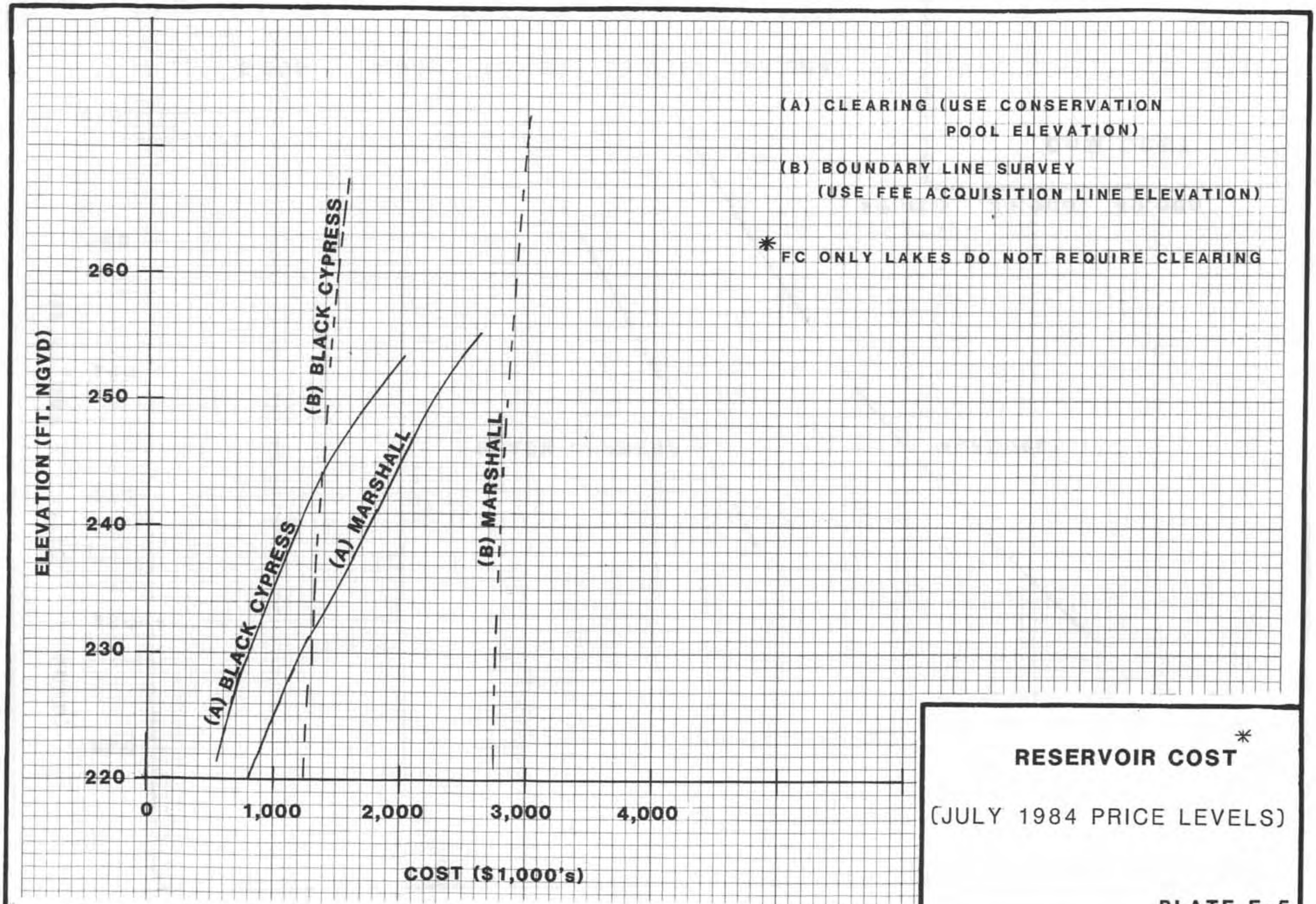
(JULY 1984 PRICE LEVELS)

PLATE E-3



MARSHALL LAKE SITE
COST TO RAISE
OIL AND GAS WELLS
(JULY 1984 PRICE LEVELS)

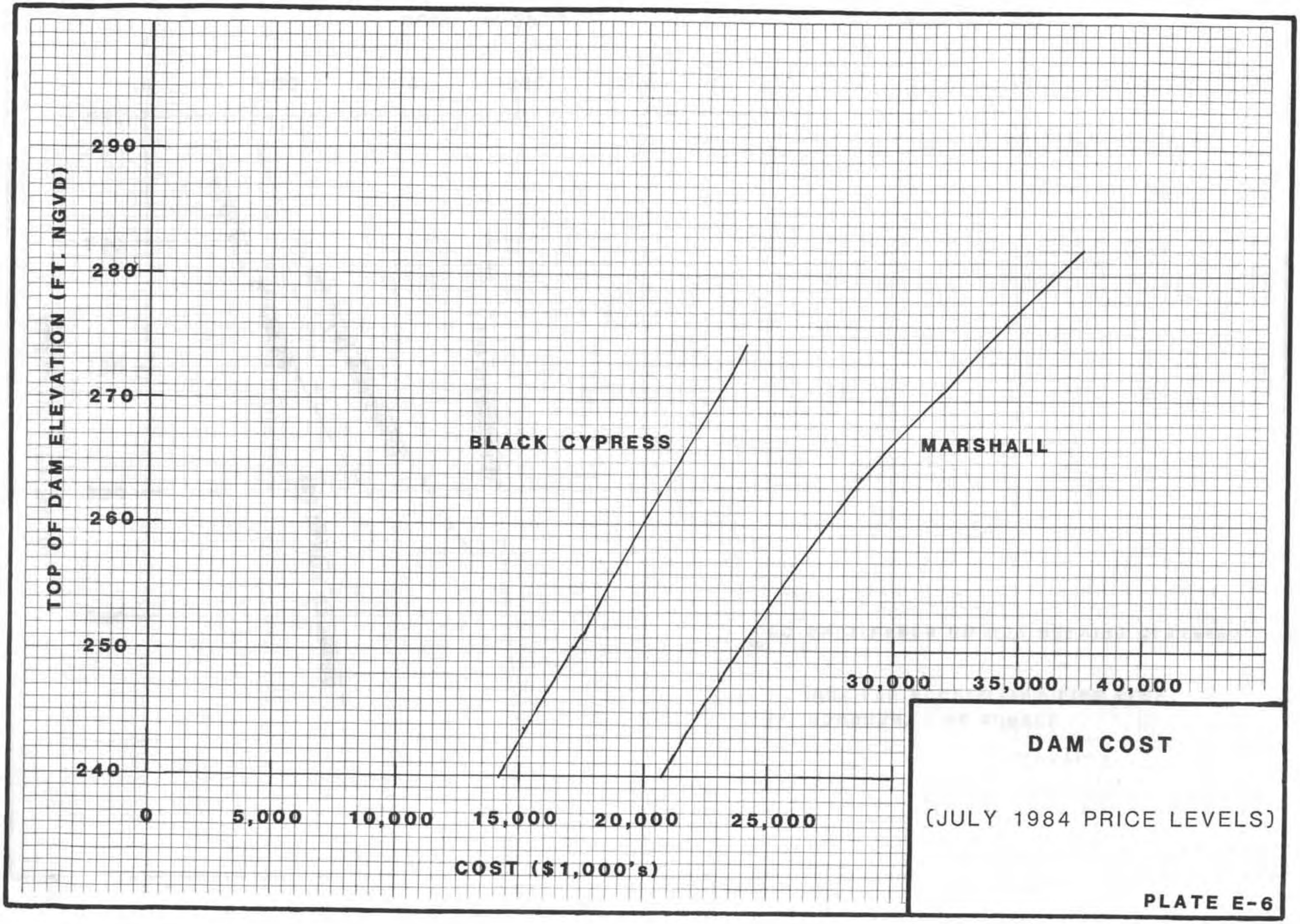
PLATE E-4



RESERVOIR COST*

(JULY 1984 PRICE LEVELS)

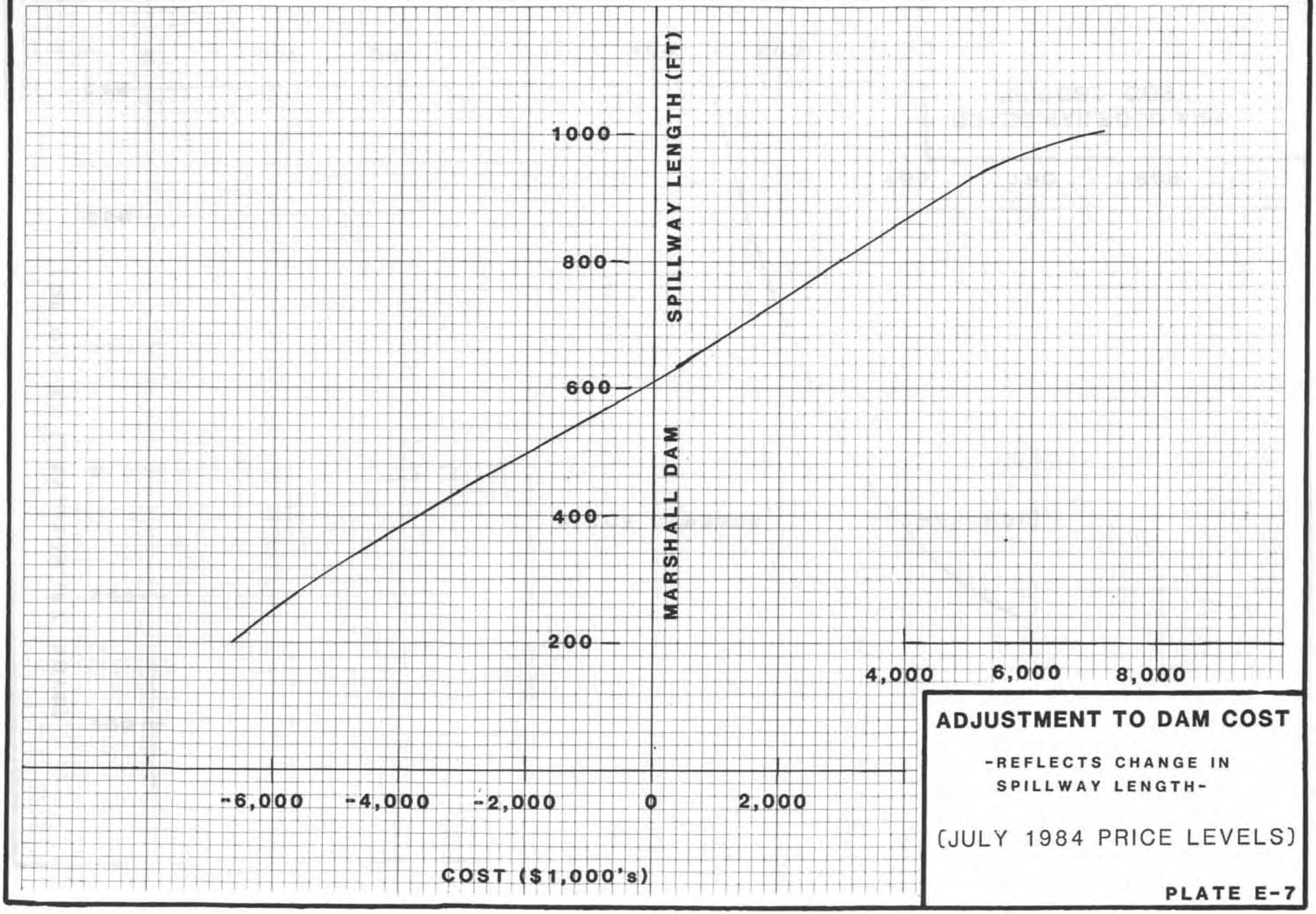
PLATE E-5



DAM COST

(JULY 1984 PRICE LEVELS)

PLATE E-6

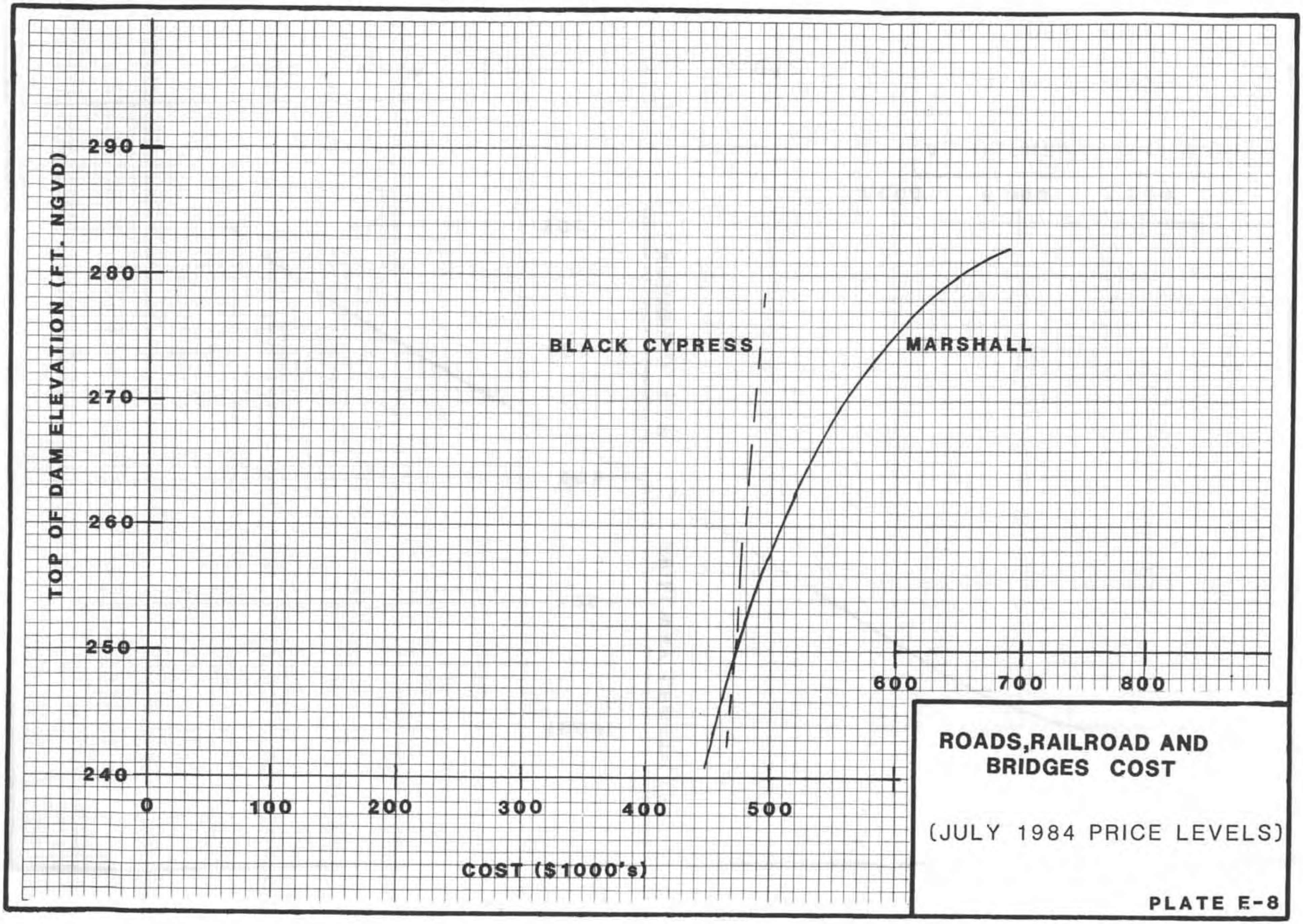


ADJUSTMENT TO DAM COST

-REFLECTS CHANGE IN
SPILLWAY LENGTH-

(JULY 1984 PRICE LEVELS)

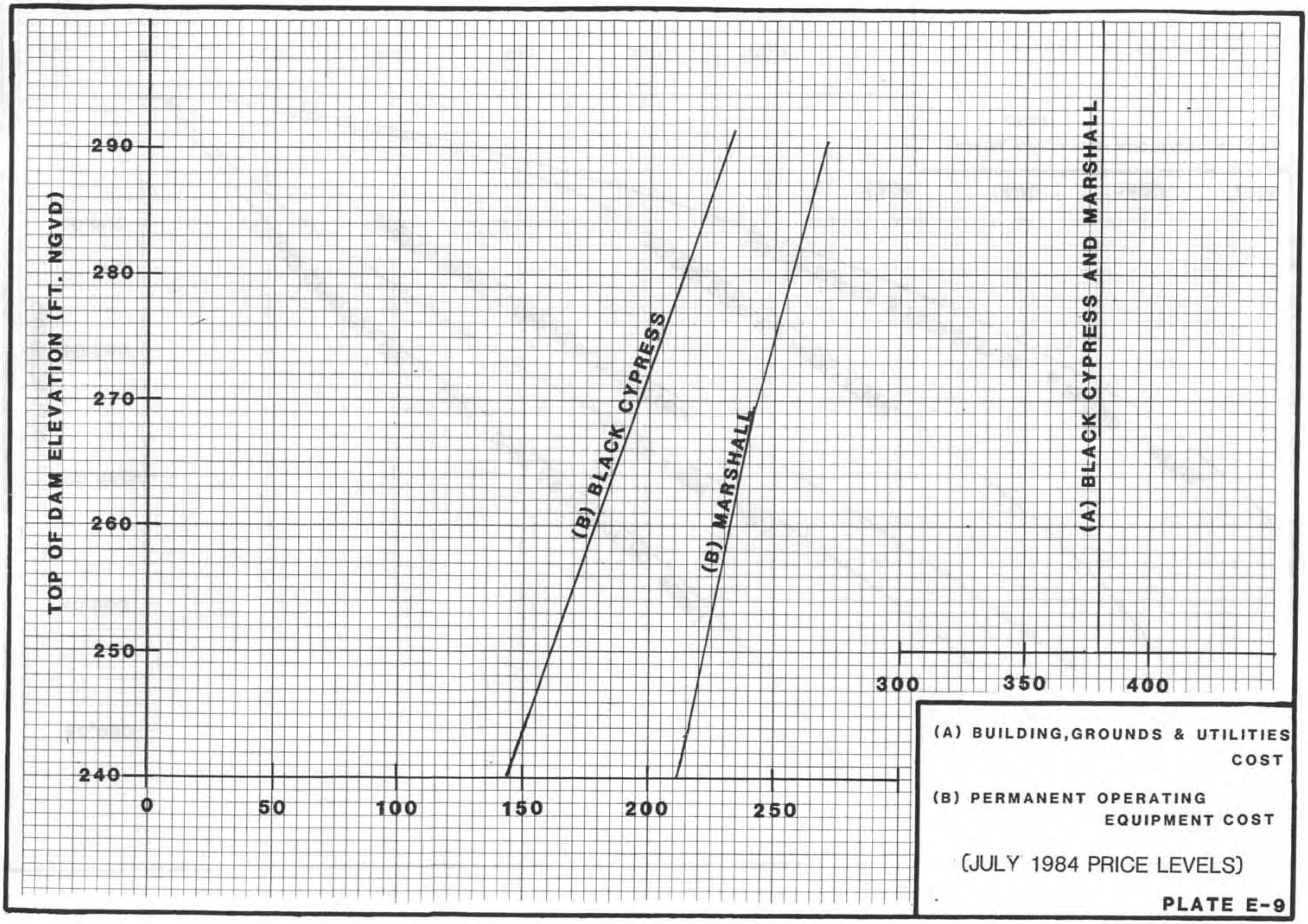
PLATE E-7



ROADS,RAILROAD AND BRIDGES COST

(JULY 1984 PRICE LEVELS)

PLATE E-8

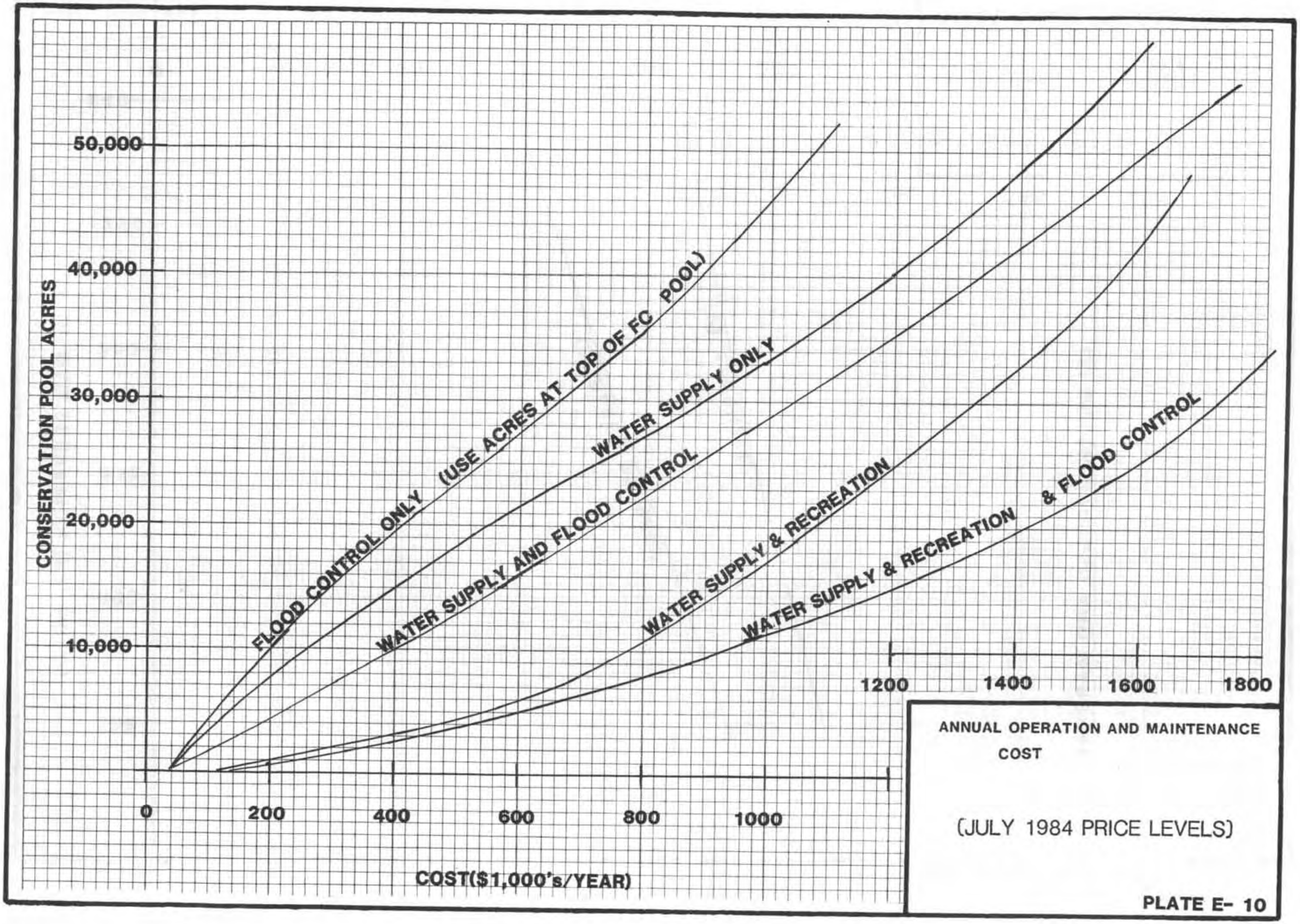


(A) BUILDING, GROUNDS & UTILITIES COST

(B) PERMANENT OPERATING EQUIPMENT COST

(JULY 1984 PRICE LEVELS)

PLATE E-9



ANNUAL OPERATION AND MAINTENANCE COST

(JULY 1984 PRICE LEVELS)

PLATE E- 10

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX F - GEOLOGY AND SOILS DESIGN

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX F - GEOLOGY AND SOILS DESIGN

CYPRESS BAYOU BASIN STUDY

APPENDIX F

GEOLOGY AND SOILS DESIGN

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CYPRESS BAYOU BASIN STUDY

APPENDIX F

GEOLOGY AND SOILS DESIGN

CHAPTER 1 - GEOLOGY

GENERAL

The Marshall damsite on Little Cypress Bayou is situated 8 miles northwest of the city of Mashall. The floodplain is about 4,500 feet wide at the axis of the proposed dam (see Figure F-1). The abutments rise abruptly from an elevation of 200 feet at the floodplain to about 325 at the top of the abutments. The outlet works and embankment spillway would be located on the right side of the valley. The spillway crest would be at elevation 233.1 N.G.V.D. The top of dam would be elevation 256.5 and the maximum water surface would be elevation 252.0. The dam would be approximately 7,000 feet in length.

PREVIOUS INVESTIGATIONS

Subsurface information at the Marshall damsite is derived from five borings (locations are shown on Figure F-1). Hole 1-MD was drilled by the New Orleans District (NOD), Corps of Engineers, in 1967. This hole is situated approximately 1/4 mile downstream from the asis on the right abutment. Holes M-1 and M-2 were drilled near the toe, and on top, respectively, of the left or northeastern abutment. These two holes were drilled by the Texas Highway Department.

Data obtained from these three holes are described in Technical Report No. 3-798, "Geological Reconnaissance of the Sulphur River and Cypress Creek Basins, Texas" by R. T. Saucier, sponsored by U.S. Army Engineer District, New Orleans, conducted by U.S. Army Engineer Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi, November 1967.

In 1980 the U.S. Bureau of Mines conducted a lignite study of the Marshall damsite for the U.S. Army Corps of Engineers and the Texas Department of Water Resources. Hole M-9 was situated 2,800 feet southeast and upstream from Texas Highway Department hole M-2. Bureau of Mines hole M-1 was situated on the right abutment side of the dam, approximately 6,000 feet upstream from the axis. Both holes were drilled to a depth of 300 feet. No samples were taken for lithologic analysis. Holes were fishtailed and electric logged to obtain lignite seam intercepts.

STRUCTURE

The damsite is situated on the northwestern flank of the Sabine Uplift. The formations in the area dip to the northwest at about 15 feet per mile. No faulting is known at the site, but because of the tectonic history of the area, some faulting may exist. The closest known faulting is approximately 5 miles downstream. Correlation based on drilling by the Texas Highway Department and NOD was not conclusive. The presence of an abnormally thick sandy zone, tentatively identified as part of the Queen City Formation, on the northeast (left) abutment suggests two possibilities: The northeast abutment may be capped by an unmapped river terrace remnant, or the northeast abutment may be downs faulted relative to the southwest (right) abutment. Correlation of the uppermost lignite seam in lignite exploration homes M-9 on the left abutment and M-1 on the right abutment, also suggests that the left abutment may be down faulted. Total displacement idicated is 70 to 80 feet. This correlation, however, is also considered to be inconclusive since Wilcox Group lignite in this northeastern part of Texas is noted for its variable seam thickness and seam discontinuity. In the absence of information which would prove or disprove whether faulting exists, the preliminary interpretation of the normal stratigraphic sequence is shown on Figure 1 with no inferred faulting.

STRATIGRAPHY

Based on results of a drilling program by NOD in 1967, and others, the formation capping the abutments was tentatively identified as the Queen City Sand, which ranges from about 20 to 60 feet in thickness. Strata identified as the Queen City Sand, which ranges from about 20 to 60 feet in thickness. Strata identified as the Reklaw Formation underlie the Queen City. The Reklaw beds are approximately 80 feet thick and are unconformably underlain by the Wilcox Formation. The Carrizo Formation, which normally occurs between the Reklaw Formation and the Wilfox Group, is missing in this region.

The Queen City Formation consists of cross-bedded fine to very fine sands with scattered lenticular silty and sandy clay layers. The thickness in northeast Texas varies from 100 to 400 feet.

The Reklaw Formation is composed of hard brown laminated glauconitic clays with lesser amounts of glauconitic sand, lignitic clay, and concretionary ironstone. The thickness varies from 30 to 130 feet.

The Wilcox Group consists of silty and sandy clay with interbedded silts and sands. It contains numerous lenticular seams of lignite and lignite clay. The thickness varies from 500 to 1,000 feet.

No holes were drilled in the floodplain alluvium at the damsite. Extrapolations from holes drilled 2 miles downstream by the Texas Highway Department indicate a thickness of 20 to 25 feet and that the alluvium consist of loose, coarse, water-bearing sand with minor amounts of clay and gravel.

MINERAL RESOURCES

In the report by Bureau of Mines, "Evaluation of Lignite Resources at Proposed Black Cypress and Marshall Reservoir sites, Cass, Marion, Harrison, Gregg and Upshur Counties, Texas", May 1982, lignite resources that would be affected by construction of Marshall Dam consist of about 30 million tons of indicated reserves in an area of about 10 square miles immediately upstream from the damsite. This indication is based on three exploration holes with lignite seams correlated over a distance of 3 to 4 iles. Bureau of Mines recommends that additional drilling with maximum 1-mile spacing between drill sites would be required to delineate the reserves with any degree of accuracy. Based on present information, stripping ratios (cubic foot of overburden removed: cubic foot of lignite mined) would be in excess of 30:1, and it is not expected that the site would be considered an attractive prospect to mining companies.

It was reported in 1983 that some isolated blocks of land had been leased for lignite mining rights south of the floodplain between the damsite and Highway 454. In a lignite study completed in 1985 by East Texas Testing Lab., Inc., for Kindle, Stone, and Associates, Inc., Longview, Texas, no lignite leasing was reported in the Marshall project area west of the damsite.

Two oil and gas fields are situated on the left or northwest abutment. The Harleton, East gas field is depleted with no active wells at the end of 1984. The Gooch (Travis Peak, Pettit) oil and gas field has declined from a production of 639,932 M.C.F. gas, 15,039 barrels of liquid hydrocarbons, 526,180 M.C.F. of casinghead gas, and 94,944 barrels of 36.9 gravity crude oil in 1978 to 488,318 M.C.F. gas, 14,718 barrels of liquid hydrocarbons, 61,324 M.C.F. of casinghead gas; and 21,800 barrels of crude oil ranging from 36.9 to 40 gravity at the end of 1984. Five gas wells were active at the end of 1978; six gas wells were active at the end of 1984. Some of the active wells in the Gooch field are probably in, or immediately upstream from the dam construction area.

GROUND WATER

No water level measurements were taken in the five borings at the site. The floodplain contains several marshy areas and based on Texas Water Development Board Report 27, "Ground Water Resources of Harrison County, Texas, August 1966", indications are that the piezometric surface is at or above the floodplain elevation.

CONCLUSIONS

a. The indications are that a natural impervious clay blanket such as is frequently present in alluvial sequences, is missing or discontinuous in the project area. In addition, the upper Wilcox group which underlies the alluvium has a moderate horizontal permeability. Pressure relief wells or some other type of seepage control will probably be necessary.

b. East Texas Testing Laboratory, Inc., estimated that due to high mining costs, which are ascribed mainly to dewatering and stripping costs, the lignite affected by the construction of the project would cost about twice as much as lignite that can be obtained from adjacent counties or about 50 percent more than imported western coal.

c. Silty and sandy beds of the Queen City and Reklaw Formations on the northwest abutment may be sufficiently permeable to cause seepage problems.

d. There are indications of faulting between the abutments.

e. Additional drilling will be required to adequately determine subsurface conditions for design of the dam and appurtenant structures.

CYPRESS BAYOU BASIN STUDY

APPENDIX F

CHAPTER 2 - SOILS DESIGN

GENERAL

Typical embankment sections and details proposed for the Marshall damsite are presented on Plates F-2 and F-3. The sections are based on the known general geologic conditions at the site as revealed through a very limited number of borings within a few miles of the proposed embankment. These borings were conducted by the New Orleans District of the Corps of Engineers, the Texas State Department of Highways and Public Transportation, and by the Bureau of Mines. If authorization for further studies of the Marshall damsite is recommended, future investigations, including borings and testing along the proposed dam axis and in potential borrow areas will be required.

MATERIALS

For purposes of this study, it has been assumed that sufficient materials are economically available from required excavations and borrow to construct a multi-zoned embankment. No borrow explorations have been conducted to verify this assumption. Due to potentially high groundwater levels in the floodplain, borrow sources will probably have to be located in areas above the floodplain. Due to the location of the site and the previous nature of the materials which appear to be available, soil-cement should prove to be an economical means of slope protection. The vertical extent of soil-cement protection will be evaluated when pool frequency-duration curves are developed. Data available at this stage are insufficient to design protection to a greater extent than shown on Plate F-2.

STABILITY

The proposed embankment section has sufficient base width to provide for possible weak foundation strata. The construction of slurry trench cutoff, relief wells, internal filter blanket, proper base width, and impervious core together will provide adequate control of both through and under seepage. Further investigations would be necessary to determine if any of the aforementioned seepage control variables could be altered or deleted for optimum design.

OUTLET WORKS

The outlet works has been tentatively selected near the base of the right abutment. Further field studies would be required to determine the best foundation area for the structure. Embankment zoning allows suitable materials from required outlet works excavations to be incorporated in the embankment.

SPILLWAY

An uncontrolled spillway approximately 400 feet wide has been recommended for this project. The proposed spillway is to be incorporated in the embankment in the general vicinity of the right abutment. Special considerations such as seepage characteristics and differential settlements will have to investigate during final design stages.

CONSTRUCTION MATERIALS

Commercial sources that produce acceptable quality and grading stone for use as concrete coarse and fine aggregate, riprap, bedding, and filter materials are available within an econmomical haul distance of this project.

1. Eagleton. - Anderson-Dunham, Inc., PO Box 848, Broken Bow, OK, produces natural sand and gravel from a pit at Eagletown, OK.

2. DeQueen. - HMB Construction Co., P.O. Box 5606, Texarkana, TX, produces riprap from a quarry 9 miles east of DeQueen, Arkansas.

3. Little River. - Gifford-Hill, Inc., P.O. Box 9, Ashdown, Arkansas, produces natural sand and gravel from a pit at Wilton, Arkansas.

4. Coleman. - Dolese Brothers, P.O. Box 677, Oklahoma City, OK, produces from a quarry 1 mile south of Coleman, TX.

CORPS OF ENGINEERS U.S. ARMY

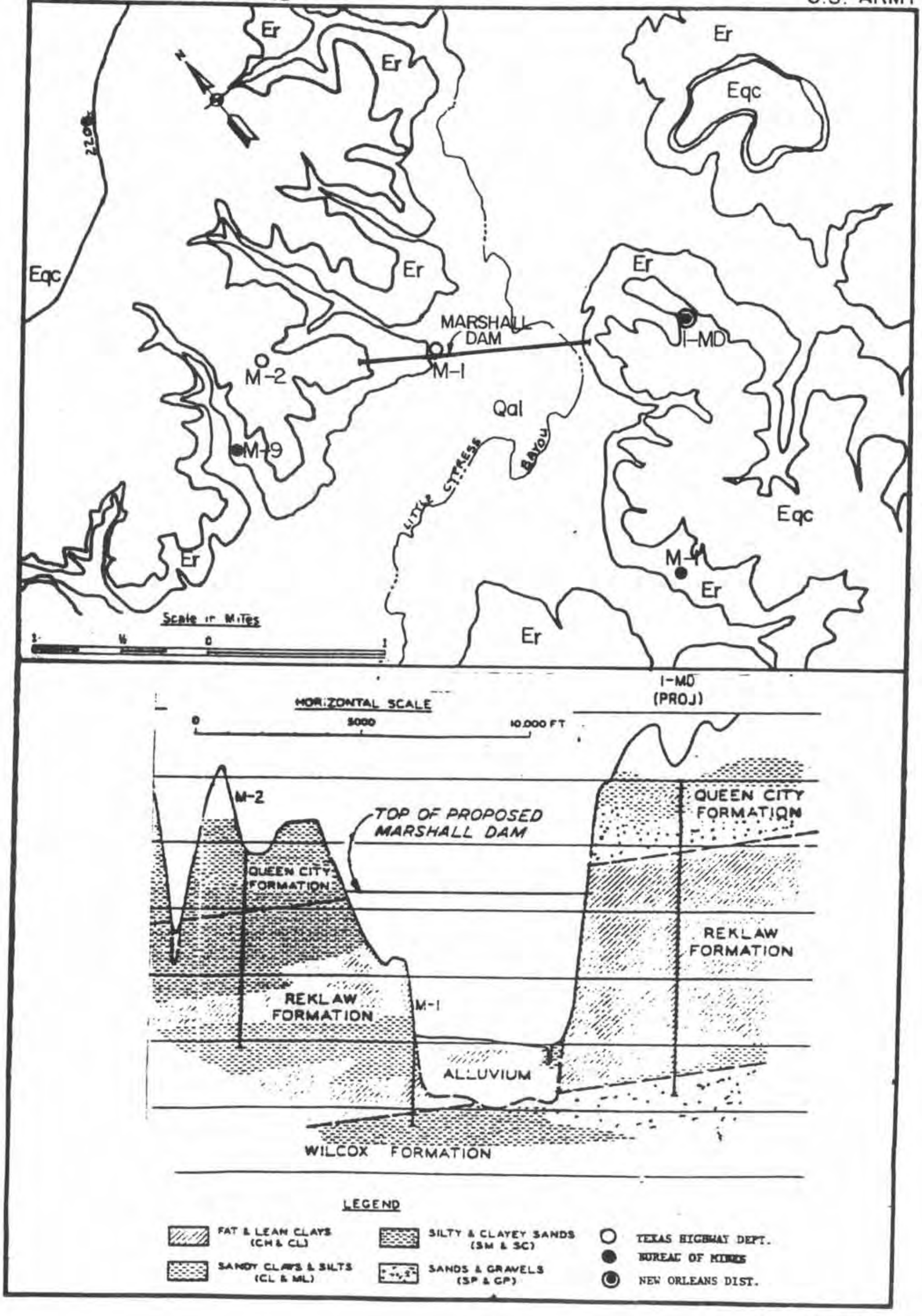
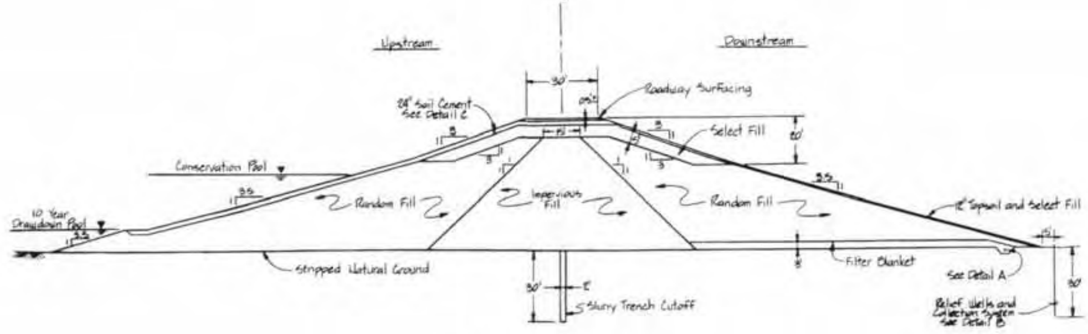
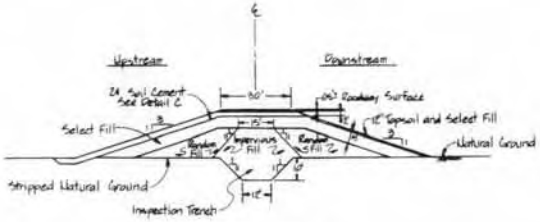


PLATE F-1



FLOODPLAIN EMBANKMENT SECTION



ABUTMENT SECTION

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

MARSHALL DAM
LITTLE CYPRESS CREEK, TEXAS

TYPICAL EMBANKMENT SECTIONS
(FEASIBILITY STUDY STAGE)

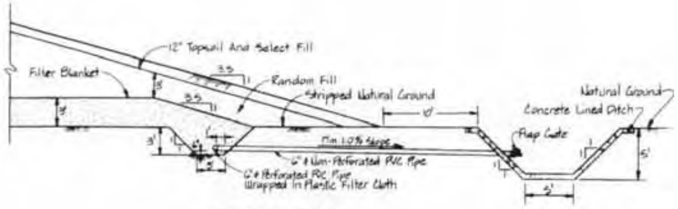
E. GRUNWALD
T. SCHMIDT

K. MILLER

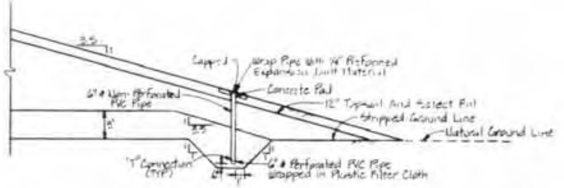
T. SCHMIDT

H.E. KARBS

PLATE [illegible]-2



PROFILE AT LATERAL

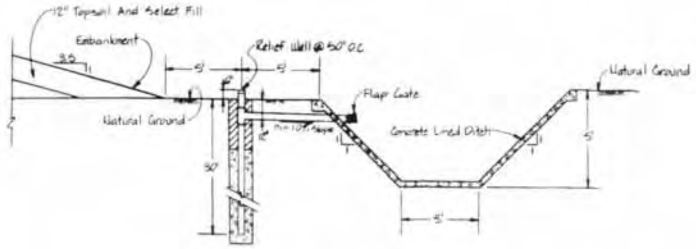


PROFILE AT RISER

DRAINAGE COLLECTOR SYSTEM DETAIL

5 0 5 10
Scale In Feet

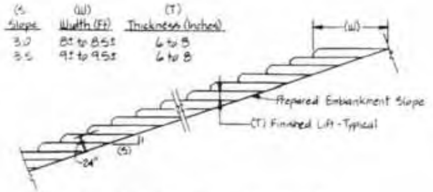
DETAIL A



RELIEF WELL DETAIL

3 0 3 6
Scale In Feet

DETAIL B



(S) Slope	(W) Width (Ft)	(T) Thickness (Inches)
3.0	8± to 8.5±	6 to 8
3.5	9± to 9.5±	6 to 8

SLOPE PROTECTION DETAIL - SOIL CEMENT

N.T.S.

DETAIL C

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

DESIGNED BY: R. GRISHAM / T. SCHMIDT
DRAWN BY: K. MILLER
REVIEWED BY: T. SCHMIDT
SUBMITTED BY: H.E. KARBS

MARSHALL DAM
LITTLE CYPRESS CREEK, TEXAS

EMBANKMENT DETAILS
(FEASIBILITY STUDY STAGE)

SOL. NO.
DATED 5 MAR 90

PLATE F-3

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX G - WATER QUALITY ANALYSIS

Alan Plummer and Associates, Inc.
ENVIRONMENTAL · CIVIL ENGINEERS

316-0303/2

May 13, 1986

Michael J. Mocek, P.E.
Chief, Planning Division
Fort Worth District
U.S. Army Corps of Engineers
P.O. Box 17300
Fort Worth, Texas 76102-0300

Dear Mr. Mocek:

We are pleased to submit to you the final report Water Quality Analysis and Projections, Cypress Bayou Basin, Marshall Damsite. We have incorporated the revisions recommended in your letter accompanying the reviewed draft. Several technical comments in the reviewed draft were not addressed in the final report. The first concerned nutrient data from point sources. Currently the only data reported by point source dischargers to the Texas Water Commission are BOD and TSS, so we are unable to present point source nutrient loadings. The second comment asked if we could address the issue of PCBs in the bottom material with reference to studies of Caddo Lake. We were unable to find any published studies of PCBs in Caddo Lake, and feel without specific data from Little Cypress Creek sediments on the ability of the PCBs to be elutriated, we could not be more specific on the fate of the pollutant.

Additional comments reflected issues concerning the treatability of the water for municipal use and its safety with respect to swimming. We feel that the lake water will be adequately treated by the standard coagulation/filtration methods currently required for surface water and no color, iron, manganese and pH problems would be present. We also feel that the quality of the lake would present no problems of visibility, temperature or pH for swimmers.

We appreciate the opportunity to work with you on this project. If you have any questions, please call me.

Very truly yours,

ALAN PLUMMER AND ASSOCIATES, INC.

Richard H. Smith

Richard H. Smith, P.E.

RHS:gh
Enclosure

841 W. Mitchell • Arlington, Texas 76013-2506 • (817) 461-1491

Fort Worth District
U.S. Army Corps of Engineers

WATER QUALITY ANALYSIS AND PROJECTIONS, CYPRESS BAYOU BASIN, MARSHALL DAMSITE

FINAL REPORT
MAY 1986

Alan Plummer and Associates, Inc.
ARLINGTON, TEXAS

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CHAPTER 1

EXECUTIVE SUMMARY

INTRODUCTION

Little Cypress Creek is an undeveloped tributary of the Red River. Located in northeast Texas, its 750 square mile basin is primarily agriculture and forestland and has a very small urban population. The proposed lake at Marshall damsite would be located at River Mile 21.3 on Little Cypress Bayou, about 9 miles northwest of the city of Marshall. Both the U.S. Army Corps of Engineers and the Little Cypress Creek Utility District are considering construction of the Little Cypress project at the Marshall damsite. The basin receives over 45 inches of rainfall annually, and yields almost a quarter of that as streamflow. Water quality is generally very good in Little Cypress Creek. Some low dissolved oxygen values have been measured, and may be due to low reaeration rates of the slow-moving creek. Water quality has been periodically measured 10 miles below the proposed Marshall damsite and that data is used as the basis for evaluation of the impact of the lake on water quality.

EXISTING WATER QUALITY

The quality of the water in Little Cypress Creek is very good. It is low in total dissolved solids, averaging 120 milligrams per liter (mg/l), and all concentrations are below the Texas Department of Health's drinking water standards. Most metals are found in very low concentrations. Iron and manganese are found in higher concentrations than the other metals as a result of the geology of the basin. Man-made organic compounds are seldom found in the water column. Only the herbicides 2,4,5-T and 2,4-D have been found more than once in measurable levels. The analyses of bottom sediments do show measurable levels of many man-made organic compounds. Average concentrations of the water quality parameters are shown in Table I-1.

TABLE I-1

AVERAGE CONCENTRATIONS OF THE WATER QUALITY

Parameters measured by the U.S. Geological Survey at Little Cypress Creek near Jefferson for the water years 1968 through 1984.

Parameter	Number of samples	Concentration mg/1	Parameter	Number of samples	Concentration mg/1
Calcium	164	7.5	Dissolved Aluminum	24	101
Magnesium	164	2.8	Dissolved Arsenic	44	.43
Sodium	135	25.0	Dissolved Barium	24	113
Potassium	116	3.7	Dissolved Cadmium	33	1.4
Bicarbonate	164	16.6	Dissolved Chromium	40	1.9
Sulfate	164	19.1	Dissolved Cobalt	24	0.25
Chloride	128	38.8	Dissolved Copper	42	2.7
Fluoride	112	0.1	Dissolved Iron	48	666
Silica	126	16.4	Dissolved Lead	43	5
TDS	128	120	Dissolved Lithium	24	10
TSS	80	23	Dissolved Manganese	48	304
VSS	79	7.2	Dissolved Mercury	41	0.16
DO	85	7.3	Dissolved Nickel	24	3.5
BOD_5	86	1.6	Dissolved Selenium	19	0.05
Nitrate-N	79	.15	Dissolved Silver	19	0.05
Nitrite-N	73	.007	Dissolved Strontium	24	227
Ammmonia-N	82	.07	Dissolved Zinc	48	41
Organic Nitrogen-N	79	.60	Total 2,4-D	31	.002
Total Phosphorus	85	.10	Total 2,4,5-T	31	0.15
Organic Carbon	63	9.1			

The potential loadings from urban, forest, and agricultural nonpoint sources were calculated, and records of the permitted point source dischargers were summarized. Comparing the observed concentrations to the calculated loadings indicated that point sources, forest nonpoint sources and urban nonpoint sources contributed little to the basin loading. Forest nonpoint sources did, however, contribute 37 percent of the suspended sediment to the basin. Nonpoint source loading from agriculture contributed a very large percent of the loading. Most of the nutrients may be attributed to the agricultural nonpoint source loading.

PROJECTED QUALITY

Land use in Little Cypress Creek Basin will probably not change dramatically in the future. Population of the Basin is expected to increase by 77 percent by 2050, but this will only represent less than 1 percent of the total land area. Even if point source loading doubled, it would represent a very small percentage of the current basin loading. Forestland has been constant over the last 20 years, varying about 2 percent. Forest and agricultural land will likely remain in the ratio as is currently seen, roughly half the Basin's total acreage in each.

When the lake is built, it will occupy what now is bottomland forest, so the nonpoint source loading from agriculture will be about the same. The lake will probably be stratified starting in March and lasting through October. This stratification, preventing a mixing of the surface layer (epilimnion) with the bottom layer (hypolimnion), will lead to low dissolved oxygen in the hypolimnion. The size of the conservation pool will determine how rapidly the hypolimnion oxygen is depleted. The larger the pool, the longer it would take to deplete the oxygen.

The lake will probably be eutrophic, although the size of the conservation pool may influence the trophic state. The Vollenweider relationship indicates the lake will be eutrophic for all conservation pool sizes. Using critical boundary conditions of total phosphorus loading indicates that a conservation pool of 700,000 acre feet, the largest pool contemplated, may be mesotrophic rather than eutrophic. Chlorophyll 'a' concentrations calculated for the lake indicated the concentration may be from 7 to 10 micrograms per liter. Lake O' the Pines is an existing reservoir on Big Cypress Bayou located just north of the proposed Marshall damsite. Although the pollutant loading is greater at Lake O' the Pines, its quality should compare with the proposed lake since it is similar in size, shape, climatic and geologic influences. A comparison of the quality in Lake O' the Pines to 102 other reservoirs in Texas indicated it was twentieth, indicating it was low in productivity for Texas, and would probably not be troubled by higher than average algal populations.

Simulating the dissolved oxygen in the river for future condition without the lake indicated that point sources, even during times of very low flow, had little effect on the overall dissolved oxygen level. The main factor in the dissolved oxygen is probably algae in the stream, a product of nutrient loading. With the lake, the dissolved oxygen below the reservoir may improve current conditions. The algae in the lake will probably produce a lower BOD loading than is currently observed. Manipulation of the releases may improve the dissolved oxygen below the dam. If releases could be made from the epilimnion, the source water would be high in dissolved oxygen. By keeping a constant low flow release, the stream would always be flowing. Currently there are many days each year with no flow, resulting in very low reaeration and little mixing.

CONCLUSIONS

The high quality of water in Little Cypress Creek will probably be maintained in the future. Growth in the basin should be monitored to assure a high quality water in the creek. A lake at Marshall damsite would provide a source of water suitable for all municipal and industrial uses. Although the lake would be classified eutrophic, high dissolved oxygen levels would probably be maintained in the epilimnion, as observed at Lake O' the Pines. Comparing quality of Lake O' the Pines to other reservoirs in Texas indicates the quality is better than most of the others. Marshall Lake will receive a lower BOD and nutrient input, so quality may be slightly better than Lake O' the Pines. The dissolved oxygen analysis indicates that the larger the conservation pool, the better the quality in the reservoir. Choice of the depth of the outlet works and release pattern will be important to the quality of the stream below the dam. By building an outlet works with variable intake depths, water could always be released from the epilimnion, which is higher in dissolved oxygen. Quality of the creek below the reservoir may be improved by maintaining flow year-round.

CHAPTER II

BASIN CHARACTERISTICS

INTRODUCTION

Little Cypress Creek Basin is a small, unregulated, tributary of the Red River located in northeast Texas. It has a drainage area of about 750 square miles, and flows easterly from Wood Country into Cypress Creek just upstream of Caddo Lake. It is predominantly rural, with forests and agriculture as the major land uses. Oil and gas were discovered in the early twentieth century in the Basin and have been fully developed. Lignite deposits in the area have recently been tapped, and may be further developed in the near future. The Basin receives an average of over 45 inches of rainfall annually, and almost 25 percent of it is seen as streamflow(16).

MONITORING STATIONS

Water quality is monitored by the U.S. Geological Survey (USGS) on a routine basis at one station just below the proposed Marshall damsite at Little Cypress Creek near Jefferson. Data on a wide range of parameters have been collected at the site, including major constituents, nutrients, metals, pesticides and sediment pesticides. Some water quality data have also been collected by the USGS at Little Cypress Creek near Ore City and Moccasin Creek near Harleton, but not on a routine basis. Flow is monitored at the Ore City and Jefferson stations. Locations of these stations and other stations on the Cypress Creek (adjacent to Little Cypress) are shown in Figure II-1. Average values of parameters measured at these stations are shown in Table II-1.

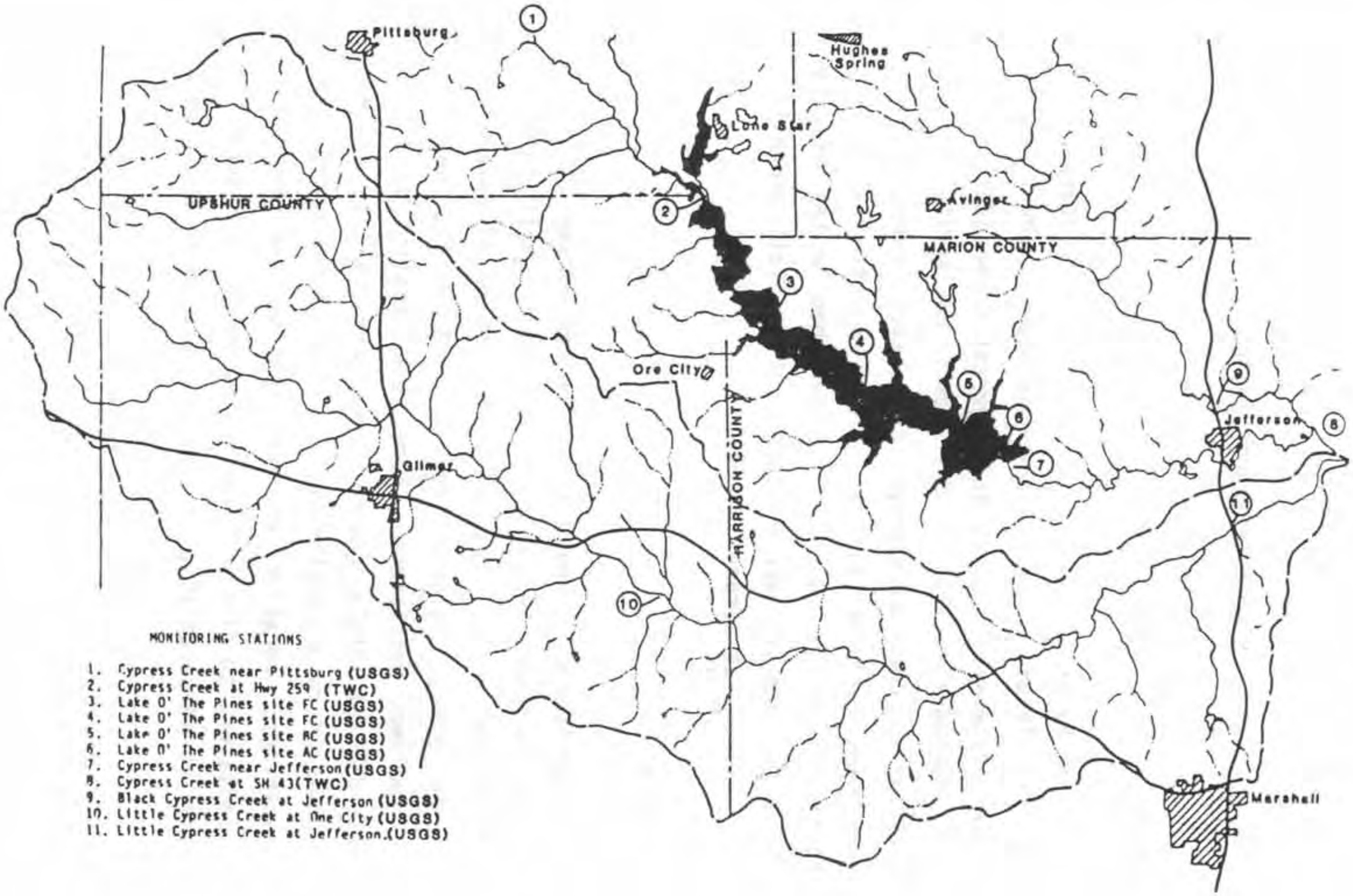


FIGURE II-1

MONITORING STATIONS IN THE CYPRESS CREEK BASIN

TABLE II-1. AVERAGE VALUES OF WATER QUALITY PARAMETERS FROM THE CYPRESS CREEK BASIN.
DATA IS FROM THE 1980 THROUGH THE 1984 WATER YEARS.

STATION NAME & NUMBER	DATA SOURCE	TURBIDITY NTU	DO mg/1	ALKALINITY mg/1 CaCO	TSS mg/1	VSS mg/1	NH3-N mg/1	NO3-N mg/1	TP-P mg/1	TDS mg/1	FC #/100 ml	CH 'a' ug/1	IRON ug/1
BIG CYPRESS CREEK NEAR PITTSBURG 7344500	USGS	19	6.8	47	31	10	1.2	1.6	0.8	198	-	9	78
BIG CYPRESS CREEK AT HWY 259 0404.0020	TWC	23	7.2	39	32	24	0.18	0.45	0.18	130	1160	15	-
LAKE O' THE PINES, SITE FC 07345900	USGS	-	7.7	25	-	-	0.28	0.09	0.07	118	13	-	220
LAKE O' THE PINES, SITE EC 07345900	USGS	-	8.1	17	-	-	-	0.03	0.03	90	2	-	645
LAKE O' THE PINES, SITE BC 07345900	USGS	-	8.3	17	-	-	-	0.05	0.04	-	-	-	703
LAKE O' THE PINES, SITE AC 07345900	USGS	3.5	9.5	16	-	-	0.08	0.04	0.03	86	9	7	428
BIG CYPRESS CREEK NEAR JEFFERSON 07346000	USGS	3	8.8	13	6	6	0.1	0	0.02	89	-	-	60
CYPRESS CREEK AT SH 43 0402.0100	TWC	22	7.7	14	9	6	0.11	0.28	0.07	68	46	8	-
BLACK CYPRESS CR. AT JEFFERSON 07346045	USGS	36	7.2	12	14	5	0.09	0.19	0.09	51	-	9	-
LITTLE CYPRESS CR AT JEFFERSON 07346070	USGS	18	7.3	13	23	7	0.07	0.15	0.1	120	-	-	666

Lake O'the Pines is a reservoir of similar size and depth as the proposed lake at Marshall damsite. It receives a larger pollution load than the proposed lake will but is useful for comparison because climate and geologic influences will be the same as the proposed lake. The data for Cypress Creek in Table II-1 show how Lake O' the Pines influences water quality. Tributary flow into Cypress Creek includes wastewater flow from Mount Pleasant and Pittsburg. Observations made in 1983 of Tankersley Creek and Hart Creek (both below Mount Pleasant) as well as Dry Creek and Sparks Creek (both below Pittsburg) showed low dissolved oxygen (less than 5.0 mg/l) in their lower reaches. The average water quality at Cypress Creek near Pittsburg, compared to the overall water quality of Cypress Creek, is high for nutrients and solids, and low for dissolved oxygen. Cypress Creek at Highway 259 is at the upper end of Lake O' the Pines. During dry periods it flows as a river, and during wet periods it is inundated by the lake. Nutrient levels are lower and dissolved oxygen higher than near Pittsburg. The Lake O' the Pines' Stations FC, EC, BC, and AC are in downstream order, with AC being near the dam. Nutrient levels and solids are greatly reduced, and dissolved oxygen levels are higher for the downstream stations. Settling has reduced some of the nutrients and solids, and aquatic life has also used some of the nutrients.

Cypress Creek near Jefferson, downstream from the dam, shows the lake has helped improve water quality. Nutrients and solids are low and dissolved oxygen high. Cypress Creek at State Highway 43 also shows the river maintains this high quality, and this station includes the contributions of Black Cypress and Little Cypress Creeks. Data from both Little Cypress and Black Cypress Creeks show high quality water with low nutrient levels compared to Cypress Creek near Pittsburg.

EXISTING LAND USE

Land use in the Little Cypress Creek Basin is almost evenly divided between forests and agriculture, with 48 percent of the Basin as forest and 52 percent of the Basin as agriculture (13). Urban areas represent about 0.3 percent of the total basin area. Figure II-2 presents a map of the Basin's land use. Agriculture is predominantly livestock, with some vegetable and orchard production but little row-crop farming. The soil is severely erosive.

Forests range from upland hardwoods as the dominate species in the western part of the Basin to pine in the eastern part. Forestland ownership is almost exclusively non-industry privately-owned tracts of 100 acres or less. Annually, about 3 percent of forest area is harvested in East Texas. Harvesting includes both clearcutting and harvesting with some trees remaining (1,19). The records of 1975 show 2 percent of the forested areas of the counties in the Basin to be clearcut, 26 percent to be seedlings and sapwood, 30 percent to be polewood and 42 percent to be sawlogs. Most site preparation after a clearcut is to mechanically cut all vegetation and then either chop it or windrow it and burn it. Clearcut areas are then usually replanted with a single species of trees to allow for even-age management.

Oil production began in the Basin in the early 1900s with the discovery of the East Texas Oil Field, one of the largest fields in the continental United States. Oil production has shown a decline in the area over the period 1970 to 1979 (20). Lignite reserves are under all the Basin's area. Currently, only three mines are in operation in the area, and one more is proposed (11). Figure II-3 shows the locations of the oil and gas fields in the Basin area, and lignite deposits and mining operations.

Only two urban areas exist in the Basin, Gilmer and north Marshall. Gilmer has a population of about 5000 and is totally in the Basin. Marshall strattles the basin boundary with most of the city below the Basin. Marshall's population is near 25,000.

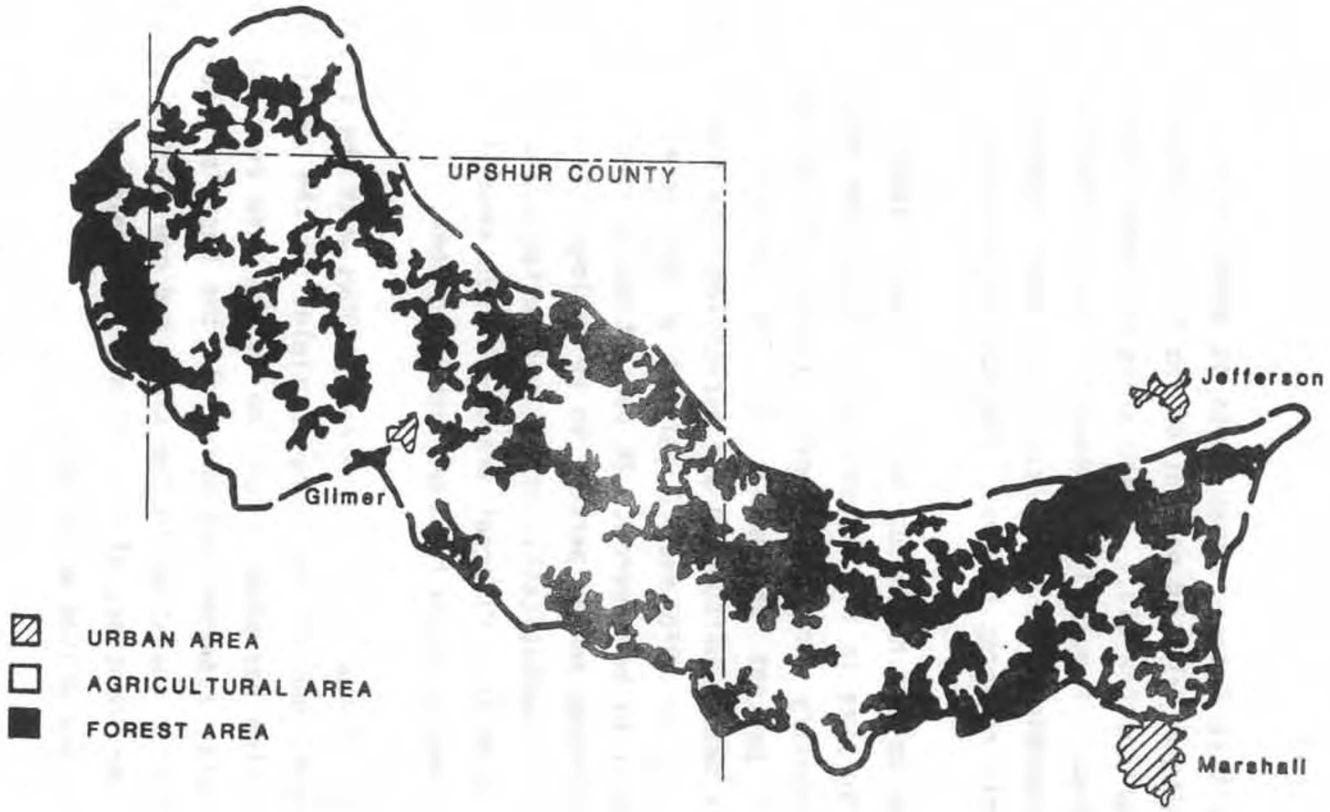


Figure II - 2

CURRENT LAND USE OF THE LITTLE CYPRESS CREEK BASIN
(FROM TEXAS DEPT OF WATER RESOURCES, 1977)

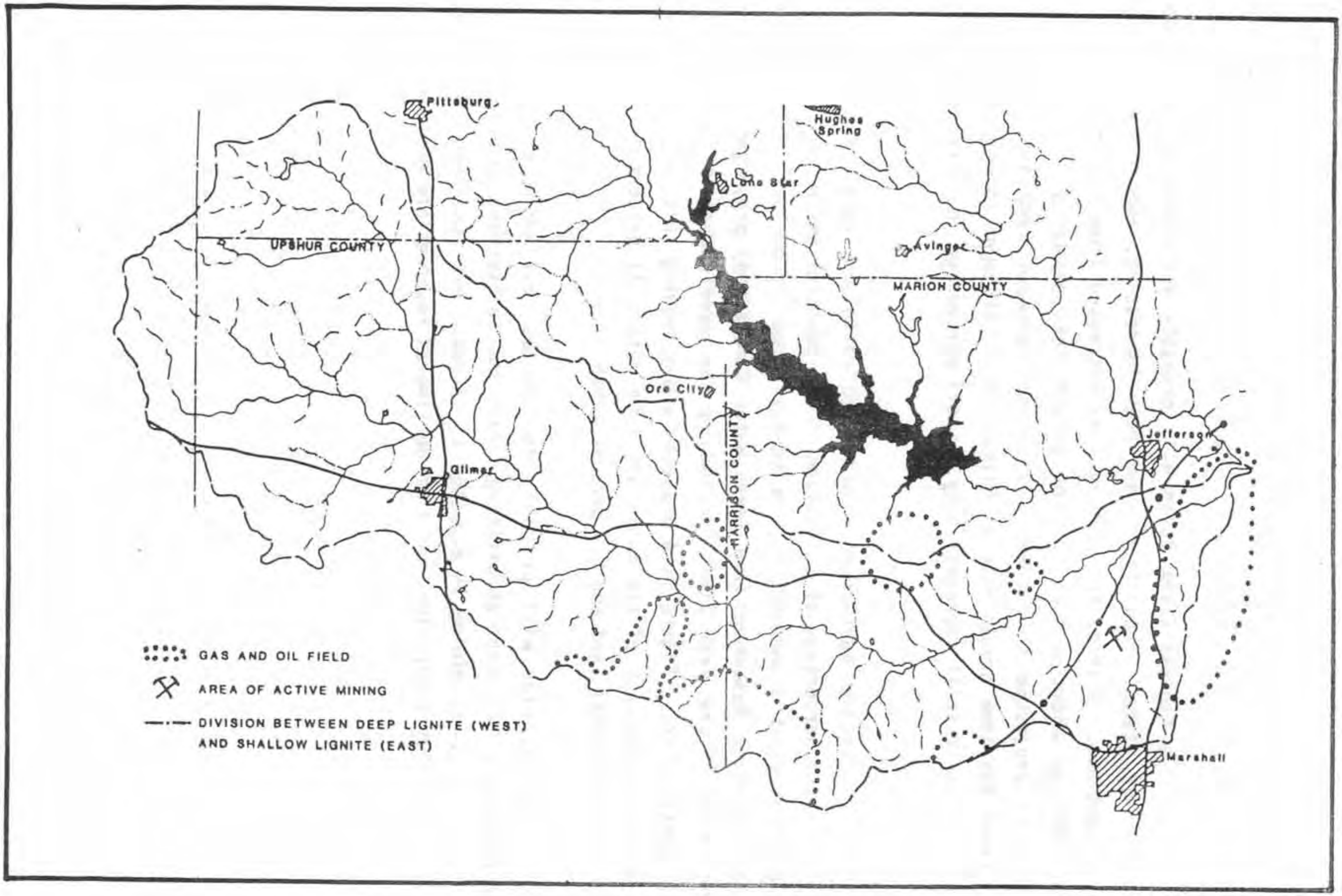


FIGURE II-3

MINING RESERVES, AND GAS AND OIL FIELDS IN THE CYPRESS BASIN

FUTURE LAND USE

Land use in Little Cypress Creek Basin will probably not dramatically change from its current state. Populations have been increasing, and this trend is likely to continue. Gilmer, for example, has increased from 4560 in 1965 to 5167 in 1980, or about a 0.85 percent growth rate annually. The area's population is projected to increase 77 percent between 1980 and 2050, or roughly about the same growth rate as Gilmer (20). Although this growth rate seems high, it will still represent only a small percentage in increased urban land area.

No major shifts in the agricultural/forestland ratio are expected. In the last 20 years the percentage of forestland in the counties making up the Basin has fluctuated about 2 percent and no steady trend is obvious. The Texas Department of Water Resources (now Texas Water Commission) projected land use for the Basin in the year 2000, including the development of a lake at Marshall Damsite (12). Figure II-4 presents a map showing this projected land use. Roughly 11 percent of the Basin would be water, 37 percent forestland, 51 percent agricultural land and 0.7 percent urban.

Gas and oil production will probably decline as reserves are depleted. Secondary recovery may occur at existing fields but no increase in development should occur. Lignite mining is expected to increase over the next 20 years, primarily for energy production, and then decline as reserves are depleted.

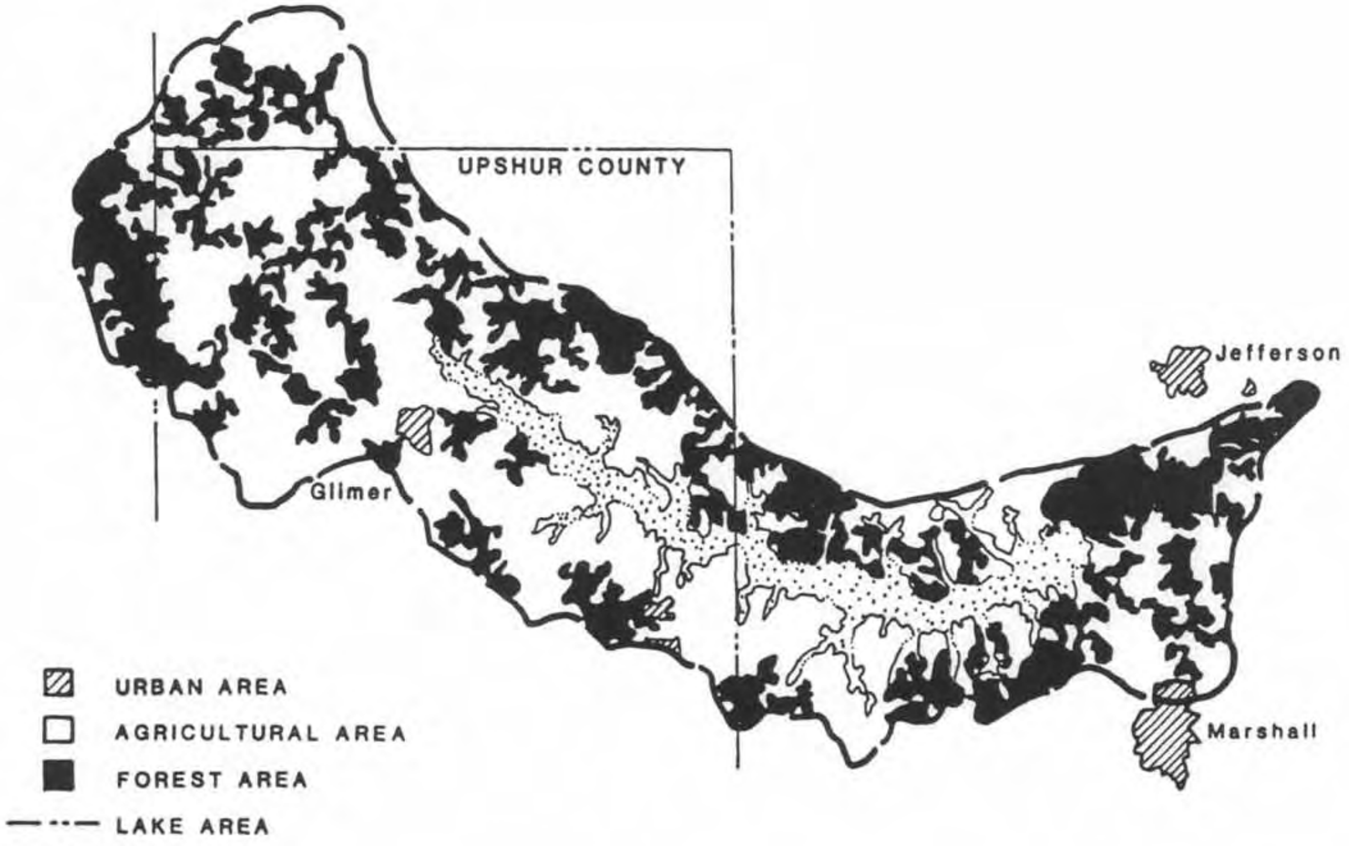


Figure II - 4

PROJECTED LAND USE FOR LITTLE CYPRESS CREEK BASIN IN THE YEAR 2000

CHAPTER III

EXISTING WATER QUALITY

INTRODUCTION

Water quality in the Little Cypress Creek Basin has been routinely monitored at the U.S. Geological Survey (USGS) Station 07346050, "Little Cypress Creek near Jefferson, Texas," beginning in the 1968 water year. Data collected by the USGS is used in this study to determine trends and changes in water quality and identify relationships between discharge and constituent concentration. Water quality parameters measured at the site are divided into four classes: major constituents, nutrients, metals, and organics. Major constituents include the major dissolved constituents, calcium, magnesium, sodium, potassium, chloride, sulfate, alkalinity and measurements of pH, color and turbidity. Nutrients include phosphorus, nitrogen, BOD, dissolved oxygen and organic carbon. Metals include all the heavy metals which are usually found at low concentrations, and organics include all man-made organic substances generally found in low concentrations.

MAJOR CONSTITUTENTS

The major constituents found in a water supply may be the limiting factor in the water's usefulness. The total dissolved solids (TDS) is a function of the geology of the basin and the inflows of water from man's activities. The geology of the Little Cypress Creek Basin is from the Eocene Age, composed mainly of sand, silt, clay lignite, and glauronite. With a high annual rainfall of about 45 inches a year, the surface soils have been well leached, so the TDS concentration is normally low, averaging about 120 mg/l. However, measurements of TDS have been as high as 460 mg/l. This may be due to oil field brines flowing into the creek, a problem that has been noted for some time (16). The average maximum and minimum concentrations of the major constituents are presented in Table III-1.

TABLE III-1

MAJOR CONSTITUENT CONCENTRATIONS OBSERVED AT STATION 07346050, LITTLE CYPRESS CREEK NEAR JEFFERSON, TEXAS WATER YEARS 1968 THROUGH 1984

Parameter	Number of Samples	Average	Minimum	Maximum
Specific conductance, micromhoms/cm	136	200	46	892
pH, standard units	128	6.25	5.3	7.4
Temperature, degrees Centigrade	132	17.6	2	32
Color, platinum-cobalt units	80	80	20	160
Turbidity, NTU	80	17.6	3	50
Calcium, mg/l	164	7.5	2.3	17
Magnesium, mg/l	164	2.8	.8	5.5
Sodium, mg/l	135	25.0	3	123
Potassium, mg/l	116	3.7	1.8	20
Bicarbonate, mg/l	164	16.6	0.0	98
Sulfate, mg/l	164	19.1	5	45
Chloride, mg/l	128	38.8	5.5	240
Fluoride, mg/l	112	0.1	0.0	0.6
Silica, mg/l	126	16.4	0.0	25
Total dissolved solids, mg/l	128	120	26	463
Total suspended solids, mg/l	80	23	1	122
Volatile suspended solids, mg/l	79	7.2	0	38

The volume of flow influences the concentration of many of the major constituents. Figure III-1(a) shows a plot of chloride concentration and flow for samples from Little Cypress Creek near Jefferson. As flow increases, chloride concentrations tend to decrease. This relationship is also found for sodium, potassium, total dissolved solids, specific conductance, magnesium and silica. This type of a relationship could result from a base flow with a high concentration being diluted by runoff and interflow with a lower concentration.

One parameter, total suspended solids concentration, may be changing over time. Figure III-1( ) shows a plot of total suspended solids samples from the 1971 through the 1984 water years. There appears to be a decrease in the average concentration and the range of samples. No other measured major constituent shows any trend over time.

In the plot of chloride concentration versus flow, there is a great deal of scatter at very low flow indicating the source of base flow may change or the quality of the base flow changes. To further examine this, the ionic balance of the water was examined. The ionic balance is examined by looking at the percentage of equivalent weight of each of the ionic species present. The equivalent weight is the mole weight divided by the ionic charge of the species. This produces a weight for each species that is chemically equivalent. Figure III-2 presents the percentage of equivalent weights for the major ionic species in a Piper diagram. The Piper diagram is a trilinear plot of the cations (lower left triangle), anions (lower right triangle) and the balance of cations and anions (center diamond). Data used in Figure III-2 are samples where flow was less than 500 cfs and specific conductance either less than 175 micromhos per centimeter (cm) or greater than 300 micromhos per cm. Comparing the cationic and anionic triangles, there is a shift towards the sodium plus potassium and the chloride vertex. This indicates that some of the low flow has higher percentages of sodium chloride than others. So, either the source of the base flow changes or, for some reason, the quality of the base flow is changing.

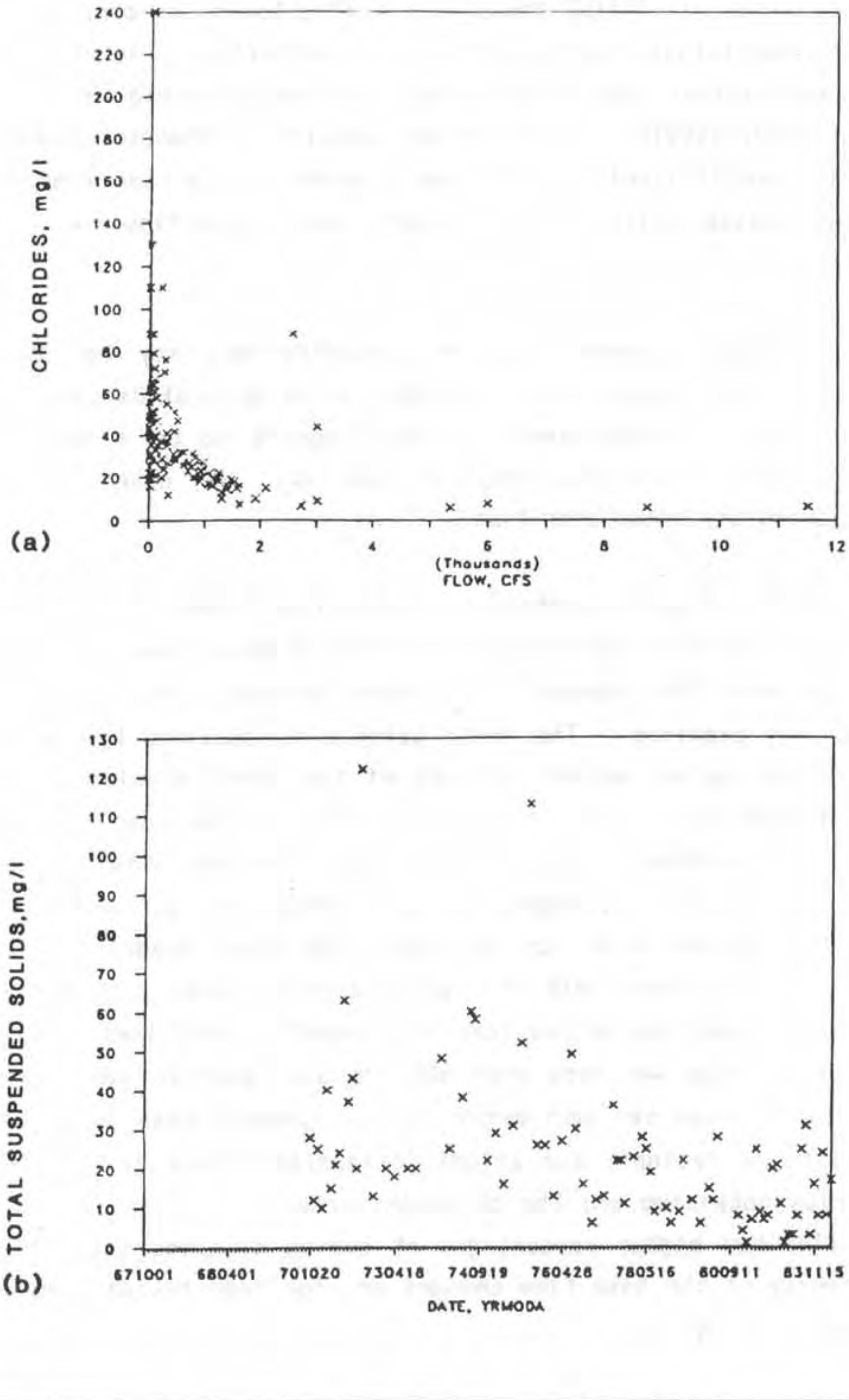
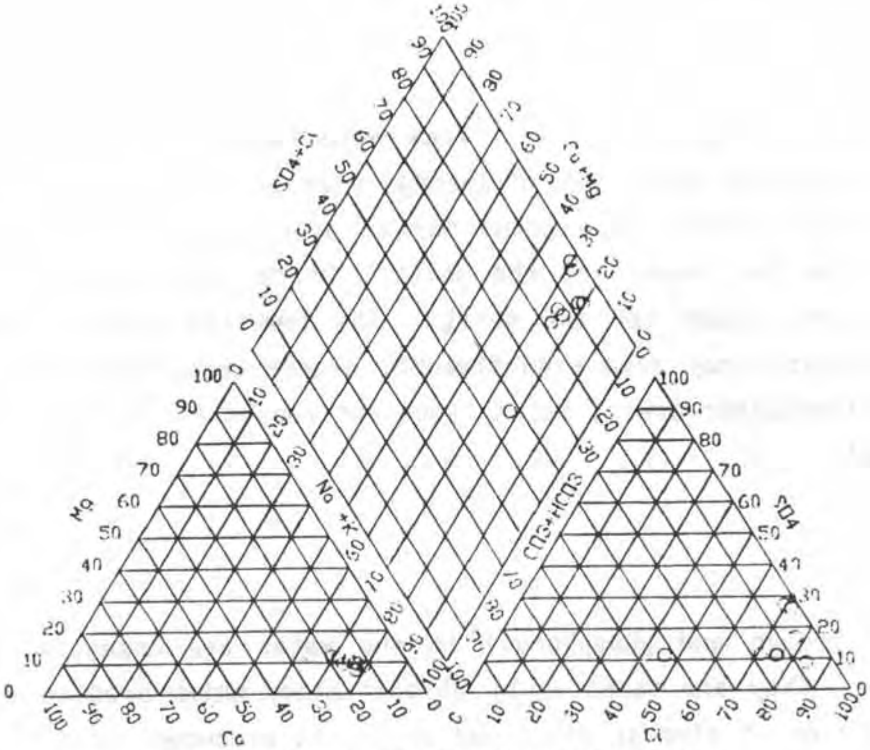
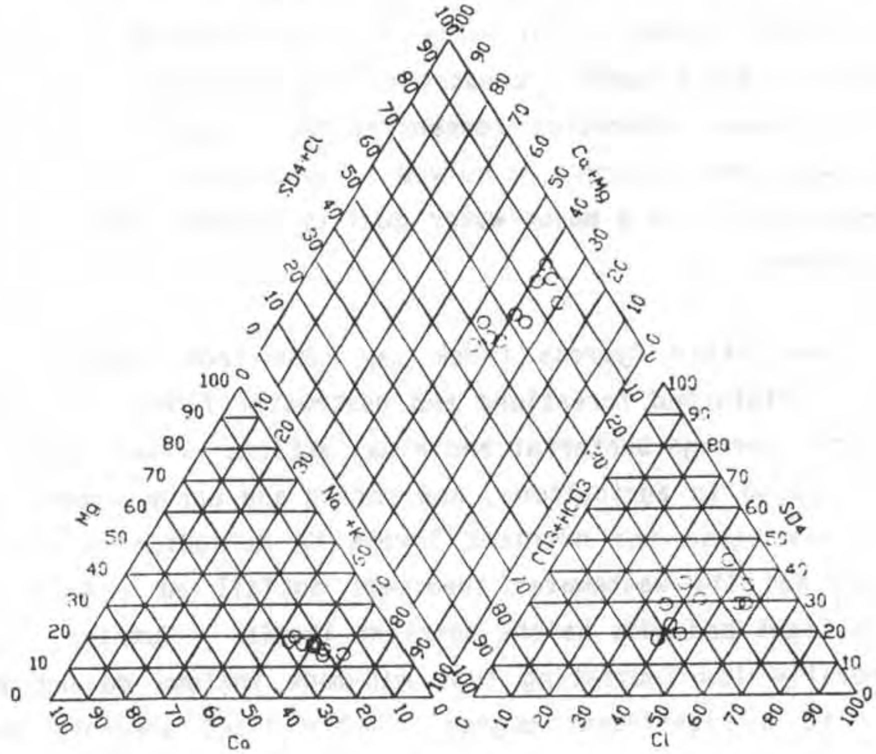


Figure III - 1

THE RELATIONSHIP OF FLOW TO CHLORIDE CONCENTRATION (a) AND THE CHANGE OF TOTAL SUSPENDED SOLIDS OVER TIME (b) OBSERVED AT LITTLE CYPRESS CREEK NEAR JEFFERSON, TX.



PERCENT OF TOTAL MILLEQUIVELANTS PER LITER
SPECIFIC CONDUCTANCE > 300 MICROMHOS/CM



PERCENT OF TOTAL MILLEQUIVELANTS PER LITER
SPECIFIC CONDUCTANCE < 175 MICROMHOS/CM

FIGURE III-2. VARIATIONS IN IONIC COMPOSITION OF WATER FOR FLOW LESS THAN 500 CFS.

The data used in Figure III-2 was from water years 1974 to 1984. The low specific conductance group had an average year of 1979 in the data base, and the high specific conductance group had an average year of 1978. Time does not seem to be the reason for the shift. Differences in the source of the flow may be the reason for the shift. The low-flow contribution from some areas in the basin may have signifigantly higher concentrations of dissolved solids than from other areas, but no apparent reason for the differences could be identified.

NUTRIENTS

Nutrients (nitrogen and phosphorus) in the water are essential to maintain aquatic life. They are taken up by phytoplankton which produce more biomass. In the production of biomass dissolved oxygen is produced and liberated to the water column. When the phytoplankton biomass is reduced (through mortality) oxygen is used in the cellular material decomposition. The production and reduction of biomass occurs concurrently creating an oxygen balance. Extreme growth, usually in early summer, creates excess dissolved oxygen in the water column commonly above saturation concentrations. Later in the year, high mortality may occur and suppress dissolved oxygen levels. This suppression of dissolved oxygen levels is a major water quality problem associated with large phytoplankton communities.

Nutrients in the Little Cypress Creek may come from rainfall runoff from agricultural and disturbed forestland and wastewater flow. Nitrogen may also be fixed in water through bacterial and algal action. Almost half of the land in the Basin is used in agriculture, and spring and early summer applications of fertilizer may cause the nutrient levels to periodically increase. The City of Gilmer has its wastewater treatment outfall on a tributary of the Little Cypress Creek and adds to the nutrient levels. Nutrient levels in the data are generally low indicating that man-made inflows do not degrade the water quality to a significant degree. Table III-2 presents the average, minimum and maximum concentration of the nutrient observed at USGS station

TABLE III-2

NUTRIENT CONCENTRATIONS OBSERVED AT LITTLE CYPRESS CREEK NEAR JEFFERSON, TEXAS WATER YEARS 1970 THROUGH 1984

Parameter	Number of Samples	Average	Minimum	Maximum
Dissolved oxygen, mg/l	85	7.3	2.7	12.2
BOD_5	86	1.6	0.3	8.5
Nitrate, mg/l as N	79	.15	0	.51
Nitrite, mg/l as N	73	.007	0	0.3
Ammonia, mg/l as N	82	.07	0	.7
Organic nitrogen, mg/l as N	79	.60	0	1.6
Total phosphorus, mg/l as P	85	.10	.01	1.1
Organic carbon, mg/l as C	63	9.1	4.4	16

Little Cypress Creek near Jefferson. Thirteen of the 85 observations (15 percent) of dissolved oxygen below the 5.0 mg/l (Texas Water Commission stream standard) have been made since 1969. These have occurred usually during low-flow periods. This problem has been generally attributed to low stream reaeration and localized decaying vegetation characteristic of streams in the Cypress Basin rates (19).

There are some obvious changes in nitrogen species over time. Figure III-3 presents graphs of ammonia, nitrate, and organic nitrogen levels measured from the 1970 through the 1984 water years. Changes in organic nitrogen levels are the most obvious. The three horizontal lines in the graph show the average during each span of time. Average organic nitrogen levels increased from .29 mg/l tc .57 mg/l to .91 mg/l. The timing of the first increase roughly coincided with the city of Gilmer building a new wastewater treatment plant (3). The new facility is a "racetrack" activated sludge plant that produces a good quality effluent very low in BOD and total suspended solids. The drop in ammonia also coincides with the increase in organic nitrogen. Nitrate also has a higher frequency of very low values during this time but still has high levels. The sampling site is 50 miles downstream from the Gilmer plant. In the time it takes the water to travel from the plant to the sampling site much of the ammonia and nitrate could have been converted to biomass and measured as organic nitrogen.

METALS

Metals found in small quantities in water may have profound effects on aquatic life. At elevated concentrations they may be very toxic, and at low levels they may have a chronic toxic effect, sometimes weakening the organism but more often interfering with reproduction. Table III-3 presents the average, maximum, and minimum concentrations of metals observed at Little Cypress Creek near Jefferson. Metal concentrations observed at Little Cypress Creek near Jefferson are generally at low levels, below the Texas drinking water standards allowable concentrations. Three isolated instances of violations of

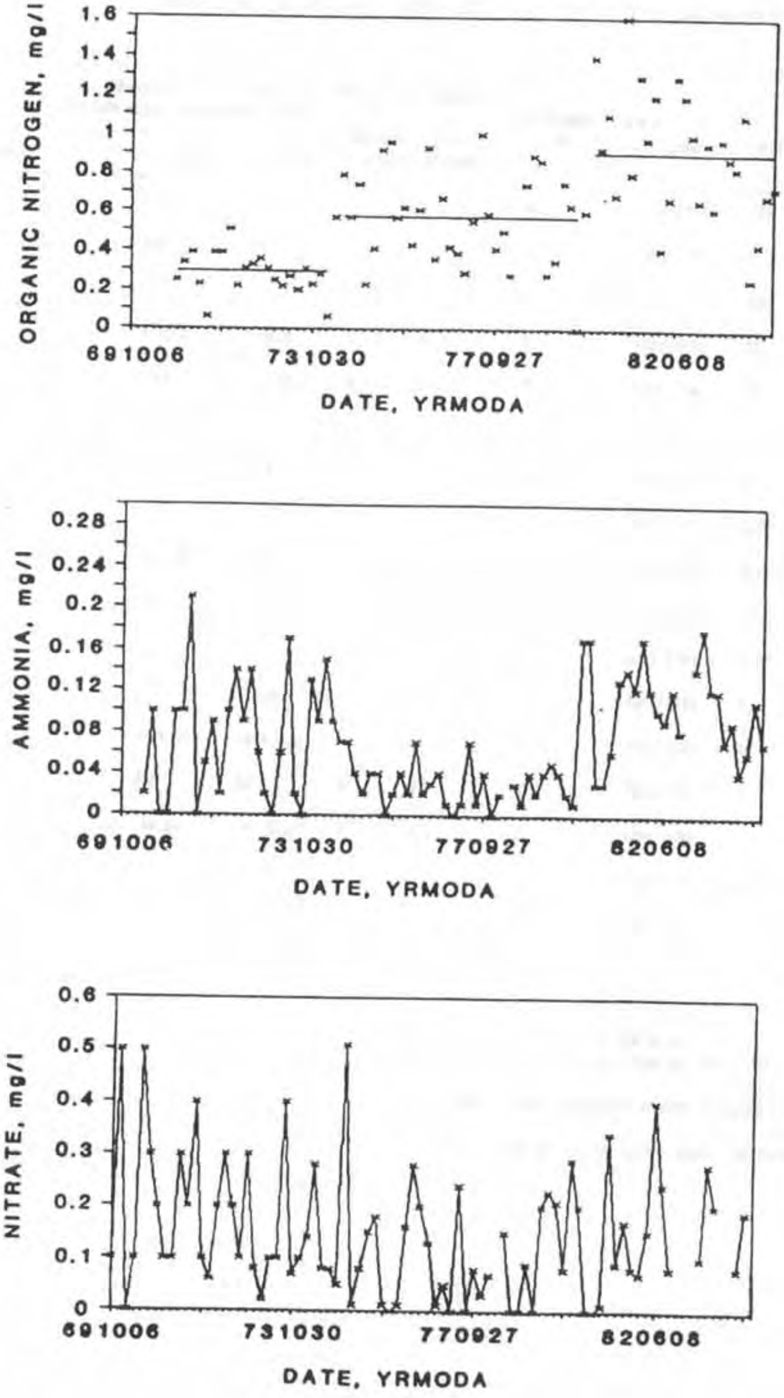


Figure III-3

CONCENTRATION OF AMMONIA, NITRATE AND ORGANIC NITROGEN AT LITTLE CYPRESS CREEK NEAR JEFFERSON FROM WATER YEARS 1970 TO 1984

TABLE III-3

DISSOLVED METAL CONCENTRATIONS, IN UG/L, OBSERVED AT LITTLE CYPRESS CREEK NEAR JEFFERSON, TEXAS

PARAMETER	AVERAGE	MINIMUM	MAXIMUM	WATER YEARS COLLECTED	NUMBER OF SAMPLES	STANDARDS VIOLATIONS		EPA AQUATIC LIFE STANDARDS (2) TOTAL RECOVERABLE CONCENTRATIONS		TEXAS DRINKING WATER STANDARDS (6)
						ACUTE AQUATIC	DRINKING WATER	CHRONIC (3)	ACUTE (4)	
ALUMINUM	101	20	420	1971-1976	24	-	-	-	-	-
ARSENIC	0.41	BDL(1)	3	1971-1984	44	0	0	190	360	50
BARIUM	113	BDL	800	1971-1984	24	-	-	-	-	1000
CADMIUM	1.4	BDL	33	1971-1984	33	1	1	0.46 * (5)	1.07 * (5)	10
CHROMIUM	1.9	BDL	20	1971-1984	40	0	0	81(11)	76(14)	50
COBALT	0.25	BDL	2	1971-1976	24	-	-	-	-	-
COPPER	2.7	BDL	14	1971-1984	42	4	0	4.4 *	6.0 *	-
IRON	666	100	2000	1971-1984	48	-	-	-	-	-
LEAD	5	BDL	110	1971-1984	43	2	1	.75 *	19.3 *	50
LITHIUM	10	BDL	20	1971-1976	24	-	-	-	-	-
MANGANESE	304	BDL	2000	1971-1984	48	-	-	-	-	-
MERCURY	0.16	BDL	2.5	1971-1984	41	1	1	0.012	2.4	2
NICKEL	3.5	BDL	14	1971-1976	24	0	-	6.6 */**	40 */**	-
SELENIUM	0.05	BDL	1	1971-1984	19	0	0	35	200	10
SILVER	0.05	BDL	1	1971-1984	19	1	0	.12 **	.56 **	50
STRONTIUM	227	BDL	520	1971-1976	24	-	-	-	-	-
ZINC	41	BDL	480	1971-1984	48	2	-	47 **	123 **	-

(1) BELOW DETECTION LIMITS
(2) FROM FEDERAL REGISTERS VOL.50 NO.145 AND VOL.45 NO.231
(3) A FOUR DAY EXPOSURE ONCE EVERY THREE YEARS EXCEPT AS NOTED BY **
(4) A ONE HOUR EXPOSURE ONCE EVERY THREE YEARS EXCEPT AS NOTED BY **
(5) THE +VI IONIC CONCENTRATION IS IN PARENTHESES
(6) PUBLIC LAW 93-523, ADOPTED BY THE TEXAS BOARD OF HEALTH, EFFECTIVE NOV. 28,1980
* BASED ON A HARDNESS OF 31.5 MG/L AS CACO3
** DENOTES CHRONIC SIMPLY AS 24 HOUR EXPOSURE AND ACUTE SIMPLY AS ANY EXPOSURE

the drinking water standards have been found, one each for cadmium, lead and mercury. Aluminum, iron, manganese, and strontium are found in moderately high levels, probably due to the geology of the region. The average values of cadmium, lead and mercury exceed the chronic toxic level set by the EPA for sensitive aquatic life. Concentrations of cadmium, copper, lead, mercury, silver, and zinc have been found at levels higher than the acute toxic level for sensitive aquatic life. The EPA standards are for total recoverable concentrations and the metal concentrations observed in the Little Cypress are dissolved, so total concentrations may actually be even higher. Many samples were found to have concentrations of most metals below the detection limit, and some concentrations are changing over time.

Changes in the concentrations of most metals appear to be random. Aluminum, copper, and mercury, however, appear to have declining concentrations as shown on Figure III-4. The plot of iron on Figure III-4 shows lower concentrations from 1975 through 1979. This coincides with the reductions of ammonia and nitrate. Strontium and magnesium both appear to have a relationship with discharge as shown by the plots on Figure III-4. With such low concentrations of metals, these changes are probably due to changes in soluble fraction rather than inflows into the creek. Total concentrations of the metals probably have not changed, rather a shift from the dissolved phase to particulate phase has occurred. The aquatic habitat in Little Cypress Creek would not be suitable for sensitive organisms due to the occasional high concentrations of some metals.

MAN-MADE ORGANICS

In this situation man's influence on water quality can be best observed by looking at the components making up the organic matter in the water. Pesticides, herbicides, and organic manufacturing wastes can usually be found in areas influenced by man. The Little Cypress Creek Basin has a low population density as reflected by the fact that there are no man-made organics being found in the water column. Analysis of bottom deposits show

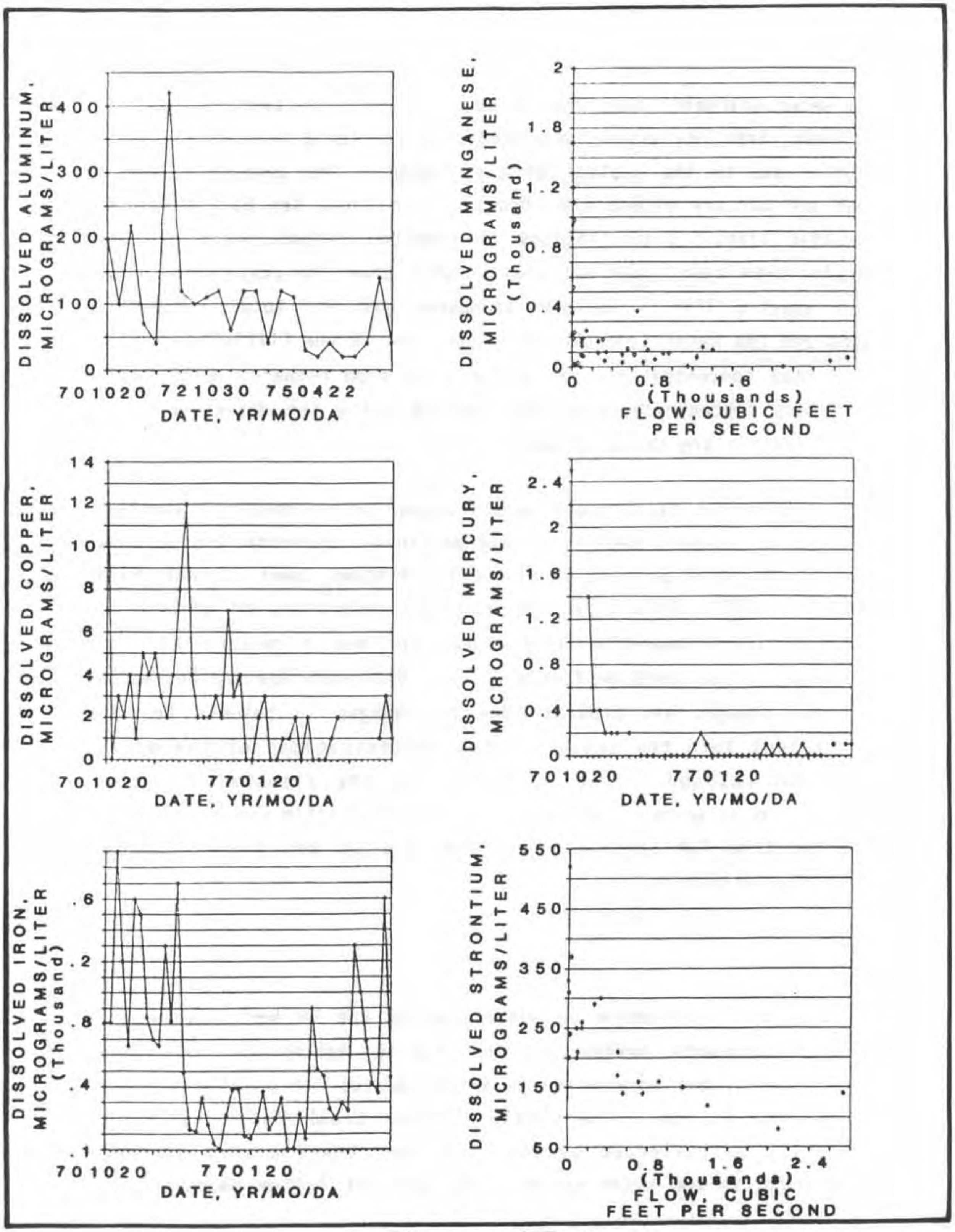


Figure III-4

CHANGES IN METAL CONCENTRATIONS OVER TIME AND RELATIONSHIPS BETWEEN FLOW AND METAL CONCENTRATIONS AT LITTLE CYPRESS CREEK NEAR JEFFERSON

measurable levels of pesticides and PCBs. Table III-4 presents the average, minimum, maximum, and percent of samples found with concentrations above zero for Little Cypress Creek near Jefferson. Since clays are predominant in the area, the organics are probably bound to them. No data concerning the ability of the organics to leach from the bottom material has been found and this should be explored.

TABLE III-4

MAN-MADE ORGANIC CONCENTRATIONS AT LITTLE CYPRESS CREEK NEAR JEFFERSON, TEXAS FOR WATER YEARS 1972 THROUGH 1981

	Average	Minimum	Maximum	Number of Positive Samples/Total Number of Samples
Water Column				
Dieldrin, ug/l	-	0	.01	1/30
PCB, ug/l	-	0	.1	1/25
Diazinon, ug/l	-	0	.01	1/31
2,4-D, ug/l	.002	0	.02	3/31
2,4,5-T, ug/l	.015	0	.4	6/31
Bottom Material				
DDD in bottom material, ug/kg	2.06	0	18	23/31
DDE in bottom material, ug/kg	.79	0	3.2	18/31
DDT in bottom material, ug/kg	1.50	0	12	13/28
Dieldrin in bottom material, ug/kg	.32	0	1.8	15/26
Heptachlor in bottom material, ug/kg	.02	0	.3	2/26
Heptachlor epoxide in bottom material, ug/kg	-	0	.1	1/26
Chlordane in bottom material ug/kg	3.22	0	Z12	17/28
PCB in bottom material, ug/kg	13.0	0	140	12/26

CHAPTER IV

POLLUTION LOADINGS

NONPOINT SOURCE POLLUTION

Nonpoint source pollution comes from three different sources in the Basin: 1) urban areas, 2) agricultural areas, and 3) forested areas. Loading from urban areas, the smallest area, was calculated using methodology developed by the U.S. Environmental Protection Agency (EPA) during their analysis of results of their Nationwide Urban Runoff Program (NURP)(21). No sampling has taken place for urban runoff in urban areas contributing to flow in Little Cypress Creek, so the analysis may not be exact, but it does represent the order of magnitude the urban loading would represent.

Urban areas in the Little Cypress Creek Basin represent only .3 percent of the total land area or about 1500 acres. These are primarily Gilmer and northern Marshall. Annual runoff in urban areas was assumed to be 40 percent of the annual rainfall. Total annual runoff produced by the urban areas was calculated as:

$$1500 \text{ acres} \times 3.81 \text{ feet of rainfall} \times \frac{.4 \text{ runoff}}{\text{rainfall}} = 2287 \text{ acre feet}$$

This estimated flow represents about 0.56 percent of the annual flow. Calculated loads were estimated using the median concentrations developed in the NURP study times the total annual calculated runoff. Table IV-1 presents the median concentrations of the parameters from the NURP study and the loads estimated for the Little Cypress Creek Basin. Also shown is the estimated yearly load associated with urban runoff compared to the observed total pollutant load in the basin for each parameter. The observed total pollutant load was calculated on the basis of measured streamflows and instream concentrations.

TABLE IV-1

NONPOINT SOURCE URBAN LOADS FOR THE LITTLE CYPRESS CREEK BASIN

Parameter	Median From NURP Study	Estimated Nonpoint Source Load lb/yr	Comparison of Estimated Urban Runoff Load With Observed Total Pollutant Load
BOD	9 mg/l	55,970	3.1%
TSS	100 mg/l	621,890	2.4%
NO_2+NO_3	.68 mg/l	4230	2.4%
TKN	1.5 mg/l	9330	1.2%
Soluble P	.037 mg/l	230	-
Total P	.101 mg/l	630	0.6%
Total Lead	.144 mg/l	900	-
Total Copper	.034 mg/l	210	-
Total Zinc	.160 mg/l	1000	-

Nonpoint source loads from forestland are dependent upon the amount of acreage undergoing harvesting and regeneration. Most rainfall is used by the forest or infiltrates into the layer of humus on the forest floor. A study conducted in northeast Texas close to the Little Cypress Creek Basin showed only 2.6 percent of rainfall was seen as direct storm runoff from undisturbed forestland (18). Harvested forestland yields 8.5 percent of the rainfall as runoff, and the first year of regeneration yields 3.5 percent of the rainfall as runoff. Runoff from forestland, assuming 2 percent of the total forest acreage is clearcut annually, would be 24,010 acre feet or 5.8 percent of the basin flow. The quality of water coming from forestland is very high. The runoff quality concentrations observed in the above mentioned study in northeast Texas which were used in calculating loads, estimated loads from forestland, and the percentage of the total basin load are shown in Table IV-2. From the loads presented in Table IV-2 it is evident that forested lands produce a small percentage of the Basin's nutrient load and a significant portion of the suspended sediment load.

Runoff quality from agricultural land varies seasonally and by specific land use. Like urban runoff, no data base exists from samples of agricultural runoff in the Little Cypress Creek Basin area. Concentrations used in this study were based on studies from other areas, where agricultural practices were about the same as those for the Little Cypress Creek Basin (4,5,6,7,9,26,27). So, estimated loads may not be exact, but rather the same accuracy as would be expected for forest and urban loads. An annual runoff coefficient of 0.066 was used for all agricultural areas. This value is representative of direct runoff from pasture and grazing land. This would produce a yearly flow volume of 62,743 acre feet from direct storm runoff of agricultural areas. Based on the estimated runoff coefficient, this represents 15 percent of the yearly flow in the Basin. The yearly agricultural load, the assumed concentrations, and the estimated agricultural load compared to the observed total pollutant load in the basin are shown in Table IV-3.

TABLE IV-2

NONPOINT SOURCE LOADS FROM FOREST LAND IN THE LITTLE CYPRESS CREEK BASIN

Parameter	Concentration	Estimated Nonpoint Source load, lb/yr	Comparison of Estimated Forest Runoff Load With Nonpoint Source Observed Total Pollutant Load
NO_3-N	.023 mg/l	1,500	.09%
NH_3-N	.073 mg/l	4,770	4.1%
Total N	.910 mg/l	59,410	4.5%
Soluble N	.602 mg/l	39,300	-
PO_4	.008 mg/l	522	-
Total P	.064 mg/l	4,180	3.9%
Suspended sediment	145 ppm	9,466,100	36.8%

(1) Flow weighted to reflect acreage in harvesting and regeneration.

TABLE IV-3

NONPOINT SOURCE AGRICULTURAL LOADS IN THE LITTLE CYPRESS CREEK BASIN

Parameter	Concentration	Estimated Nonpoint Source load, lb/yr	Comparison of Estimated Agricultural Runoff Load with Observed Total Pollutant Load
NH_3-N	.45 mg/l	71,651	61%
NO_3-N	1.14 mg/l	194,480	127%
TKN	5.55 mg/l	948,820	74%
Soluble P	1.14 mg/l	194,480	-
Total P	2.14 mg/l	365,080	338%(1)
TOC	28.8 mg/l	4,913,230	49%
COD	70.9 mg/l	12,095,400	-
Total dissolved solids	160 mg/l	27,295,700	20%
Total suspended solids	57.8 mg/l	9,860,600	38%
Total coliform	500,000 colonies/ 100 ml	-	-
Fecal streptococci	12,340 colonies/ 100 ml	-	-
Fecal coliform	617,000 colonies/ 100 ml	-	-

(1) The overestimation of phosphorus load compared to the total observed phosphorus load may be due to settling of phosphorus adsorbed on sediments and loss due to biological action.

From the table it can be seen that agricultural loading represents by far the majority of the nutrient input to the Basin. The estimated phosphorus load from agriculture is three times the observed phosphorus load in the Basin. This may be due to settling of phosphorus adsorbed on sediments and utilization of nonpoint source phosphorus before the sampling point. Phosphorus tends to adsorb onto sediment and settle. During very large flows the sediment carrying the phosphorus will be flushed downstream. So, on a particular day during storm runoff the majority of the yearly phosphorus load may pass downstream and not be sampled. The discrepancy in estimated and observed phosphorus load is commonly found in basin studies. If more stormflows were sampled, the estimation would tend to be closer to observed. Both nitrogen and phosphorus are used in phytoplankton growth.

POINT SOURCE LOADS

Seven point source discharges are currently permitted in the Little Cypress Creek Basin. Table IV-4 lists these dischargers and the 1985 effluent characteristics (15). Figure IV-1 shows their location and the location of other dischargers in the adjacent Cypress Creek Basin. One permitted discharger in the Little Cypress Creek Basin, Snider Industries, uses the water in a power cogeneration facility and recycles the water in a cooling pond and does not release it to the creek. Only 0.3 percent of the annual flow, 0.9 percent of the annual BOD load, and 0.07 percent of the annual suspended solids is contributed by the six dischargers that discharge to the Little Cypress Creek.

The discharge from Robroy Industries, in Gilmer, is from one-pass noncontact cooling operation, and the quality is essentially that of the groundwater in the area so they simply augment the flow. Robroy Industries, Gilmer Potteries, Gilmer Wastewater Treatment Plant, and Diana Wastewater Treatment Plant all will flow into Marshall Lake. The others will discharge below the lake. If the Snider Industries cooling pond were to overflow, it would discharge below the proposed dam and not affect Marshall Lake.

TABLE IV-4

POINT SOURCE DISCHARGERS IN THE LITTLE CYPRESS CREEK BASIN

Permittee	1985 Average Values Flow mgd	 BOD_5 lb/day	 TSS lb/day
Robroy Industries	.128	-	3.31
Gilmer Potteries	.0066	-	1.15
Gilmer WWTP	.746	38.2	40.9
Diana WWTP	.0451	3.17	4.30
Joy Manufacturing	.0076	0.48	0.13
Snider Industries	14.4	-	-
Sabine Valley Regional Mental Health Mental Retardation Center	.00147	0.94	1.02
Total	.93477	42.79	50.81

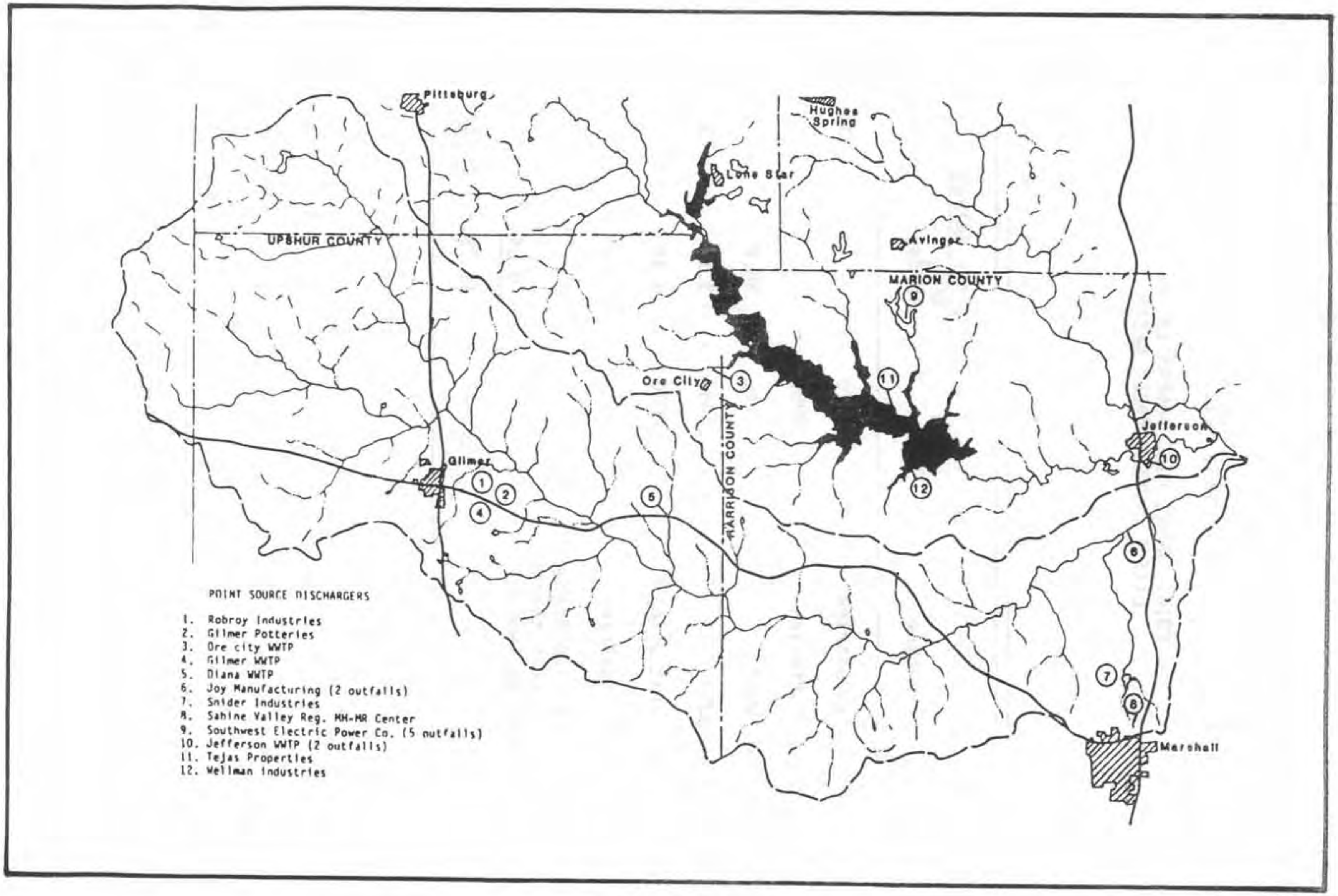


FIGURE IV-1

POINT SOURCE DISCHARGES IN THE CYPRESS CREEK BASIN

Two hazardous waste sites are located near Gilmer, both of which have been treated to prevent further contamination and are undergoing closure. These will present no problems in the future. The City of Gilmer manages a landfill just east of the city, and this too should not present any water quality hazard since it is only for domestic waste. Brine disposal from oil wells is now enforced by the Texas Railroad Commission, and no future releases should contact the Little Cypress Creek. Oil spills also should present no problem since strict spill control regulations are now in force which should prevent pollution of surface waters from this source.

Runoff from coal mines that may be in the proposed lake's drainage area will have to be treated prior to release in accordance with new source standards established by the EPA. Limitations on the effluent quality from this source should protect the proposed lake's water quality from any deleterious effects of coal mine runoff.

COMPARISON OF LOADS

From the calculations of pollutant loads for each land use, it is obvious that agricultural runoff inputs most of the loads observed in the basin. Table IV-5 summarizes the estimated percentage of yearly loading that each major pollutant source contributes to the basin.

TABLE IV-5

SUMMARY OF BASIN LOADINGS

	Percentage of Each Source Estimated Loading Compared to Total Estimated Basin Loading(1)			
Parameter	Urban runoff	Forest runoff	Agricultural runoff	Point sources
BOD	0.9	2.1(2)	96.8(3)	0.2
TSS	3.1	47.4	49.4	0.1
Total nitrogen	1.1	4.6	88.8	5.5(4)
Total phosphorus	0.2	1.1	94.3	4.4(5)

(1) These percentages are based on the synthesized loads developed earlier and are for comparison rather than a definitive analysis of the loadings.

(2) Based on an assumed BOD_5 concentration of 2 mg/l.

(3) Based on a BOD_5/COD ratio of .5.

(4) Based on an assumed total nitrogen concentration of 25 mg/l.

(5) Based on an assumed total phosphorus concentration of 6 mg/l.

CHAPTER V

LAKE WATER QUALITY PROJECTIONS

INTRODUCTION

The methodology used in this study of a lake at Marshall Damsite, developed by the U.S. Environmental Protection Agency, is a screening procedure to determine if a problem may exist, rather than a definitive water quality assessment (22,23,24). This study addresses five points of lake quality:

1. Impoundment stratification
2. Sediment accumulation
3. Toxics
4. Eutrophication
5. Impoundment dissolved oxygen

Analysis of each will be based on site specific information, if it exists, and general conditions associated with the area.

STRATIFICATION

A lake at Marshall Damsite will be a thermally stratified lake. During certain times of the year the temperature of the water will differ dramatically over a short depth (thermocline). The warm inflowing water will flow over the colder, denser water in the lower depths of the lake. The differences in water density will tend to keep the water from mixing in the lake, making two distinct horizonally-bounded, water quality regions. The hypolimniom is the deeper water and the epilimniom is the surface layer. Since the water in the bottom layer of the lake (hypolimniom) does not mix with the surface layer (epilimniom), it has little chance to replenish the oxygen supply through reaerational and photosynthetic activity. If a sufficient oxygen demand is exerted by the biological and chemical reactions occurring in the hypolimnion and bottom sediments, the hypolimnion may become anoxic. This may result in significant chemical and biological changes. Iron and manganese may be reintroduced into the water column in their reduced forms. Generation of hydrogen sulfide gas is common through biological activity. Settled nutrients may also be reintroduced.

Thermal stratification will follow an annual cycle. Through late fall and winter the water temperature will be constant throughout the lake, and the lake will be well mixed. As spring warms the surface of the lake and the incoming water, less and less mixing will occur and a temperature difference will begin to emerge. By summer, stratification will be complete and the epilimnion and incoming flow will not mix with the hypolimnion. This will continue through fall until inflow temperature decreases and mixing begins again. The depth of the epilimnion is a function of the heating of the lake and mixing due to wind. The stratification may vary from year to year, depending on the climatic conditions.

Prediction of stratification in a lake at Marshall damsite was accomplished using plots (Figure V-1 and Figure V-2) developed by the EPA in <u>Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants - Part 2</u> for geometry similar to the proposed lake and climatic conditions of Atlanta, Georgia (closest area of similar latitude) and stratification observed at Lake O' the Pines. These plots represent what would likely be the conditions month to month but probably underestimate the water temperatures. Using observations of thermal stratification from Lake O' the Pines as a guide (the lower right-hand graph of Figure V-1), the water temperature on the other graphs is lower than the observed temperatures. The wind plays a minor role in mixing as determined from the Lake O' the Pines data by comparing the average shape of the observed thermal decline to plots developed with various degrees of mixing. Figure V-1 shows the stratification pattern if a conservation pool of about 300,000 acre-feet is maintained and Figure V-2 shows the stratification pattern if a 700,000 acre-foot pool is maintained. Both plots show the time periods of likely stratification, but underestimate thermocline depth and water temperature.

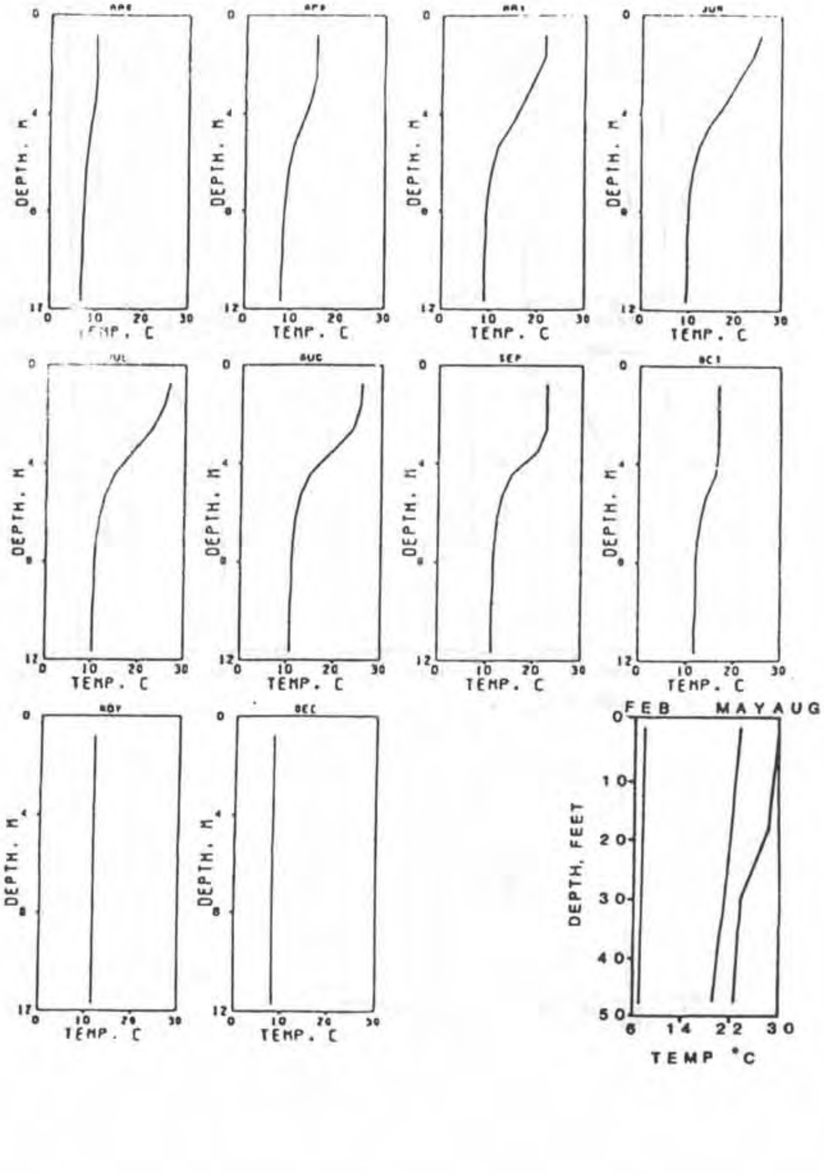


FIGURE V-1
STRATIFICATION FOR A LAKE OF SIMILAR GEOMETRY AND INFLOW OF A 300,000 ACRE FOOT CONSERVATION POOL FOR MARSHALL LAKE

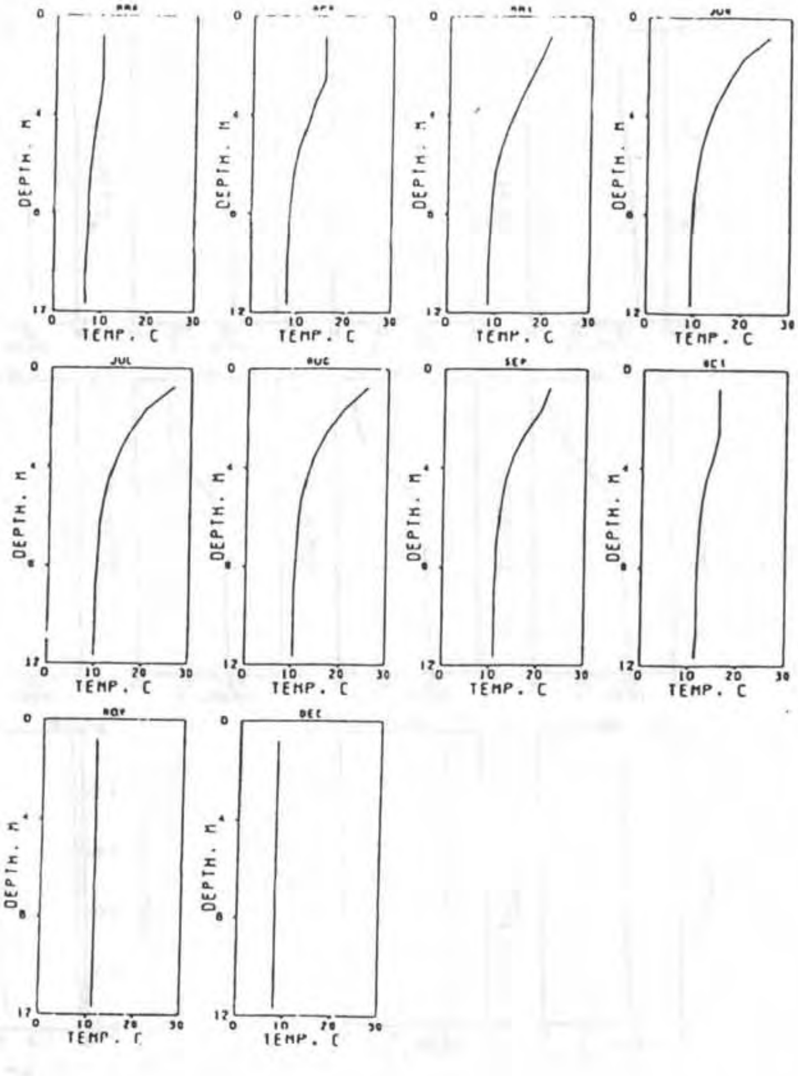


FIGURE V-2
STRATIFICATION FOR A LAKE OF SIMILAR GEOMETRY
CONSERVATION POOL FOR MARSHALL LAKE
AND INFLOW OF A 700,000 ACRE FOOT

Comparison of the two plots shows that as the size of the lake increases, the depth of the thermocline decreases. This changes because as the size of reservoir grows the volume per unit of surface area increases, so the energy input on the surface is for a greater volume and cannot heat the water to the same temperature, decreasing the epilimnion depth. These plots represent only average conditions. A great deal of variation in stratification is possible due to changes in climatic conditions. Figure V-3 presents plots of stratification at Lake O' the Pines for water years 1979 through 1984. The February and May plots show a great deal of variation. February may or may not be stratified, and the depth of the thermocline in May may vary from 10 to 30 feet. August does show a more uniform pattern year to year.

SEDIMENT ACCUMULATION

Sediment accumulation in a reservoir is a function of the inflowing sediment rate and the percentage settled in the reservoir. Predicted sediment accumulation in a lake at Marshall damsite was based on observed accumulation in two nearby lakes, Century Lake near Sulphur Springs on the Sulphur River, and Lake Cherokee on the Sabine River. Century Lake is just north of the basin, and Cherokee Lake is just south. Both lakes drainages are a mix of agricultural and forestland, and both are predominately rural. Measured sediment accumulations were:

lake	acre-foot/mi^2	tons/mi^2
Century Lake	1.53	2832
Lake Cherokee	1.37	2480
Average	1.45	2656

The proposed lake, with a contributing area of 617 square miles would have an annual deposition of 895 acre feet of sediment, or 1,640,000 tons of sediment. Based on this rate it would take 34 years for enough accumulation to reduce a 300,000 acre-foot conservation pool by 10 percent, and 78 years to reduce a 700,000 acre-foot pool by 10 percent.

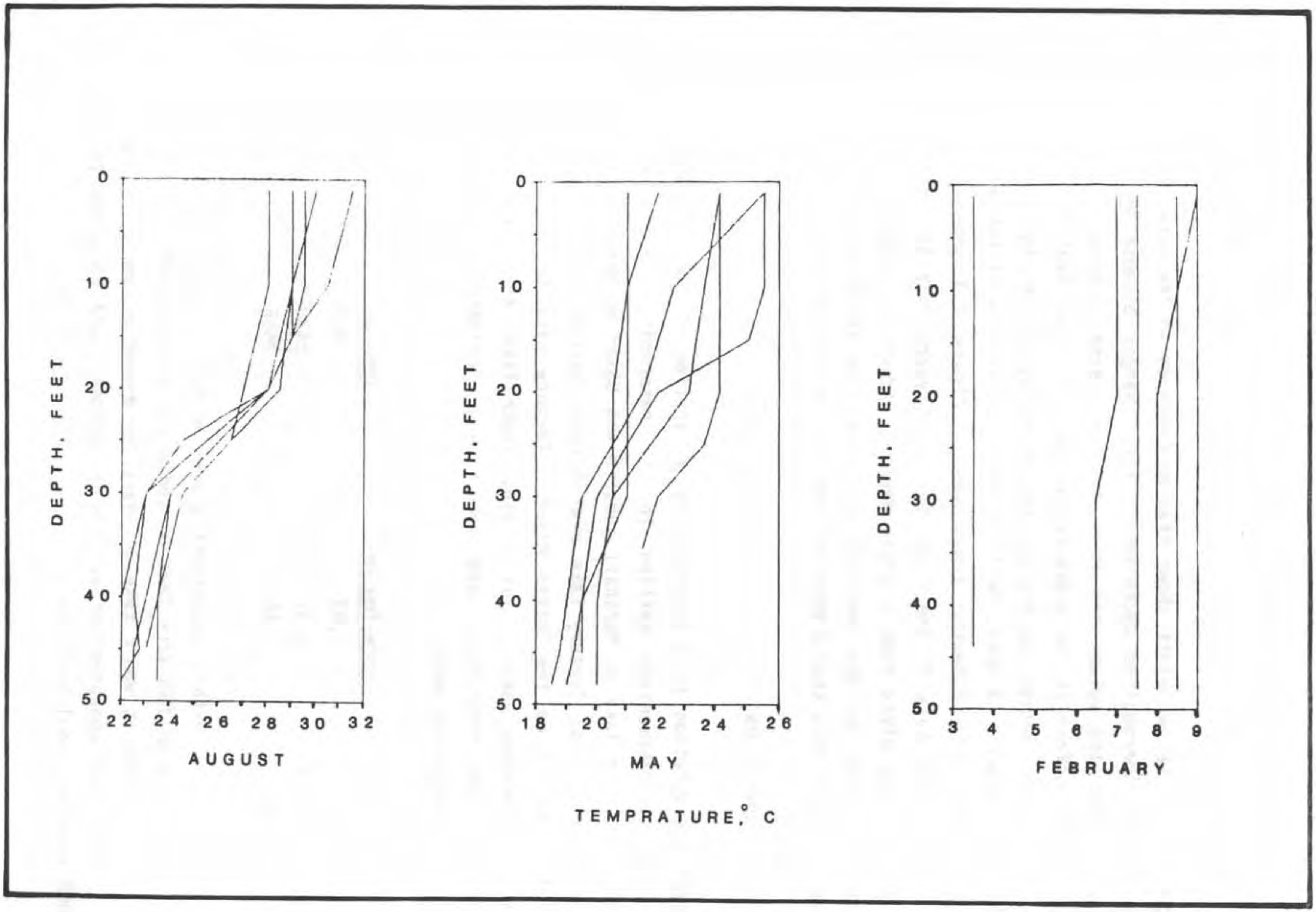


FIGURE V-3

VARIATIONS IN STRATIFICATION OF LAKE O' THE PINES

TOXICS

Levels of man-made organics measured at Little Cypress Creek were very low in the water column. Only infrequent samples produced positive results. The herbicides 2,4-D and 2,4,5-T were the only compounds found more than once in the water column. Organics in the water column are not expected to be a problem in Marshall Lake. The dissolved trace metal levels found in Little Cypress Creek are likely to be found in the lake. There may be some precipitation of metals if absorbed to settling algae. Metals concentrations may be a problem if sensitive species are introduced into the lake.

High levels of some organics were found in the sediments. Since they were not found in the water column, it appears they are tightly held to the sediments. Analyses of leachability need to be conducted on the sediments to determine if a problem may exist in the proposed lake. Since the lake will not be a flowing body as the stream is now, the toxics in the sediments will be exposed to different conditions. There will be a greater depth of accumulated sediment, and the sediment may be periodically exposed to anaerobic conditions. The anaerobic conditions, along with the already low pH (Average = 6.25), may increase the probability of the toxics being reintroduced into the water column. Observed data at the Lake O' the Pines does not show any high toxics levels, but the proposed lake should be periodically monitored.

EUTROPHICATION

Plant growth in a lake is a function of nutrient availability, light, heat and the interaction of other chemical and biological processes. Plantlife represents the foundation of the aquatic community. All other aquatic life feeds directly or indirectly on plants. Nutrients many times are the limiting factor in the growth of plantlife, and phosphorus is estimated to be limiting 60 percent of the time. This study uses relationships of annual phosphorus loading to eutrophic state to estimate the potential of the proposed lake to be eutrophic. All procedures and guidelines presented were developed by the EPA and published in either "Technical Guidance Manual for Performing Waste Load Allocations" or "Water Quality Assessment: A Screening Procedure for Toxic and Conventional Pollutants". It should be noted that the classification of oligotrophic, mesotrophic, and eutrophic apply more to temperate lakes than lakes in Texas, especially man-made lakes. Most lakes in Texas have high chlorophyll 'a' concentrations compared to northern lakes, and are fairly rich in nutrients. The techniques used to classify trophic states may not be particularly valid for Texas lakes analyses.

The ratio of nitrogen to phosphorus is used to determine which is the limiting nutrient. This ratio for the average algae cell is 7.2/1, so theoretically a ratio greater than this is phosphorus limited, and less than this nitrogen limited. If the lake contains nitrogen fixing algae then phosphorus would always be the limiting factor, but the actual determination of their existence in the lake under study must be made. The nutrients measured may not all be accessible to plantlife. Studies done for phosphorus indicate only about 30 percent of the total phosphorus is actually available for algae growth. Using the observed concentrations from Little Cypress Creek near Jefferson to estimate the nitrogen to phosphorus ratio for the proposed lake, the calculated ratio is 11.8/1, so phosphorus would probably be the limiting nutrient.

The surface loading of phosphorus was calculated for two scenarios of the conservation pool; the smallest anticipated pool of 181,626 acre feet and the largest anticipated pool of 700,000 acre feet of storage. Using an average phosphorus inflow concentration of 0.1 mg/l, the surface loadings were .803 $g/m^2/yr$ and .389 $g/m^2/yr$ for the small and large pools, respectively. The Vollenweider phosphorus loading relationship bounds eutrophic state by comparing phosphorus loading to the mean depth divided by the residence time. The Vollenweider relationship does not determine if light may be limiting, and thus is a worst case condition. Since Little Cypress Creek has some turbidity (Average = 17.6 NTU) and color (Average = 80 platinum-cobalt units) found in the water, growth may be somewhat inhibited by light. The mean depth over the hydraulic residence time, the independent variable in the Vollenweider relationship was 12.4 and 6.4 for the small and large pools, respectively. Figure V-4 shows a plot of the Vollenweider relationship with the two scenarios analyzed located on the plot. Both scenarios show that the lake will be eutrophic.

Another analytical procedure using phosphorus loading assumes the levels of 0.01 mg/l P and 0.02 mg/l P are the divisions the oligotrophic/mesotrophic and mesotrophic/eutrophic states, respectively. These boundaries are calculated by:

$$W_1 = .01 \text{ (average depth} \cdot \text{detention time + phosphorus settling rate)}$$

$$W_2 = .02 \text{ (average depth} \cdot \text{detention time + phosphorus settling rate)}$$

where W_1 is the oligotrophic/mestrophic boundary and W_2 is the mesotrophic/eutrophic boundary. The phosphorus settling rate is assumed to be 12.4 meters per year. The boundaries for the proposed lake are:

	W_1	W_2	$(g/m^2/yr)$
Small pool	.154	.308	
Large pool	.355	.709	

Comparing these values to the estimated loading rates indicates that the large conservation pool may be in the mesotrophic state rather than the eutrophic state as indicated by the Vollenweider relationship.

The algal biomass may be estimated using the calculated phosphorus loading. The concentration of phosphorus may be calculated by:

$$P = \frac{W}{Zp + V_s}$$

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$$P = \frac{W}{Zp + V_s}$$

where:

P = phosphorus concentration mg/l

W = aeral loading rate ($g/m^2/yr$)

Z = average depth, meters

p = Inflow/volume, 1/yr

V_s = phosphorus settling velocity, 12.4 m/yr

Using the previously calculated loadings, the phosphorus concentration would be .032 mg/l for the small conservation pool and .026 mg/l for the large conservation pool. The chlorophyll 'a' concentration may then be calculated by:

$$\log_{10} (\text{Chlorophyl 'a'}) = 0.087 \log_{10} (P) - .194$$

Using the above calculated concentrations, the small pool may have 10.5 mg/l of chlorophyll 'a' and the large pond 7.4 ug/l.

The Carlson Trophic Index, a measure of lake quality based on secchi depth, chlorophyll 'a' concentration, and total phosphorus concentration is calculated by the Texas Water Commission for 102 reservoirs in the state. This is presented in the Texas Water Commission Report <u>The State of Texas Water Quality Inventory</u>. The reservoirs are then ranked with one being the least productive reservoir. Lake O' the Pines is ranked twentieth, indicating that it has no real eutrophic problem when compared to the rest of the state. The proposed lake at Marshall damsite should be very comparable in quality to Lake O' the Pines and not exhibit any problem.

The State has prepared some guidelines for alert levels of lake quality. They are:

Total phosphorus	.4 mg/l
Orthophosphate	.2 mg/l
Inorganic nitrogen	1.0 mg/l
Chlorophyll 'a'	50 ug/l

It appears the proposed lake will be well below these alert levels.

IMPOUNDMENT DISSOLVED OXYGEN

Dissolved oxygen levels in a lake are a result of the interactions of many biological and chemical processes. Since the proposed lake's inflow will probably be good quality water, low levels of dissolved oxygen are likely to occur only in the hypolimnion of the lake during months when the lake is stratified. This analysis of the dissolved oxygen levels in the lake is only in the hypolimnion, where no mixing with the inflow occurs. Several assumptions were made to simplify modeling:

1. Prior to stratification the lake is completely mixed. Once stratified the epilimnion and hypolimnion are each completely mixed.
2. The dissolved oxygen in the hypolimnion, once stratified, is depleted through BOD oxidation in the water column and on the lake bottom.
3. Photosynthesis is unimportant in the hypolimnion.
4. Once stratified the hypolimnion does not mix with the thermocline.
5. BOD loading is in steady state.

Two different lake scenarios were used in the dissolved oxygen analysis, a conservation pool of 181,626 acre feet, the smallest contemplated, and a conservation pool of 700,000 acre feet, the largest contemplated. Average depth was assumed to be 20 feet and maximum depth 33 feet for the small pool, and average depth of 40 feet and maximum depth of 58 feet was assumed for the large pool. The daily BOD loading was a function of influent BOD, algae productivity (based on phosphorus loading), and lake volume. The BOD decay rate, BOD setting rate and the settled BOD decay rate were constant for both lake scenarios. The analysis used conditions prior to stratification as an initial boundry condition, for the proposed lake this was February conditions. Dissolved oxygen was assumed to be at saturation, 12 mg/l for the 7.5^{O}C water temperature. The algae production was also estimated to be at the 7.5^{O}C water temperature. Stratification was assumed to occur on March first, and oxygen consumption was calculated for 5-day intervals. Oxygen is consumed by BOD oxidation in the water column and by BOD oxidation of settled BOD on the bottom.

The equation for dissolved oxygen at time t is:

$$0_t = 0_o - 0_1 - 0_c$$

Where:

0_t is the dissolved oxygen at time t
0_0 is the initial dissolved oxygen level before stratification
0_1 is the oxygen decrease due to benthal demand
0_c is the oxygen decrease due to hypolimnium BOD oxidation

Table V-1 lists the calculated variables and the resultant dissolved oxygen depletion for both scenarios. The BOD degradations show both scenarios reach low levels of dissolved oxygen in the hypolimnion. This has been observed annually at Lake O' the Pines. The size of the hypolimnion layer regulates how long the degradation takes. The larger the reservoir, the slower the degradation.

The assumptions used in this analysis were more for ease of calculation and bias the results somewhat. There was no account for vertical dispersion of oxygen which always occurs. The thermal gradients are not always stable and tend to allow some mixing during times of the stratification period. The rate the dissolved oxygen was used in the analysis was very fast for the small conservation pool. This is not likely to occur. The analysis does indicate that the lake will have a period of anaerobic conditions in the hypolimnion, and the larger the lake, the longer it will take to reach anaerobic conditions.

TABLE V-1

CONSTANTS, VARIABLES, AND RESULTS OF THE DISSOLVED OXYGEN CALCULATIONS FOR A LAKE AT MARSHALL DAMSITE

BOD decay rate at 20 C = .1/day
BOD settling rate of 20 C = .03/day
Bottom BOD decay rate at 20 C = .003/day

	SMALL POOL	LARGE POOL
Detention time	188 days	728 days
Hypolimnion volume	62,331 acre ft.	355,455 acre ft.
Height of hypolimnion layer	7 feet	20 feet
Steady state BOD loading	0.30 mg/l/day	0.13 mg/l/day
BOD in water column	g/m^3 3.2	g/m^3 1.5
Benthic BOD load	g/m^2 196	g/m^2 178

Date	Small Pool	Large Pool	Date	Large Pool
3/1	12	12	6/14	2.7
3/5	9.9	11.2	6/19	2.4
3/10	8.0	10.6	6/24	2.1
3/15	6.3	10.0	6/29	1.8
3/20	4.8	9.5	7/4	1.5
3/25	3.4	9.0	7/9	1.2
3/30	2.0	8.6	7/14	0.9
4/5	.6	8.2	7/19	0.6
4/10	0	7.7	7/24	0.3
4/15	0	7.3	7/29	0
4/20	0	6.9		
4/25	0	6.6		
4/30	0	6.2		
5/5	0	5.8		
5/10	0	5.4		
5/15	0	5.1		
5/20	0	4.7		
5/25	0	4.4		
5/30	0	4.0		
6/4	0	3.7		
6/9	0	3.0		

CHAPTER VI

RIVER QUALITY PROJECTIONS

INTRODUCTION

The dissolved oxygen in the Little Cypress Creek was simulated from Sugar Creek (Gilmer's discharge point) to the confluence with Cypress Creek using the following Streeter-Phelps dissolved oxygen sag curve equation (8).

$$D = D_o e^{-Kat} + \frac{LoKr}{Ka-Kr} (e^{-Krt} - e^{-Kat}) + \frac{LNo\ Kn}{Ka-Kn} (e^{-Knt} - e^{-Kat})$$

Where:

Do = Initial deficit

D = Deficit at time t

Ka = Reaeration rate

t = Time

Lo = Initial carbonaceous BOD

Kr = carbonaceous BOD decay

LNo = initial nitrogenous BOD

Kn = nitrogenous BOD decay rate

Reaeration was estimated by the Texas Water Commission's "Texas Equation":

$$Ka = 1.923 \frac{(\text{Velocity})^{.273}}{(\text{depth})^{.894}}$$

The simulation uses only BOD and ammonia (ammonia as nitrogenous BOD) to give an indication of the relative impact of pollution loading rather than a predicted absolute value of dissolved oxygen. Data for the benthic demand and chlorophyll 'a' concentration in Little Cypress Creek do not exist. Both of these parameters contribute to the dissolved oxygen levels.

FUTURE CONDITIONS WITHOUT THE PROPOSED LAKE AT MARSHALL DAMSITE

The dissolved oxygen simulation for future conditions assumed the municipal point source flows would double while their quality would remain the same as current conditions and all industrial point source discharges would remain the same. No flow above Sugar Creek, the point where Gilmer has its outfall, was assumed. A temperature of 31°C, a typical summertime temperature, was assumed. A BOD decay rate of .16 per day at 31°C was used, and reaeration rate of about 1.5 per day was calculated. The creek has a very slow velocity and is shallow and fairly wide. At no flow conditions the creek will still be nearly 1-foot deep and 30-feet wide. The resulting dissolved oxygen concentration and deficits are shown in Figure VI-1. The results show the point sources will have only an initial impact on the dissolved oxygen and as flow moves downstream recovery is rapid.

Observed dissolved oxygen (DO) has been measured below 5.0 mg/l during periods of low flow. The BOD_5 levels associated with the low DO ranged around the average 1.5 mg/l. The source of the BOD is probably from dead algae in the stream and organic matter carried into the stream, and not from point sources. The depressed DO is probably a result of benthic demands from the settled algae along with the BOD decay in the water column. Figure VI-2 shows the oxygen deficit (or increase) from algae growth and respiration of a net increase of 1 mg/l per day and from a benthic demand of 1 g/m^2/day. If the benthic demand were very great, the impact could be significant on the stream dissolved oxygen. For every 1 g/m^2/day of demand, almost 1.35 mg/l of oxygen would be consumed in the water column. Likewise, if algal growth were high, an increase in dissolved oxygen in the stream would be seen. However, when the algae population recedes, it may consume oxygen. Both the benthal oxygen demand and algal interactions should be measured to determine their influence on stream dissolved oxygen. Since flow in the Little Cypress is usually zero for some days each year, it is likely this will still occur.

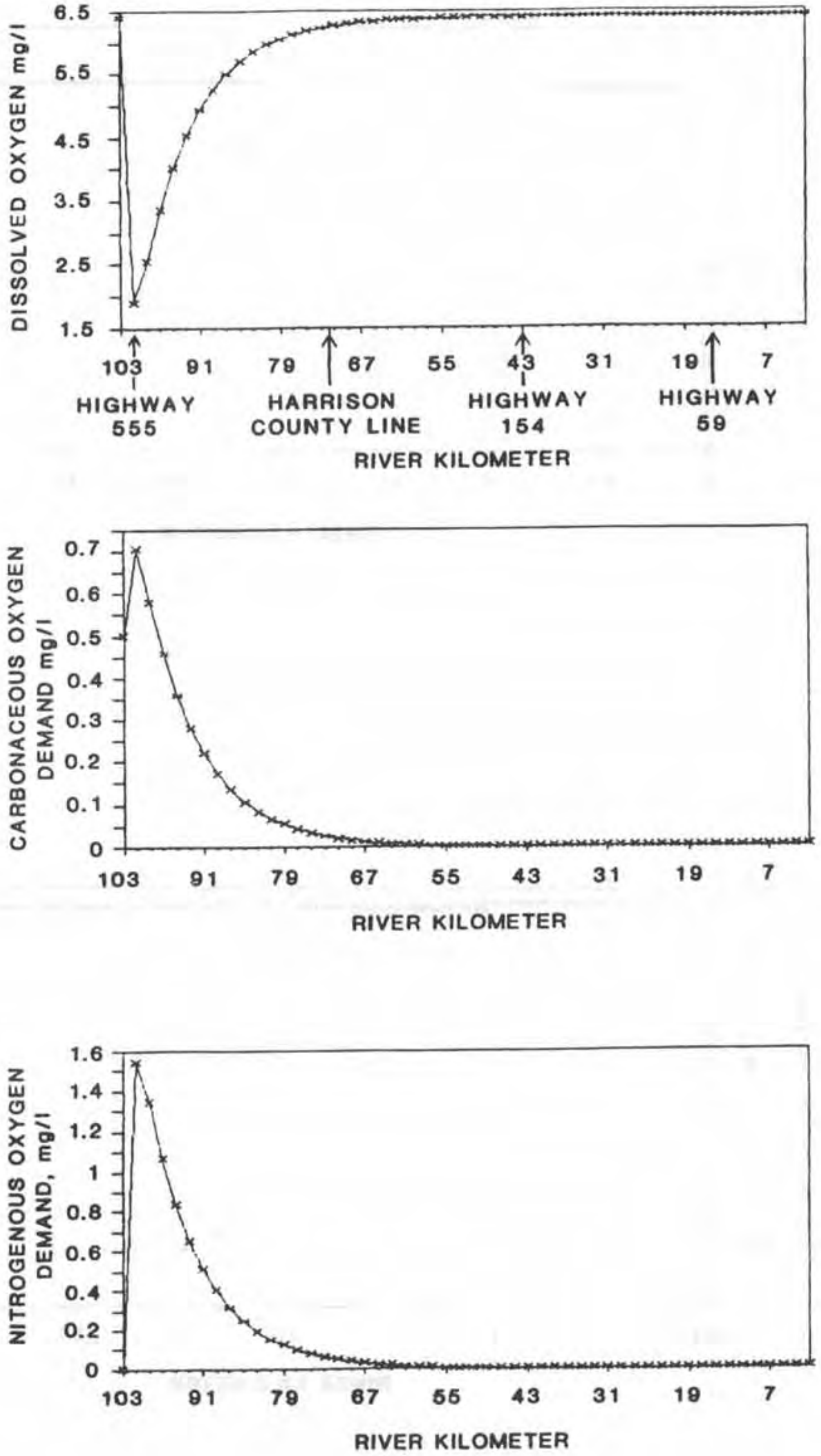

Figure VI-1

CALCULATED DISSOLVED OXYGEN AND OXYGEN DEFICITS FOR FUTURE CONDITIONS IN LITTLE CYPRESS CREEK.

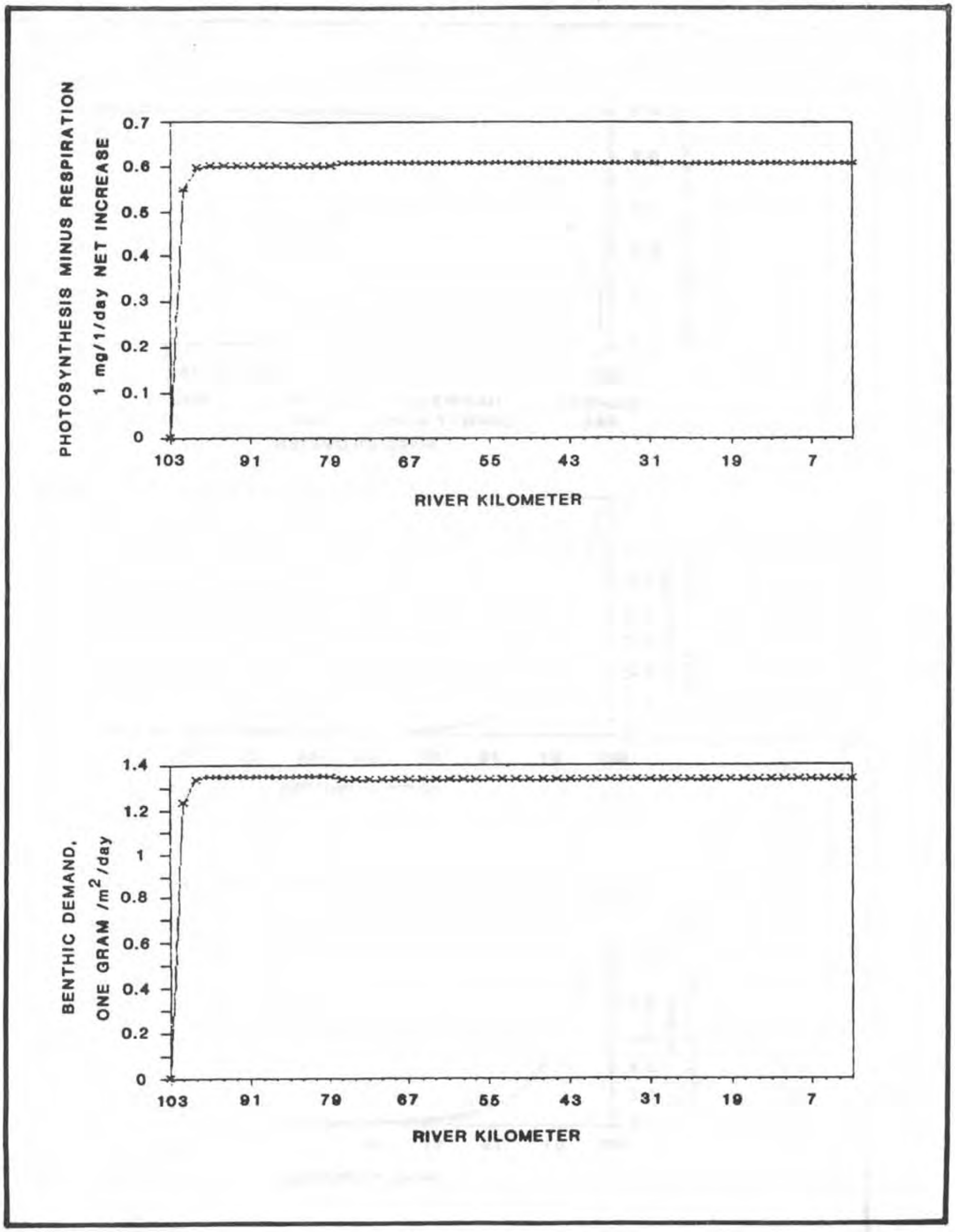

Figure VI - 2

DEFICIT CREATED BY A UNIT INPUT OF BENTHIC OXYGEN DEMAND AND INCREASE CREATED BY UNIT INPUT BY ALGAE

FUTURE CONDITIONS WITH A LAKE AT MARSHALL DAMSITE

Dissolved oxygen below the proposed lake will primarily be influenced by the sustained level of release and the depth of the outflow works in the lake. Since the lake is likely to stratify during the warmer months, the hypolimnion will have very low levels of dissolved oxygen. Release of this water into the 20 miles of channel below the dam would result in depressed DO. The flow released would also affect the reaeration rate of the water. As velocity increases, so does reaeration. By careful planning and design the downstream DO could be enhanced.

The detention time of the lake would allow all point source oxygen consuming material to be degraded before it flows out of the lake. The BOD in the water being released would be a result of the algae growth in the lake. From the earlier predicted chlorophyll 'a', a BOD_5 concentration of about 0.4 mg/l may be estimated. This means the oxygen demand in reach below the lake would be less than its current state, and by manipulation the flow and outlet level in the lake, the dissolved oxygen levels may be further enhanced.

Water from the lake will be suitable for all municipal and industrial uses. The treatment of surface water for use as drinking water requires chemical coagulation and filtration. This should remove the color, iron, and manganese to acceptable levels. The already low total dissolved solids would not require additional softening. Since the segment is already classified as suitable for all contact recreation, the proposed lake should be suitable for all forms of recreation. Fecal coliform levels observed at Lake O' the Pines show that there is no apparent problem for contact recreation, and the same should be true for the proposed lake.

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CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX H - COORDINATION WITH THE U.S. FISH AND WILDLIFE SERVICE

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX H - COORDINATION WITH THE U.S. FISH AND WILDLIFE SERVICE

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CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX H - COORDINATION WITH THE U.S. FISH AND WILDLIFE SERVICE

SECTION 1

A REPORT ON THE AQUATIC RESOURCES OF THE CYPRESS BAYOU BASIN, TEXAS

JULY 1984

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
FORT WORTH, TEXAS

A REPORT
ON THE
AQUATIC RESOURCES
OF THE
CYPRESS BAYOU BASIN, TEXAS

JULY 1984

PLANNING AID REPORT

on the

AQUATIC RESOURCES

of the

CYPRESS BAYOU BASIN, TEXAS

Prepared by
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Reviewed by
Jerome L. Johnson, Fish and Wildlife Administrator

U.S. FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
FORT WORTH, TEXAS
JULY 1984

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INTRODUCTION

The following aquatic resources information is provided as planning assistance on the Cypress Bayou Basin study. It has been prepared in accordance with Section 2(a) of the Fish and Wildlife Coordination Act (48 Stat.401, as amended; 16 U.S.C. 661 et seq.) and the fiscal year 1984 Transfer Funding Agreement, Appendix A Scope of Work.

A planning aid report, dated January 22, 1981, was previously provided to the Corps of Engineers describing the effect various flow regimes in Big Cypress Bayou below Lake O'the Pines would have or stream fisheries habitat. Preliminary aquatic resources data on Cypress Bayou Basin was also provided in a second planning aid letter of March 16, 1982. The latter report presented a brief description of the basin's aquatic resources and a discussion of problems, needs, and opportunities for these resources.

The purpose of this current report is to provide detailed aquatic resources data for use by the Fort Worth District during the project Plan Formulation Conference scheduled for September 1984. Specific objectives include the presentation of aquatic baseline information, characterization of aquatic habitats within the project area, and development of preliminary instream flow and fishery-related recreation recommendations.

Should the District identify a viable water resources project in the Cypress Bayou Basin, fish and wildlife studies will be refined during subsequent planning activities, and recommendations to protect, mitigate, or enhance these resources will be provided in a final Fish and Wildlife Coordination Act report.

DESCRIPTION OF THE STUDY AREA

The Cypress Bayou Basin study area is located primarily in northeast Texas, upstream from and including Caddo Lake. It is bounded on the north by the Sulphur River Basin, on the west and south by the Sabine River Basin, and on the east by Twelvemile Bayou Basin. The watershed lies within Franklin, Wood, Titus, Camp, Morris, Cass, Upshur, Gregg, Marion, and Harrison Counties in Texas and Caddo Parrish, Louisiana (Plate 1).

Major streams of the Cypress Bayou Basin study area include Big Cypress, Little Cypress, and Black Cypress Bayous. Above its confluence with Little Cypress and Black Cypress Bayous, Big Cypress drains 950 square miles. Little Cypress and Black Cypress have drainages of 730 and 390 square miles, respectively. The entire basin, including Caddo Lake, has a length of approximately 88 miles, maximum width of 48 miles, and drains 2,780 square miles. The Cypress Bayou watershed represents about 1.1 percent of the total area of Texas.

Climate of the Cypress Bayou Basin is generally considered subtropical with hot, humid summers and relatively mild winters. Precipitation is evenly distributed throughout the year and averages 45 inches.

More detailed information on the climatology, topography, geology, and description of the study area watershed can be found in reports by the Texas Water Development Board (1966), Smith et al (1966), U.S. Army Corps of Engineers (1968, 1981) and Kindle, Stone & Associates, Inc. (1982).

AQUATIC RESOURCES

Three major types of aquatic ecosystems occur within the Cypress Bayou Basin. These include natural streams, stock ponds and small conservation lakes, and large manmade reservoirs. For the purposes of this report, discussions will be limited to streams and reservoirs greater than 250 surface acres, since these ecosystems are the most likely to be impacted or created by water resources development projects.

Ponds and other small water areas provide important aquatic habitats and a significant recreational fishery. However, the extent of these waters in the basin planning area has not been accurately or recently inventoried. In 1967, the U.S. Soil Conservation Service (1970) estimated a total of 6,547 surface acres of small water areas between 2-40 acres in size occur within the five major counties of the Little and Black Cypress Bayou watersheds. This was an increase over the 5,600 surface acres inventoried in 1958 by SCS. Biological or recreational data are generally not available for these small water areas, because they are privately owned and have no public access facilities or management.

Stream Habitats

Lotic habitats within the Cypress Bayou Basin are diverse, ranging from intermittent headwaters to perennial, sluggish meandering streams. Within the Texas portion of the Cypress Basin, there are approximately 380 miles of free-flowing streams. Numerous oxbows, sloughs, and backwaters occur throughout the basin, especially in its lower reaches near Caddo Lake. Plates 2 and 3 display major stream habitat features observed during surveys of the basin. These features primarily include riffles, heavily timbered runs, open water pools, and backwaters or sloughs.

Substrates of the streams are relatively homogeneous and are composed primarily of sand, silt, clay, or organic detritus. The nature of the substrate depends upon the geology and runoff characteristics (i.e., soils, topography, stream gradient, current velocity, etc.) of the specific stream.

Aquatic vegetation in Cypress Basin streams is dictated by these same physical features as well as the fluctuating nature of the streams and their water quality. The most common aquatic plants noted during field surveys included smartweeds (Polygonum spp.) pondweeds (Potamogeton spp.), duckweed (Lemna sp.), water primrose (Ludwigia peploides), and a variety of sedges and rushes. Major woody species occurring on the stream banks or overhanging the stream include baldcypress (Taxodium distichum), water elm (Planera aquatica), black willow (Salix nigra), and buttonbush (Cephalanthus occidentalis). These latter species provide important canopy and instream cover for aquatic life, especially where their rootwads or limbs interface with the stream's surface (Plate 4).

Water quality of the basin is rated as good to excellent with most parameters exceeding the State water quality standards (Freese and Nichols 1977, WAPORA 1981, Kindle, Stone & Associates 1982). Localized water quality problems have occurred in the basin, however, as a result of low dissolved oxygen levels and elevated concentrations of chlorides, total dissolved solids, coliforms, and nutrients.

Low dissolved oxygen levels (<5.0 mg/l) typically occur during the summer months and result from a combination of high water temperatures, low stream flows, and oxidation of naturally occurring organic materials deposited in the stream from forestland runoff. The lowest concentrations of dissolved oxygen in the basin (yearly averages between 5.5 and 5.9 mg/l) occur in Black Cypress Bayou, Segment 406, and Jim's Bayou, Segment 407. Higher chlorides, total dissolved solids, coliforms, and nutrient concentrations are generally attributed to industrial, municipal, and residential discharges to the basin's waters. Oil field brines have also contributed to the deterioration of water quality.

Stream flows in Little Cypress and Black Cypress Bayous are relatively uninfluenced by man's activities. No major impoundments or diversions have been constructed on either the main stem or tributaries of these streams. In contrast, extensive water resources development has occurred on Big Cypress Bayou.

According to U.S. Geological Survey records for water years 1947-1983, annual stream flows as measured at the Little Cypress Bayou gage 6.8 miles upstream of its confluence with Big Cypress Bayou (U.S.G.S. 07346070) averaged 527 cubic feet per second (cfs). Average median flow was 285 cfs. Discharges at Black Cypress gage (U.S.G.S. 07346045) located 5.2 miles upstream from its mouth had annual mean and median values of 333 and 184 cfs, respectively.

Stream Fishery

Little baseline data is available on the stream fishery of Cypress Bayou Basin. Texas Parks and Wildlife Department conducted a basic survey and inventory of fish species present in the Marion County portions of Little, Black, and Big Cypress Bayous in the early 1950's (Kemp 1954a, 1954b). In 1956, a similar study was conducted by the State for upstream counties of the basin (Bonn 1956). In 1980, Central and Southwest Services, Inc. sampled aquatic habitats on Big Cypress, Little Cypress, and four nearby creeks in conjunction with baseline studies for a potential lignite surface mine near Karnack, Texas (Central and Southwest Services 1980). A composite checklist of the fish species observed during these studies is included as Appendix A to this report.

A total of 71 fish species were observed during the surveys, with a similar number of species found in Little Cypress, Black Cypress, and Big Cypress

Bayous. Three species, the bowfin, creek chubsucker and striped shiner, were observed only in the smaller tributary streams and may be indicative of the specialized habitat preferences of these fish. Major stream sport fishes include the largemouth and spotted bass, channel catfish, white bass, white and black crappie, and the sunfishes. Primary forage species include gizzard and threadfin shad, forage size sunfishes, and various shiners, minnows and suckers.

The variety of species collected throughout the Cypress Basin is indicative of the high diversity and quality of the lotic habitats. These habitats have high value for aquatic species and are becoming scarce on a national and ecoregion basis due to man's activities such as water resources, agricultural, and forestry development. The Fish and Wildlife Service classifies Cypress Bayou Basin stream habitats as Resource Category 2 and prescribes a mitigation goal of "no net loss of in-kind habitat value" (U.S. FWS 1981).

Reservoir Habitats

Extensive water resources development has occurred on Big Cypress Bayou. Eight reservoirs ranging in size from 650 to 26,800 surface acres at normal pool elevation have been constructed for municipal and industrial water supply, recreation, and flood control (Table 1).

Table 1. Pertinent data for existing reservoirs, Cypress Bayou Basin, Texas.

	Conservation Pool	
Reservoir	Capacity (Acre-ft.)	Surface Area (Acres)
Lake Cypress Springs	100,400	3,400
Monticello	40,100	2,000
Bob Sandlin Lake	213,350	9,460
Ellison Creek	24,700	1,516
Johnson Creek	10,100	650
Welsh	23,587	1,365
Caddo Lake	128,810	26,800
Lake O'the Pines	254,900	18,700

These reservoirs provide excellent lentic habitats for a variety of warm water fish species. In general, most of the reservoir watersheds contain large amounts of upland and bottomland timber, much of which was left uncleared and inundated during impoundment. The relatively flat topography of the watersheds and numerous small tributary streams also provides abundant shorelines with large littoral areas. The combination of large amounts of timber, brush, littoral zones, and nutrients provides for a highly productive fishery.

Lush growths of aquatic vegetation provide ample cover and a food source for forage and sport fishes within the basin's impoundments. Management surveys indicate American lotus (Nelumbo lutea) and water hyacinth (Eichornia crassipes) are the two most common floating aquatics. Other major floating and submerged species include pondweeds, water milfoil (Myriophyllum spicatum), muskgrass (Chara sp.), coontail (Ceratophyllum demeraum), elodea (Elodea densa), parrotfeather (Myriophyllum brasiliense), water primrose, and duckweed (Toole 1981, 1983a, 1983b). A checklist of aquatic plants noted during State management surveys of basin reservoirs is attached as Appendix B.

Aquatic vegetation is normally abundant in shallow-water shoreline areas by mid-summer and is often considered noxious due to its impact on reservoir recreation activities. However, control measures are normally required only in high-use recreation areas.

Physiochemical characteristics of the reservoirs are typical of other impoundments located in the east Texas pineywoods ecoregion. pH levels are slightly acidic and total alkalinity, specific conductance, turbidity, and total hardness are relatively low. The reservoirs thermally stratify during the hot summer months. Low dissolved oxygen concentrations are also common due to decomposition of organic materials and a lack of water mixing from reduced inflows and wind action. However, no major water quality problems harmful to the fish populations have been observed during the State's fisheries management surveys.

Reservoir Fishery

Numerous surveys have been conducted on basin reservoirs by the Texas Parks and Wildlife Department during the course of their fisheries management activities. The State's surveys indicate the reservoirs provide an excellent fishery. Major species sought by fishermen include the largemouth bass, white bass, channel and flathead catfish, and white and black crappie. Other important sport fishes are the bluegill, redear sunfish, spotted bass, chain pickerel, and introduced hybrid striped bass. Primary forage species are the gizzard and threadfin shad, forage size sunfishes, shiners, and minnows (Toole 1981, 1983a, 1983b). Appendix C provides a composite checklist of 66 fish species collected in major reservoirs of the Cypress Basin.

Standing crop estimates for Caddo Lake, Lake O'the Pines, and Bob Sandlin Lake, based on cove rotenone sampling, illustrate the productivity of these waters. In 1980, Caddo Lake yielded a total of 1,062 pounds of fish per acre of cove sampled (Toole 1981). Approximately 9 percent (%) of this total was sport fish, while 87% of the total represented one forage species - gizzard shad. Most of the shad were greater in length than 8 inches and were not considered forageable size. Sampling bias is thought to have contributed to this unbalanced situation, since samples sites were selected in relatively deep coves and large schools of shad moved into the area prior to treatment. Discounting the gizzard shad collection, largemouth bass composed about 8.5 pounds per acre or 6.4% of the standing crop. According to Toole, however, the representation of catchable size largemouth bass in the 1980 Caddo Lake data does not accurately represent the standing crop of this important sport fish, since sampling could not be conducted in the numerous bayous and secondary channels of the lake which concentrate fish during the summer months.

Cove rotenone data for Lake O'the Pines and Bob Sandlin Lake may be more indicative of the sport fishery. Average standing crops, based on two years of data for each reservoir, yielded approximately 299 and 177 pounds of fish per acre, respectively. Sport fish comprised 63% of this total at Lake O'the Pines and 42% at Bob Sandlin. These numbers are high, since most of the sunfishes are included as sport fish, and the standing crops have not been adjusted to reflect that portion of the sunfish population of forage size. Black bass populations averaged 37.5 pounds per acre or 12.4% of the population at Lake O'the Pines and 22.2 pounds per acre or 11.3% of the population at Bob Sandlin.

Several of the basin's reservoirs, particularly Monticello and Welsh, have become well known for their trophy largemouth bass fishing and are drawing widespread interest from the press, outdoor publications, and bass clubs. As of Spring 1984, six of the top 10 largemouth bass in Texas came from these two reservoirs. The second largest, a 15-pound, 3-3/4 ounce fish, was taken from Lake Welsh and is the largest bass ever taken from public waters in Texas. The introduction of Florida-strain largemouths in the early 1970s is generally credited with the success of the largemouth bass fishery on these reservoirs.

AQUATIC EVALUATION METHODOLOGY

Pursuant to the FY 1984 Scope of Work and coordination with members of the Corps of Engineers planning team, this report provides preliminary recommendations concerning instream flows for Little Cypress and Black Cypress Bayous. Instream flow studies are being conducted on these streams to correspond with water development alternatives (i.e., Marshall and Black Cypress Lakes) being evaluated by the Fort Worth District. Preliminary human use and economic data, in the form of estimated recreation resource requirements, is also provided for economic analyses.

Instream Flow Methodology

Streamflows were evaluated using the Fish and Wildlife Service Instream Flow Incremental Methodology (IFIM). This method quantifies available aquatic habitat for target evaluation species and their individual life history stages (i.e., adult, spawning, fry, and juvenile) at different flow regimes. Such information can be utilized to identify streamflow levels or other management features necessary to meet fishery management objectives for the stream (Bovee 1982).

The IFIM consists of two subroutines: (1) a hydraulic simulation model and (2) a habitat model. The hydraulic model simulates velocity, depth, and substrate distributions within a channel as flow is varied and expresses these measurements as surface area. The model is calibrated with field measurements of a known flow. Several hydraulic simulation techniques are available, however, for the purposes of this initial planning aid report the one-flow, Water Surface Profile (WSP) model was used. This model requires only one set of cross-section and water surface elevation measurements to calibrate, and is useful for developing "ball park" estimates of habitat conditions. More detailed hydraulic simulation models (i.e., the three-flow, IFG-4 program) will be used to refine the streamflow recommendations as additional data is collected and planning progresses on the Cypress Basin project.

The habitat program or Physical Habitat Simulation System (PHABSIM), uses probability-of-use or habitat preference curves of target evaluation species to compute a species' preference for a combination of velocity, depth, and substrate conditions. This preference factor is multiplied by the surface area of the stream having that specific velocity, depth, and substrate combination to obtain the species' weighted usable area (WUA). WUA's, which are analagous to habitat units of the Habitat Evaluation Procedures, can be calculated for a range of flows thus providing an estimate of the impact of streamflow changes on aquatic habitats.

The calibration flows measured on Little Cypress and Black Cypress Bayous permitted an extrapolation range of 25-150 cfs for evaluation in this report. All field hydraulic measurements and PHABSIM analyses referenced above were conducted in accordance with published IFIM guidance manuals (Bovee and Milhous 1978, Milhous et al. 1981, Bovee 1982). Field techniques used in the collection of hydrologic stream data are illustrated in Plate 5.

Study sites for the streamflow investigations were selected on Little Cypress and Black Cypress Bayous in the vicinity of the alternative damsites under consideration. Two reaches were evaluated on Little Cypress--one immediately downstream from the Highway 154 crossing and one upstream of the Highway 3001 crossing. The Highway 154 site is located in the proposed Marshall Reservoir basin, while the Highway 3001 site is approximately 3 1/2 miles downstream of the damsite. The study reach on Black Cypress Bayou is located north of Berea, about 3/4 mile above the proposed damsite. Study sites were selected on the basis of their representativeness of the streams and their ability to provide access for boats and other field equipment. Photographs of the selected study reaches are provided in Plates 6, 7, and 8.

Instream flow recommendations for the Cypress Basin are based on the habitat needs of the channel catfish, spotted bass, white bass, longear sunfish, and river darter. These species were selected for evaluation because of their preference for stream habitats during all or part of their life cycle, their significance as sport fish, their varied reproductive and feeding requirements, and the availability of habitat preference curves. Due to project time constraints, existing species preference curves, developed by the Cooperative Instream Flow Group of the U.S. Fish and Wildlife

Service, were used to compute WUA's in the IFIM analyses. These curves, constructed from criteria and guidance provided by Bovee and Cochnauer (1977), are attached as Appendix D.

The preference curves utilized are drafts developed during efforts to collate published data related to the preferences of fish for such hydraulic parameters as velocity, depth, and substrate. The Fort Worth Ecological Services field office is currently cooperating with the Corps District and Waterways Experiment Station in a cooperative fishery study of the Cypress Bayou Basin. The objective of this study is to gather fisheries data specific to the Cypress Basin and to develop species preference curves for application of IFIM and Habitat Evaluation Procedures during project impact analyses. Techniques utilized for the collection of this fisheries data are illustrated in Plates 9 and 10. Additional biological and hydrological sampling will allow refinement of the instream flow recommendations as planning proceeds.

Recreation Supply-Demand Analysis

This report provides estimates of the recreation resource requirements in mandays needed to maintain the quality of sportfishing within the Cypress Bayou Basin study area. For the purposes of this recreation analysis, the five major counties drained by Little Cypress and Black Cypress Bayous were considered. These counties are Cass, Gregg, Harrison, Marion, and Upshur (Plate 1).

Fishing recreation supply data for streams and reservoirs was developed from inventories of aquatic habitat and estimated fisheries production and harvest statistics (Wood 1961; Toole 1975, 1976). For these evaluations, it was assumed that the total resource capability or mandays supply would remain constant through the period of analysis, 1980-2000. However, under actual conditions supply would be expected to vary as a result of unquantifiable factors such as losses or gains of habitat, population dynamics, and fisheries management activities.

Fishing recreation demand data was supplied by the Comprehensive Planning Branch of the Texas Parks and Wildlife Department. This data, abstracted from the 1968 Household Demand Survey and Texas Outdoor Recreation Plan, represents the total resident and non-resident fishing pressure exerted upon the study area (TPWD 1981).

Fishing recreation resource requirements, or needs for fishing in mandays, are the difference between supply and demand available for the county within the study area. Preliminary data are also provided on the estimated sportfishing gains or losses which could potentially occur from development of alternative damsites in the basin, based upon the maximum resource capability of the reservoir and streams.

RESULTS AND DISCUSSION

Instream Flow Methodology

The range of streamflows evaluated during the Water Surface Profile (WSP) hydraulic simulation (i.e., 25-150 cfs) permitted the identification of maintenance flows for Little Cypress Bayou and Black Cypress Bayou. Maintenance flow is basically defined as the instantaneous discharge required to maintain the fishery at a biologically acceptable level of productivity, or the flows necessary to maintain the status quo of the stream fishery. These maintenance flows are the baseline by which the health of the ecological system should be judged, and from which incremental impacts or enhancement values can be evaluated.

The current WSP hydraulic simulation can not be used to identify minimum (survival) or optimum flows for these streams, since the one calibration flow does not allow extrapolation to lower or higher flows than 25 and 150 cfs, respectively. Project investigations will be conducted the remainder of this fiscal year to gather additional hydraulic and biological data for refinement of the IFIM and for input into the Cooperative Fishery Study.

Weighted usable areas (WUA's) computed from the WSP hydraulic simulation for the five evaluation species are summarized in Tables 2, 3, and 4 for the three study sites. Only the adult life stage of the longear sunfish and river darter was evaluated due to the lack of preference curves on other life history stages. These WUA's were plotted versus the discharges simulated in order to determine the inflection point (i.e., where each incremental decrease in flow sharply reduces WUA and each incremental increase in flow yields a marginal increase in WUA). This inflection point was assumed to represent the maintenance flow required for the species' life history stage.

WUA's for spawning, fry, juvenile, and adult life history stages of the evaluation species as determined for the Little Cypress Bayou, Highway 154, site are displayed in Figures 1-4. At this site, stream flows ranging from 50-100 cfs appear to represent the level at which evaluation species can maintain an adequate spawn (Figure 1). Figure 2 indicates that fry appear to require a flow of 50-75 cfs. Juveniles and adults appear to require maintenance flows of approximately 50 and 100 cfs, respectively. The higher flow levels required for adults and spawning is generally indicative of the affinity of the evaluation species for medium to larger rivers and the greater space requirements of the species to carry out their biological functions (Orth and Maughan 1981, Bovee 1982).

Figures 5-8 and Table 3 display the WUA's determined by the IFIM for Little Cypress Bayou just upstream of Highway 3001. Spawning requirements for the channel catfish, spotted bass, and white bass are approximately 100 cfs, although WUA's increase throughout the range of flows simulated (Figure 5).

Table 2. Weighted usable area in ft^2/1,000 ft. of stream for Little Cypress Bayou at Highway 154, January 31, 1984.

Life Stage Evaluation Species	Discharge (cfs)					
	25	50	75	100	125	150
Spawning						
Channel catfish	11,256	27,527	36,847	40,395	40,841	40,531
Spotted bass	36,853	43,153	38,193	33,352	26,989	24,674
White bass	17,736	22,376	24,463	27,913	29,274	30,028
Fry						
Channel catfish	2,477	3,635	4,507	4,901	5,175	5,356
Spotted bass	20,748	35,712	41,835	44,519	46,657	49,964
White bass	37,132	40,487	38,322	37,123	34,098	33,366
Juveniles						
Channel catfish	1,925	2,872	2,992	2,651	2,341	2,203
Spotted bass	21,482	33,675	36,574	37,366	38,352	39,680
White bass	26,191	38,945	43,517	47,775	50,947	53,408
Adults						
Channel catfish	3,455	12,500	21,297	26,650	30,281	33,293
Spotted bass	8,766	26,182	37,858	42,237	43,879	45,606
White bass	5,614	19,416	31,370	38,396	41,805	44,473
Longear sunfish	34,828	38,952	34,224	29,281	32,755	34,485
River darter	25,746	34,545	38,558	41,681	47,727	52,680

Table 3. Weighted usable areas in ft.^{2}/1,000 ft. of stream for Little Cypress Bayou at Highway 3001, February 1, 1984.

Life Stage & Evaluation Species	Discharge (cfs)					
	25	50	75	100	125	150
Spawning						
Channel catfish	2,335	7,116	11,084	13,931	15,473	16,699
Spotted bass	19,424	27,536	33,498	37,828	40,031	41,635
White bass	10,639	16,497	20,739	24,906	28,276	31,482
Fry						
Channel catfish	3,119	5,069	6,673	8,134	9,518	10,853
Spotted bass	6,694	12,353	15,214	15,710	16,596	16,632
White bass	17,984	24,985	27,979	29,483	30,679	31,875
Juveniles						
Channel catfish	859	1,614	2,298	2,793	3,114	3,350
Spotted bass	5,918	9,874	11,757	12,893	13,875	14,321
White bass	10,861	18,927	25,224	29,744	34,125	37,627
Adults						
Channel catfish	1,683	6,084	12,052	17,029	19,942	22,860
Spotted bass	1,028	5,736	9,847	12,422	13,457	14,773
White bass	764	4,457	9,330	13,441	17,508	20,961
Longear sunfish	16,283	17,812	16,145	16,812	18,584	20,414
River darter	16,324	25,192	30,497	36,018	40,845	45,239

Table 4. Weighted usable areas in ft.^{2}/1,000 ft. of stream for Black Cypress Bayou Near Berea, February 2, 1984.

Life Stage & Evaluation Species	Discharge (cfs)					
	25	50	75	100	125	150
Spawning						
Channel catfish	4,682	13,031	18,588	22,380	23,544	24,000
Spotted bass	26,895	32,755	36,431	37,079	36,377	34,897
White bass	14,196	18,417	21,980	24,911	27,456	29,724
Fry						
Channel catfish	2,907	4,512	5,818	6,978	7,966	8,723
Spotted bass	11,353	20,611	26,265	26,657	26,019	24,717
White bass	27,192	30,946	31,657	31,462	30,534	29,928
Juveniles						
Channel catfish	1,229	2,056	2,535	2,795	2,874	2,828
Spotted bass	11,340	16,697	18,795	18,617	18,496	18,261
White bass	16,257	25,653	31,271	34,818	37,665	40,324
Adults						
Channel catfish	1,975	8,931	16,497	24,175	28,200	30,369
Spotted bass	2,783	11,458	18,091	22,580	23,153	23,044
White bass	1,908	7,491	14,549	20,445	24,994	28,766
Longear sunfish	23,556	20,535	17,729	16,913	15,760	15,166
River darter	19,817	27,791	32,768	36,586	39,983	42,830

FIGURE 1

LITTLE CYPRESS BAYOU AT HIGHWAY 154

LIFE STAGE & EVALUATION SPECIES

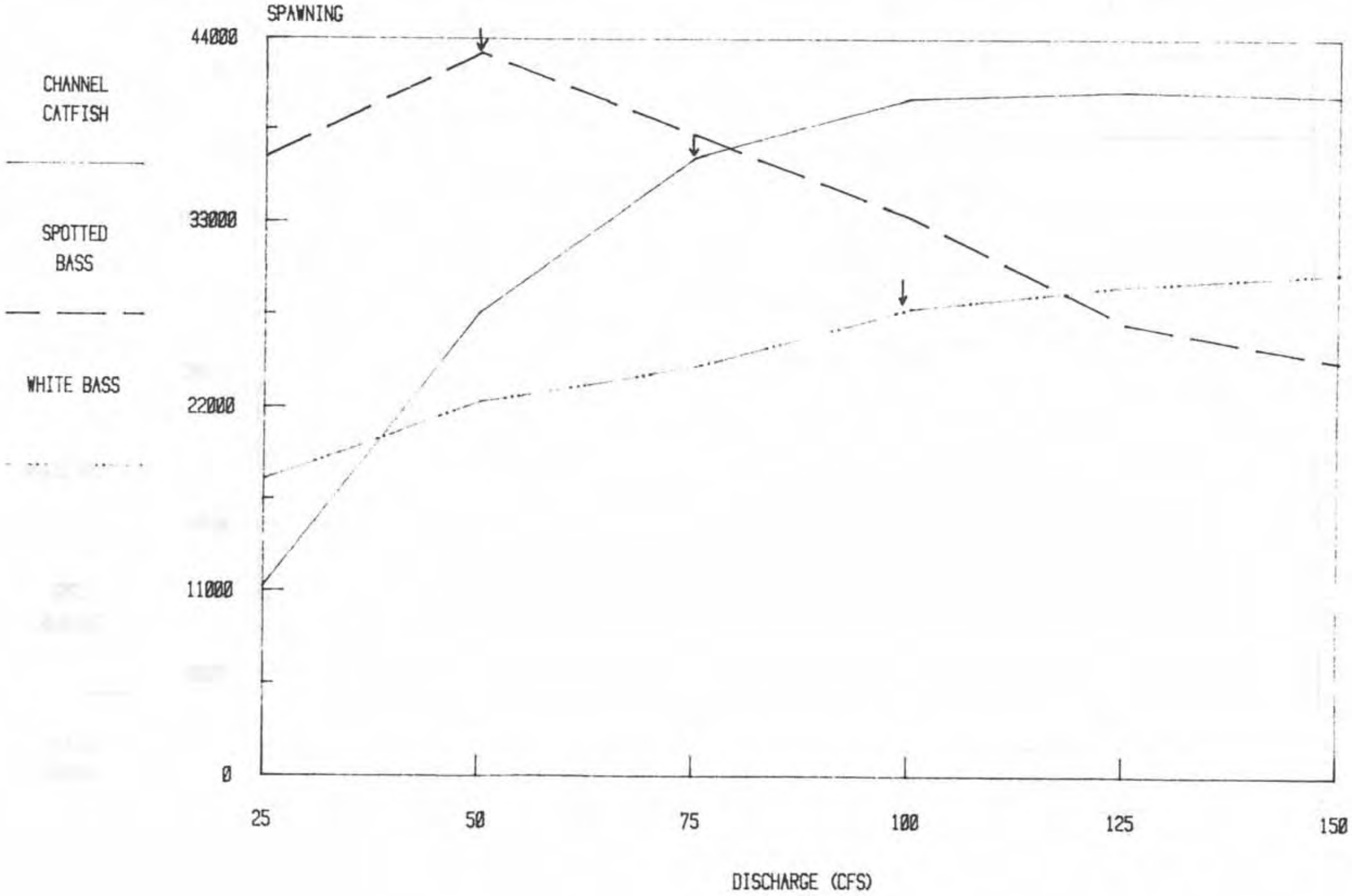


FIGURE 2

LITTLE CYPRESS BAYOU AT HIGHWAY 154

LIFE STAGE AND EVALUATION SPECIES

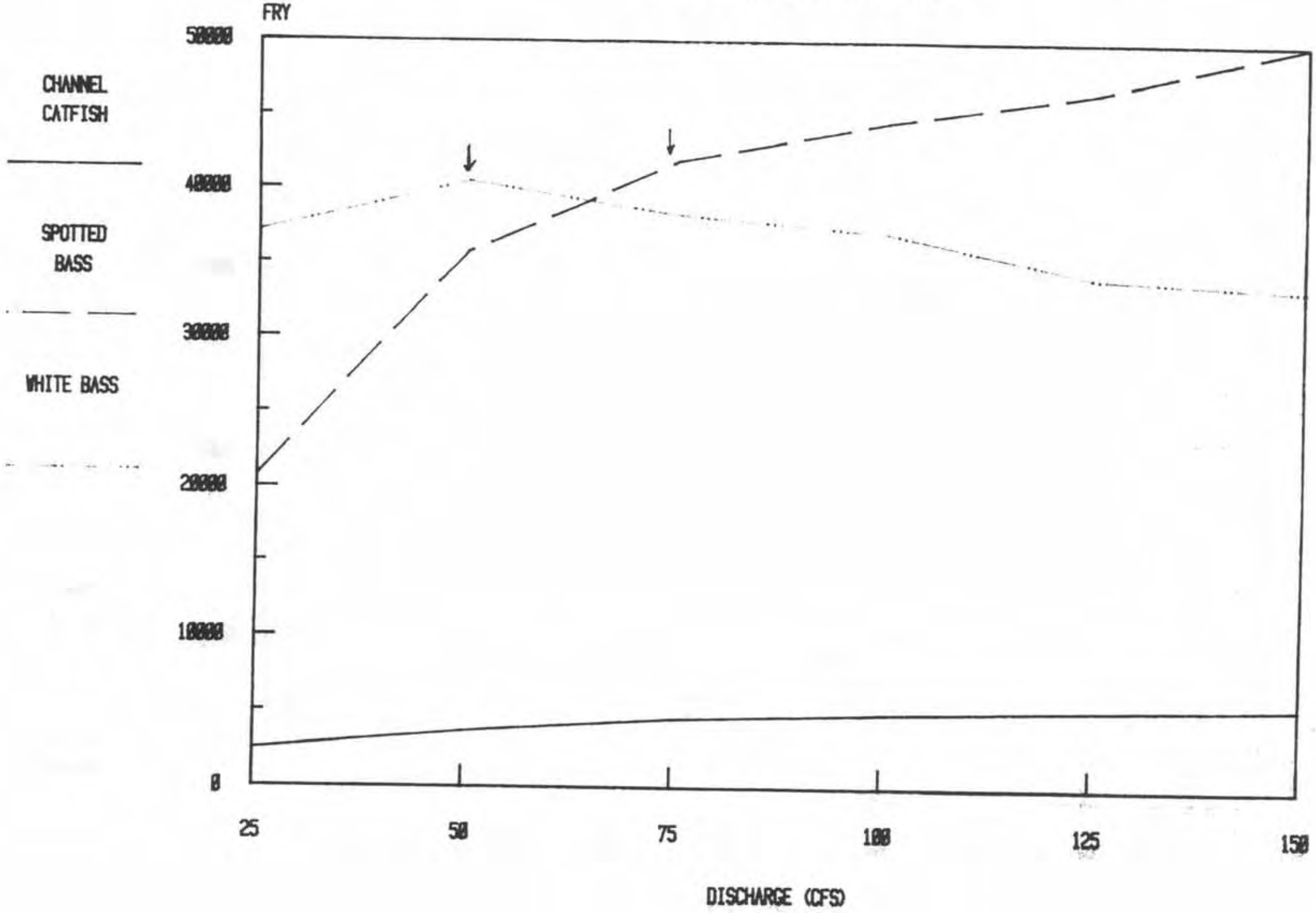


FIGURE 3

LITTLE CYPRESS BAYOU AT HIGHWAY 154

LIFE STAGE AND EVALUATION SPECIES

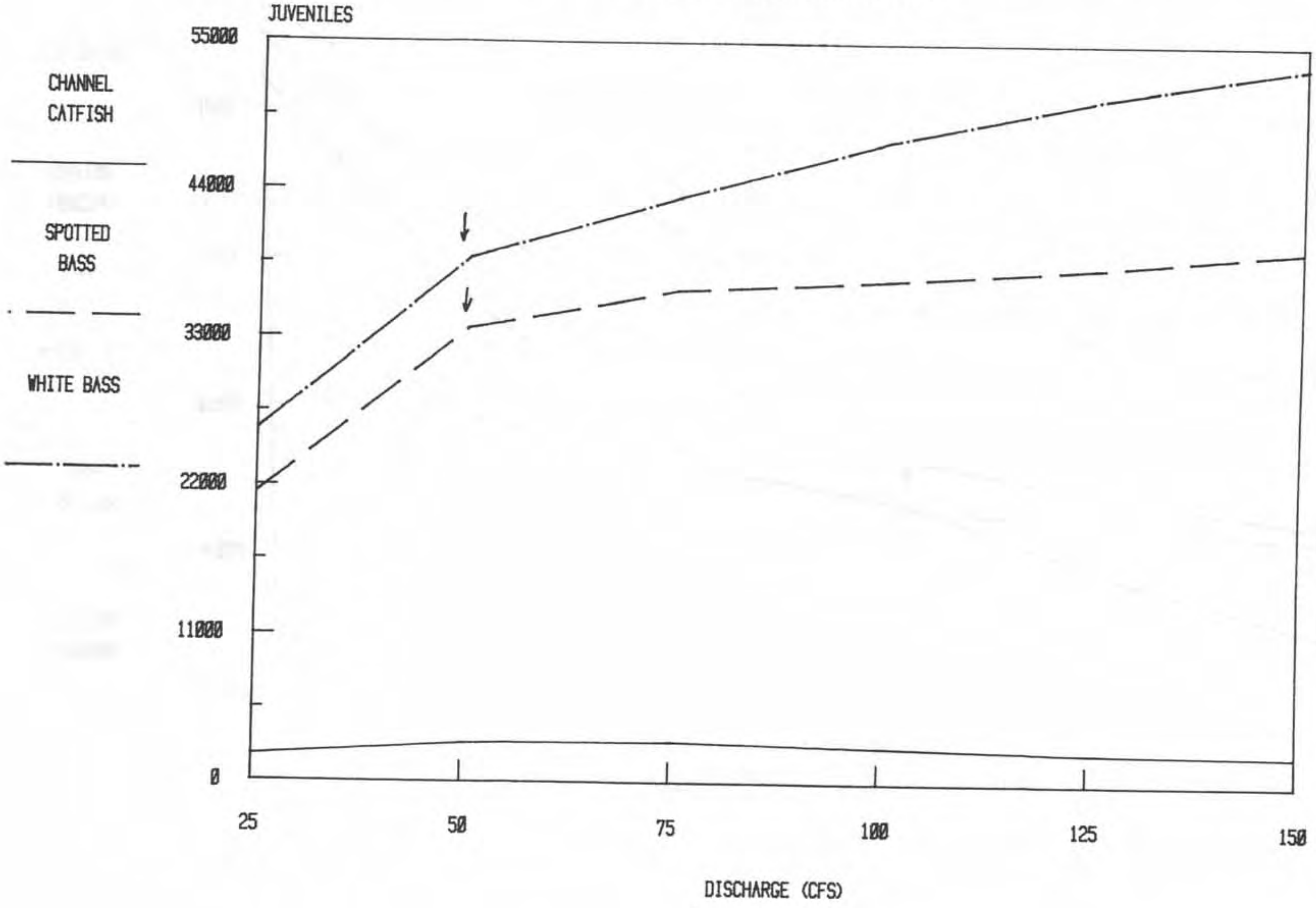


FIGURE 4

LITTLE CYPRESS BAYOU AT HIGHWAY 154

LIFE STAGE AND EVALUATION SPECIES

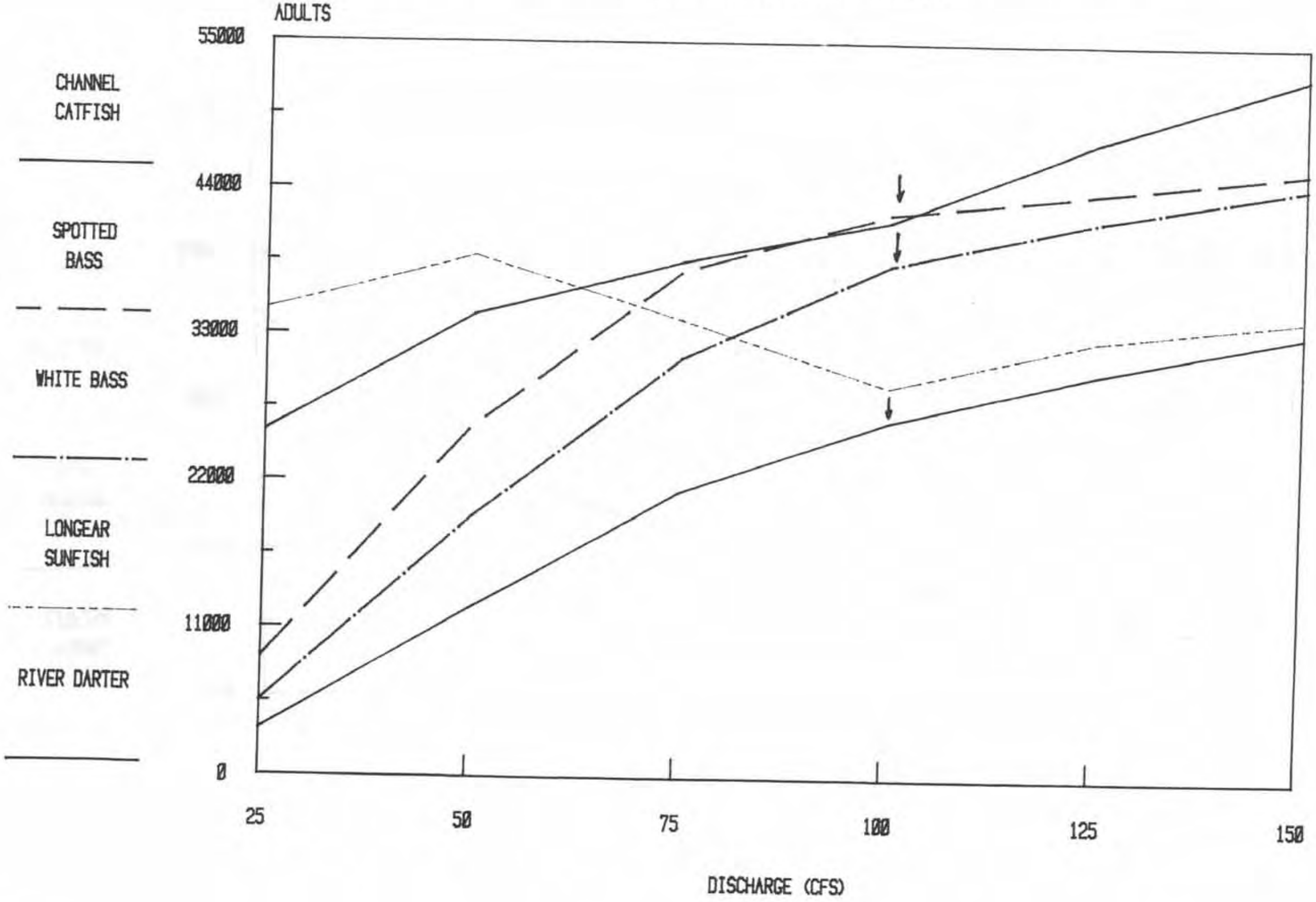


FIGURE 5

LITTLE CYPRESS BAYOU AT HIGHWAY 3001

LIFE STAGE AND EVALUATION SPECIES

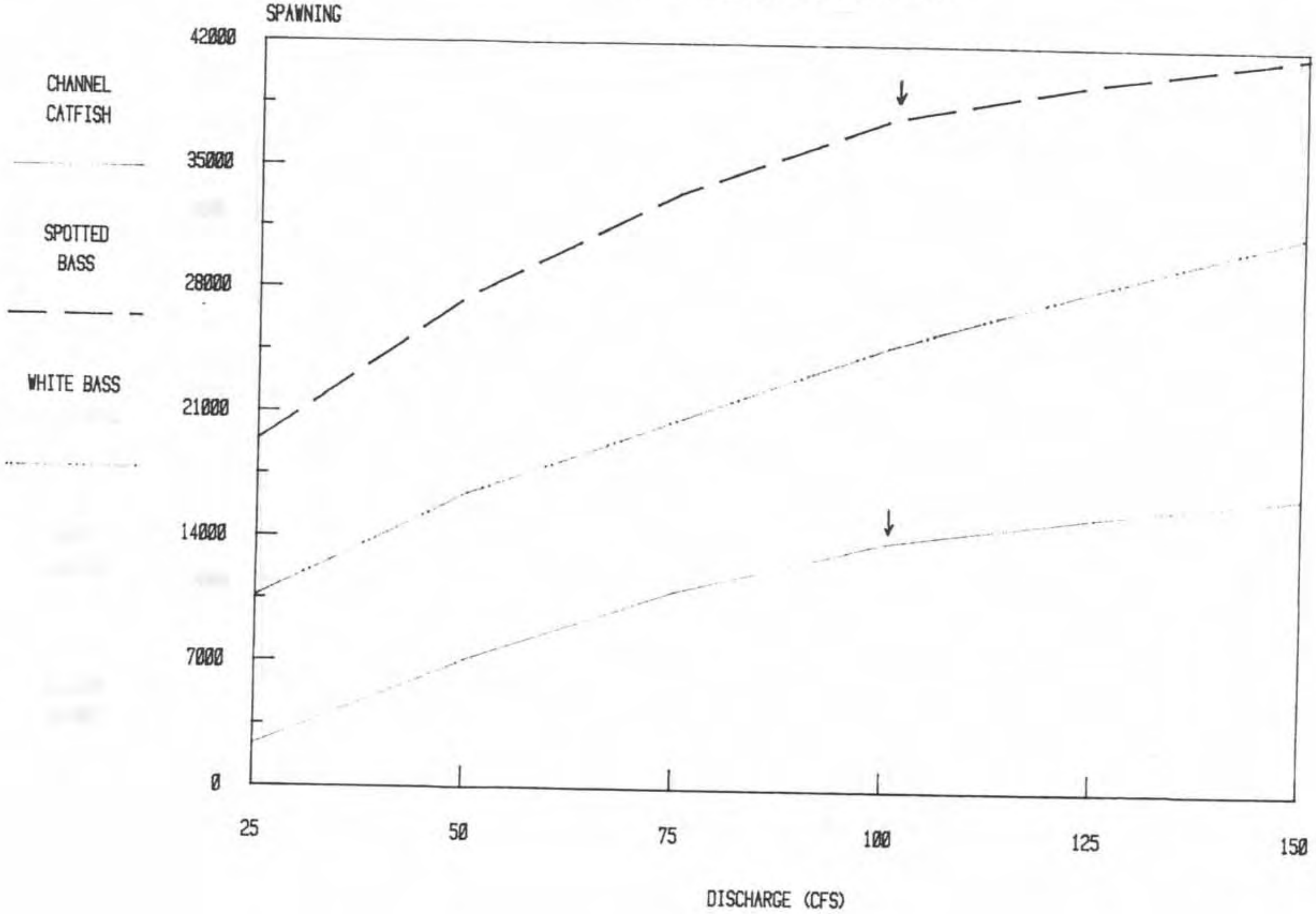


FIGURE 6

LITTLE CYPRESS BAYOU AT HIGHWAY 3001

LIFE STAGE AND EVALUATION SPECIES

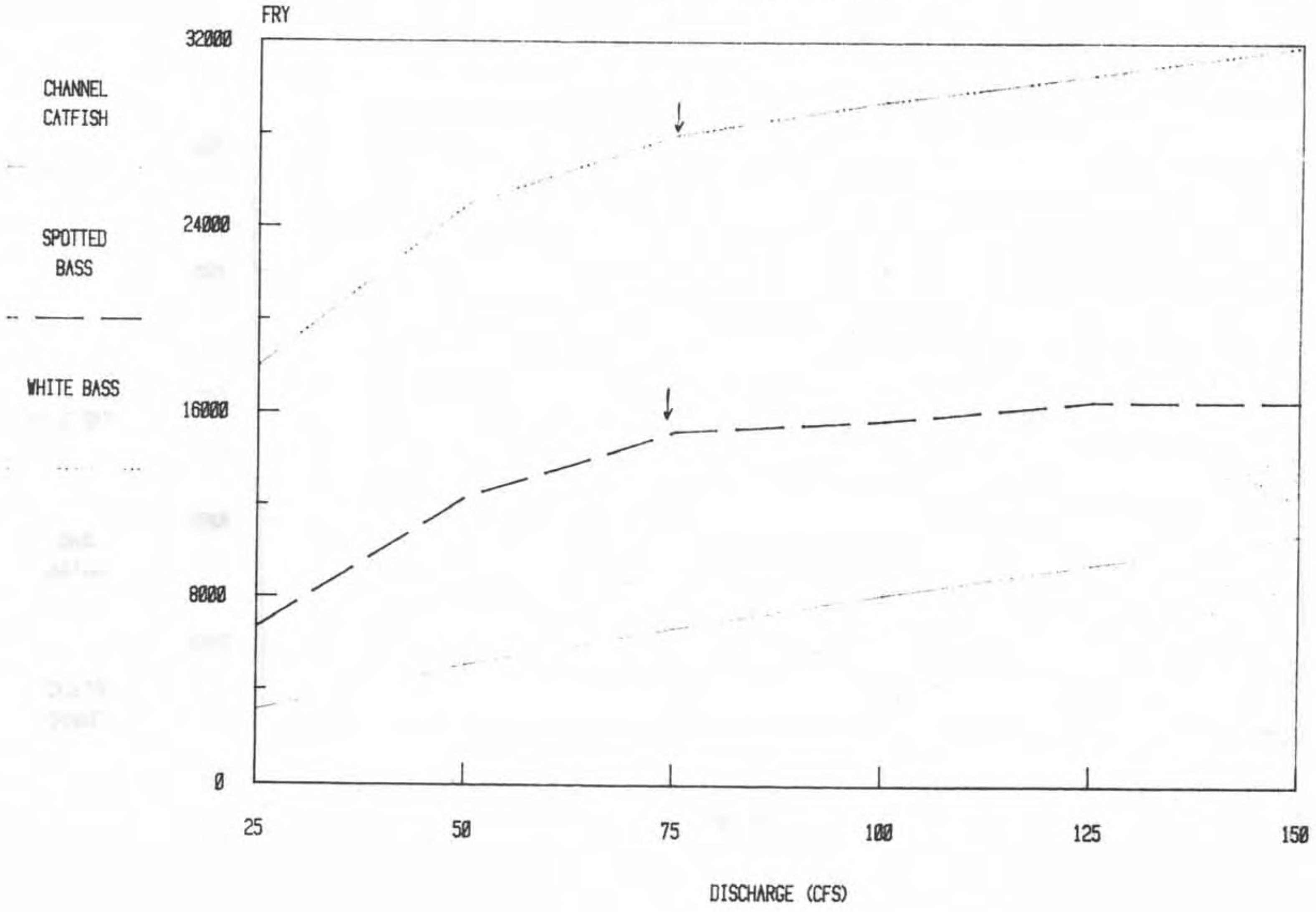


FIGURE 7

LITTLE CYPRESS BAYOU AT HIGHWAY 3001

LIFE STAGE AND EVALUATION SPECIES

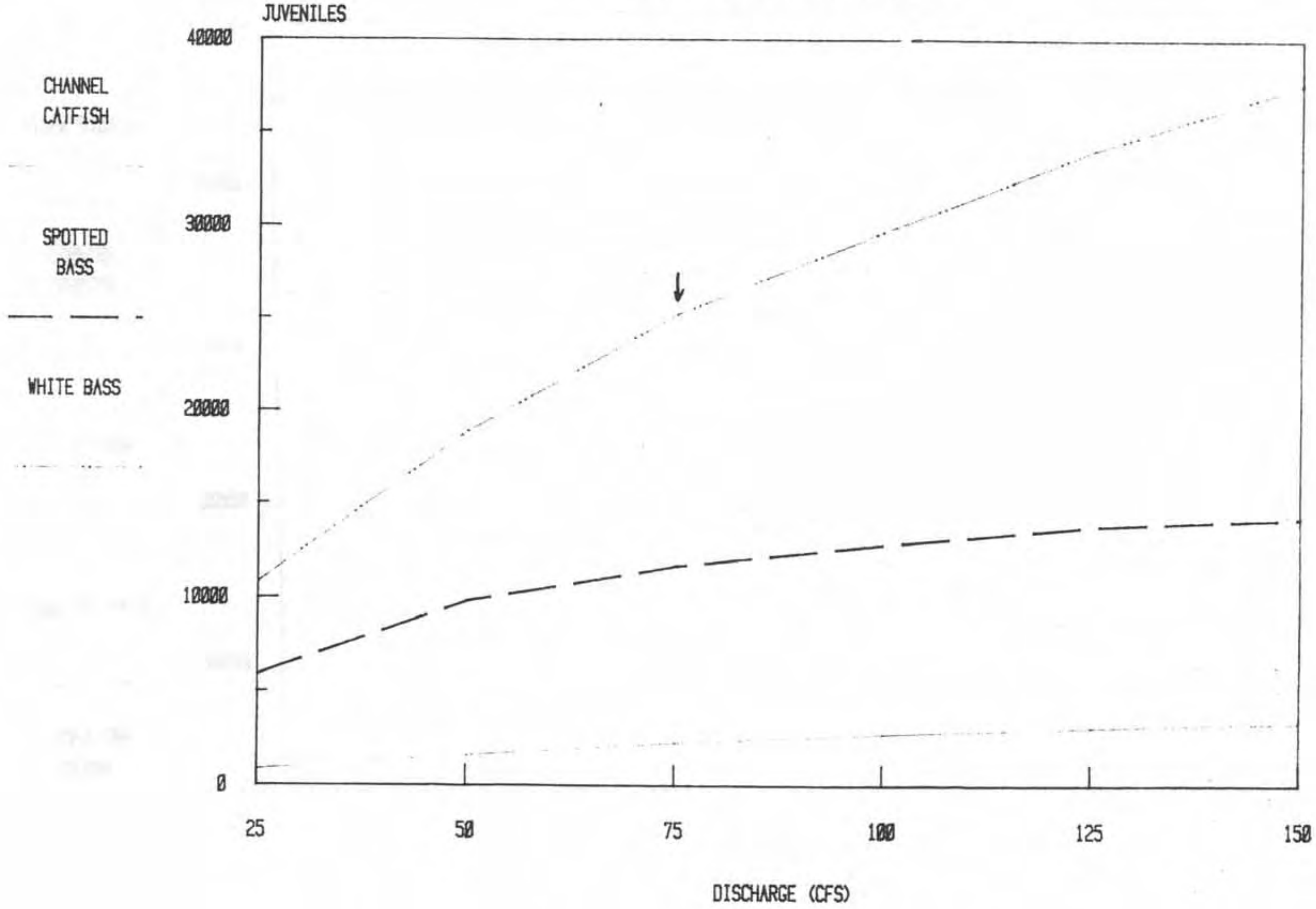
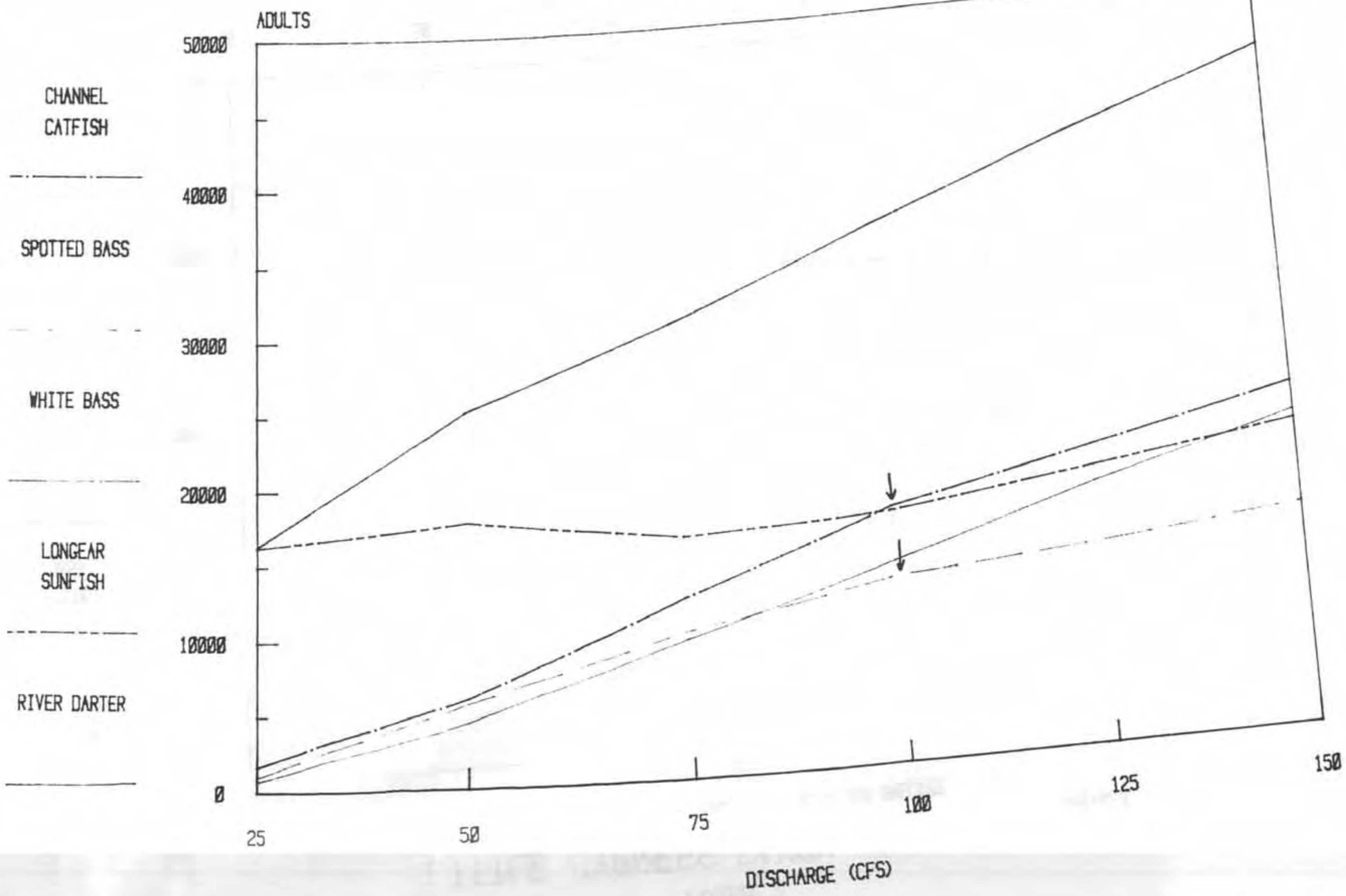


FIGURE 8

LITTLE CYPRESS BAYOU AT HIGHWAY 3001

LIFE STAGE & EVALUATION SPECIES



The variation in spawning flows required for spotted bass at Highways 154 and 3001 (50 and 100 cfs, respectively) is thought to result from differences in macrohabitat conditions at each study site. Habitat at Highway 154 is essentially pool (see Plate No. 6), and higher flows contribute little to increased habitat area, while increasing velocities which are less desirable for spawning. On the other hand, greater flows at Highway 3001 contribute substantially to increased habitat area due to the constricted nature of the stream channel (Plate No. 7). The range of flows simulated at Highway 3001 also probably tend to spread out more within the floodplain, which would hold velocities somewhat lower and permit enhanced spawning even during higher discharges.

Maintenance flows for Little Cypress, Highway 3001, are approximately 75 cfs for fry and juveniles (Figures 6 and 7) and 100 cfs for adult fish species (Figure 8). Inflection points are difficult to detect for the simulation at Highway 3001, since as previously discussed, each increment of discharge essentially increases aquatic habitat availability. Inflection points are most notable for spotted bass and white bass fry, white bass juveniles, and spotted bass and channel catfish adults. Discharge requirements for evaluation species were slightly higher at the Highway 3001 site than the Highway 154 site for the aforementioned reason, but not significantly so.

Results of the IFIM on Black Cypress Bayou are comparable to Little Cypress Bayou (Figures 9-12, Table 4). Streamflows required to maintain spawning ranged from about 75-100 cfs; fry 50-75 cfs; juveniles, 50-75 cfs; and adults 75-100 cfs. As can be observed from the figures, it appears that optimum flow for some evaluation species, such as spotted bass and channel catfish occurs within the simulated range of discharges. This may result from channel configuration of the Black Cypress study reach, which generally has higher banks and deeper water than the sites evaluated on Little Cypress Bayou (see Plate No. 8). These physical characteristics would not necessarily lead to greater amounts of aquatic habitat being provided with increased streamflows. Refined streamflow analyses, however, with additional flow and biological data would be required to confirm this conclusion.

Recommendations on monthly maintenance flows required for Little Cypress and Black Cypress Bayous are based upon the discharges identified in the IFIM and the seasonal occurrence of evaluation species' life history stages (Table 5). The seasonal periodicities of the evaluation species were determined from a variety of sources identified at the bottom of Table 5.

For the Cypress Bayou Basin, preference was given to the spawning requirements of white bass during the months of March and April, since these fish are early spawners and require relatively high flows for their upstream spawning run. Streamflow recommendations for May-June were weighted for the spawn of spotted bass and channel catfish. Flows recommended for the months of July-November were based on the habitat requirements of fry and juveniles of these three sport fish. Adult requirements were emphasized for the remaining months of the year.

FIGURE 9

BLACK CYPRESS BAYOU

LIFE STAGE & EVALUATION SPECIES

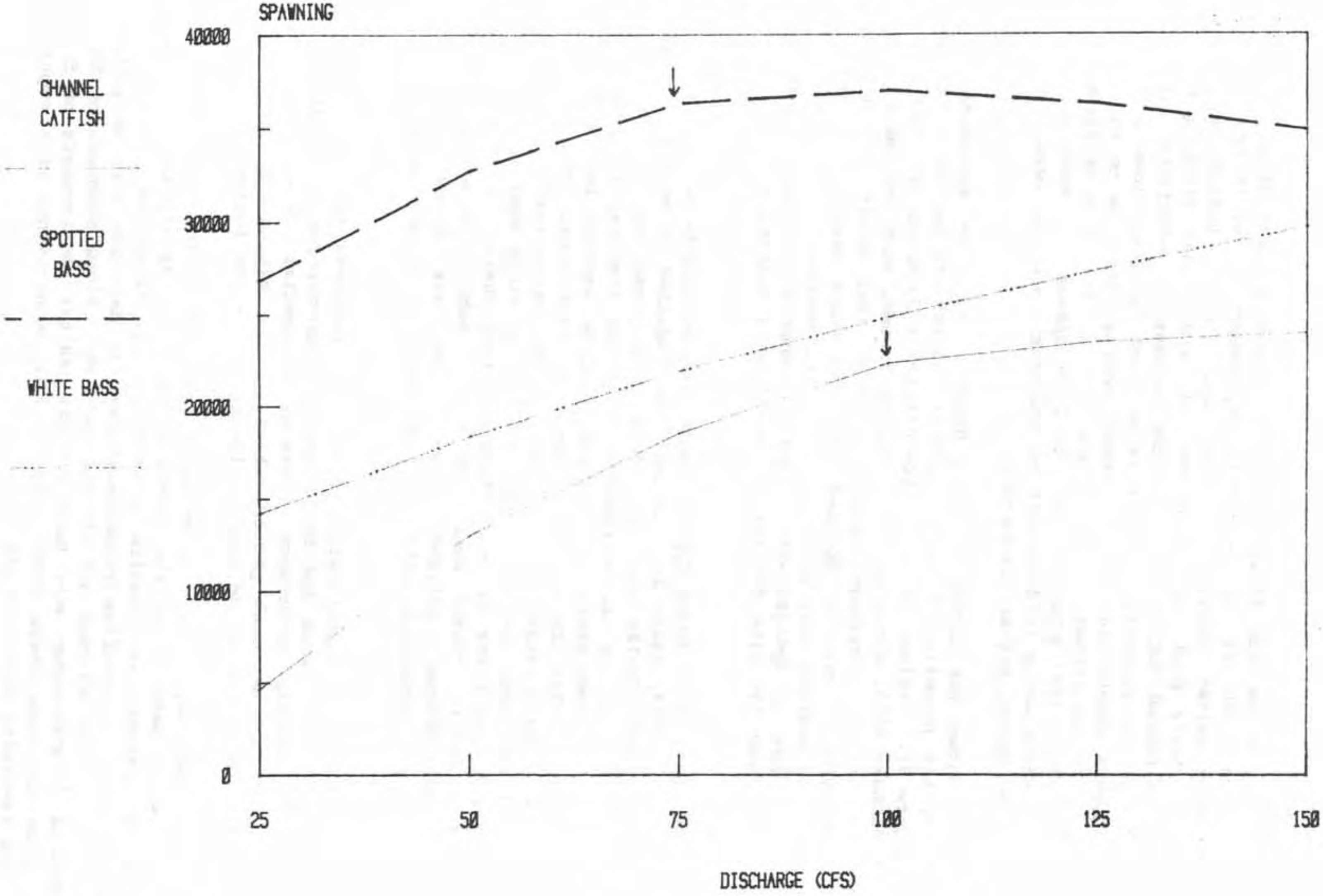


FIGURE 10

BLACK CYPRESS BAYOU

LIFE STAGE & EVALUATION SPECIES

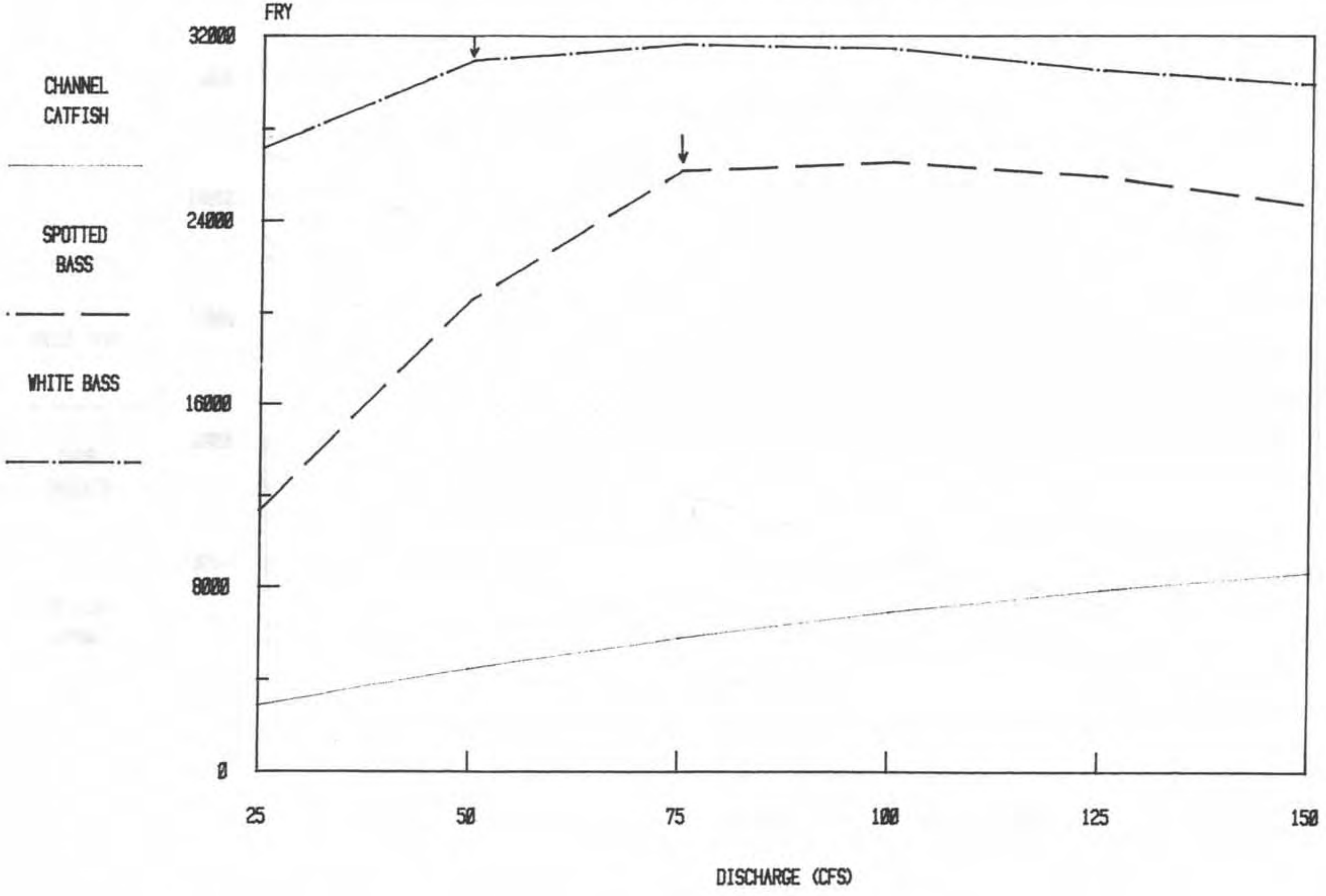


FIGURE 11

BLACK CYPRESS BAYOU

LIFE STAGE & EVALUATION SPECIES

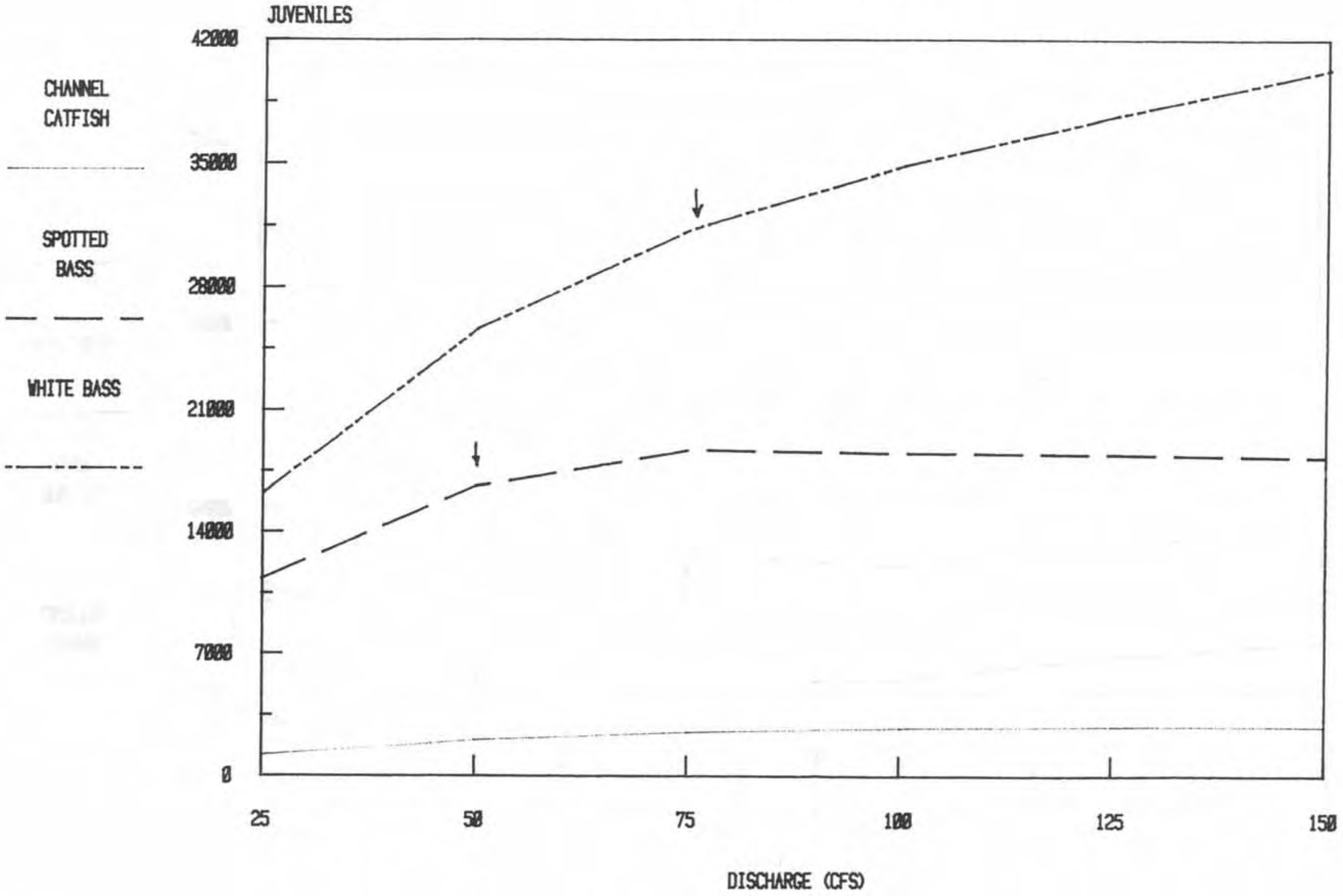


FIGURE 12

BLACK CYPRESS BAYOU

LIFE STAGE & EVALUATION SPECIES

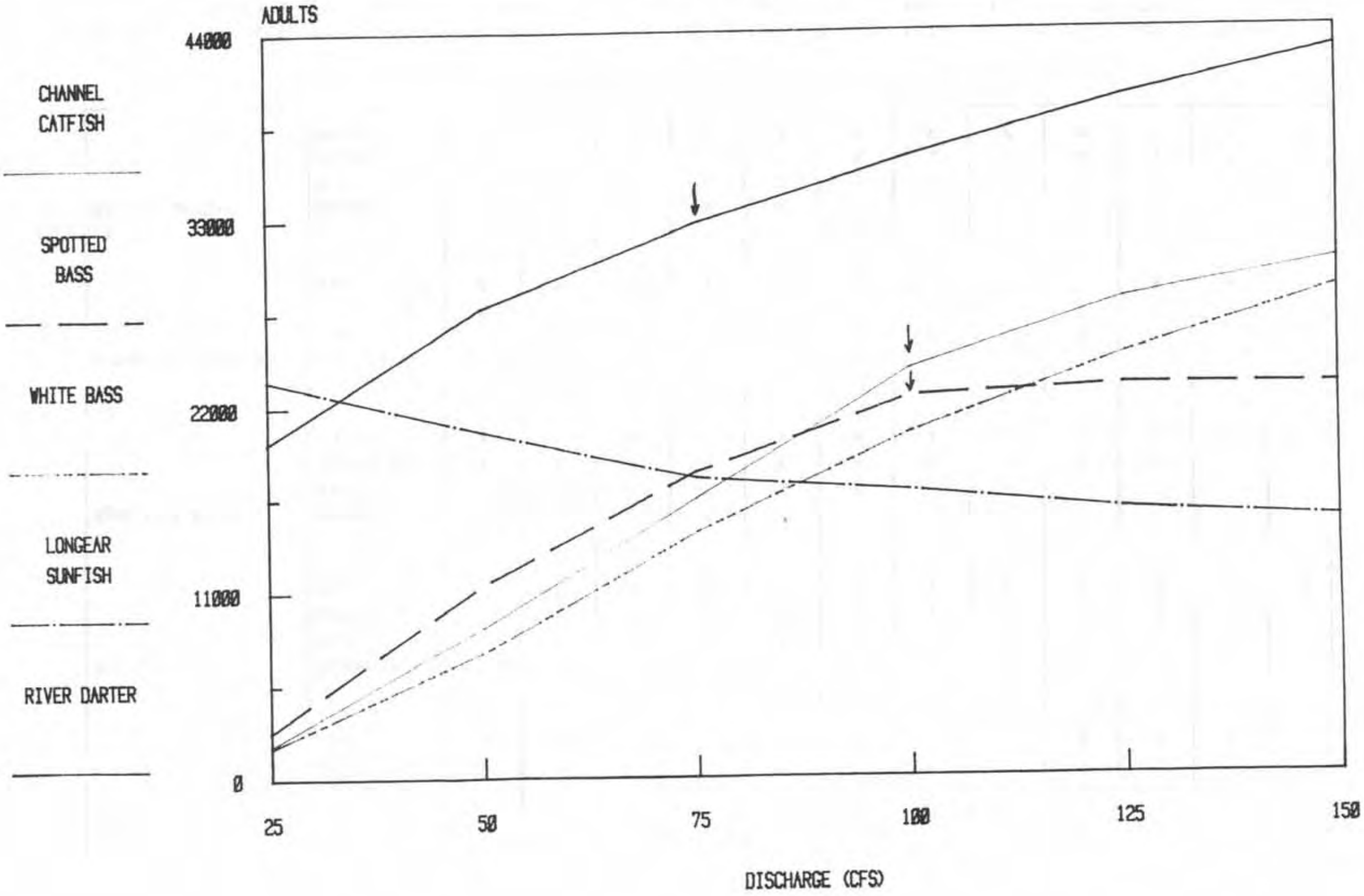


Table 5. Seasonal periodicity of evaluation species by life history stage.

Species	Life History Stage	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Channel catfish	Spawning					X	X	X					
	Fry					X	X	X	X				
	Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
White bass	Spawning			X	X								
	Fry			X	X	X							
	Juvenile				X	X	X	X	X	X	X	X	
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Spotted bass	Spawning				X	X							
	Fry				X	X	X						
	Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Longear sunfish	Spawning					X	X	X	X				
	Fry						X	X	X	X			
	Juvenile	X	X	X			X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
River darter	Spawning				X	X							
	Fry				X	X	X						
	Juvenile						X	X	X	X	X	X	
	Adult	X	X	X	X	X	X	X	X	X	X	X	X

Source: Bennett 1971, Berra and Gunning 1972, Houser and Bryant 1970, Lee et al. 1980, McMahon and Terrell 1982, Oklahoma Dept. of Wildlife Conservation 1970, Pflieger 1975, Ryan 1968, Starostka and Nelson 1974, Texas Parks and Wildlife Dept. 1971, Thomas 1970, Vogele 1975.

The recommended monthly maintenance flows for both Little Cypress and Black Cypress Bayous are 100 cfs for the months December-June and 75 cfs from July-November (Table 6). This represents an average annual discharge requirement of 90 cfs. The recommended maintenance flow is approximately 17% and 32% of the average annual mean flow and median flow, respectively, for Little Cypress Bayou over the period of record. The 90 cfs flow comprises 27% and 49% of the average annual mean flow and median flow of Black Cypress Bayou.

As displayed in Table 6, recommended flow regimes are substantially less than naturally occurring spring and winter high flows. Similarly, the recommended flows are greater than the summer low flows. Any reservoir plan considered for either the Little Cypress or Black Cypress sites should include a storage and operation plan to meet these seasonal differences. Such a plan is necessary to mitigate the direct loss of stream habitats from impoundment and alterations in flow regimes downstream of the impoundment. Operation of the project in conjunction with Caddo Lake or any other in-channel water transfer technique could possibly meet instream flow needs for fisheries.

Finally, it is noted that the recommended flows do not include a recommendation for flushing. Flushing flows are important to stream ecosystems because of their role in nutrient exchange and the removal of sediment and debris from riffles and pools. The IFIM, as currently used, does not include information for the development of flushing flow recommendations (Orth and Maughan 1981). Hydraulic measurements would be required at much higher flows, and in the case of the Cypress Bayou Basin, would probably be infeasible from a channel morphology and safety standpoint. For this study, it is assumed that normally high, spring runoff would provide sufficient flushing action for the stream channel.

Recreation Supply and Demand

Results of the stream and reservoir sport fishing recreation supply-demand analyses for the study area are displayed in Tables 7 and 8. As noted in the methodology section of this report, the mandays supply of fishing was estimated from the amount (i.e., surface acreage) of aquatic habitat multiplied by the resource capacity of the water body in angler days.
Resource capacity was computed from the formula presented by Wood (1961):

$$\text{Resource Capacity} = \frac{\text{Total Productivity x } A\ \overset{h}{t} \text{ value}}{\text{Harvest Ratio}} : \text{Catch/Angler day,}$$

Where, Total productivity = standing crop (pounds);

$A\ \overset{h}{t}$ = annual yield of harvestable fish in percent of standing crop

Harvest Ratio = percent of harvestable fish subject to capture; and

Catch/Angler day = allocation of one pound per day at the medium level of satisfaction for fisherman success.

Maximum resource capability for streams and reservoirs evaluated in the Cypress Basin averaged 45 mandays per acre. Creel surveys for Lake Cypress

Table 6. Historic and recommended monthly maintenance streamflows (cfs) for the Cypress Bayou Basin, Texas.

Stream and Flow Regime	Month												Avg. Ann-ual
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Little Cypress Bayou													
Mean Flow	666	869	895	1073	1092	471	117	52	121	115	310	543	527
Median Flow	428	659	700	566	556	142	31	10	11	16	75	227	285
Recommended Flow	100	100	100	100	100	100	75	75	75	75	75	100	90
Black Cypress Bayou													
Mean Flow	467	575	653	656	438	321	55	56	64	71	234	404	333
Median Flow	334	473	509	353	268	135	25	6	3	13	89	249	184
Recommended Flow	100	100	100	100	100	100	75	75	75	75	75	100	90

Table 7. Estimated recreation resource requirements (M.D.'s x 1,000) for stream fishing in the Cypress Bayou Basin, Texas.

County	1980			1985			2000		
	Supply	Demand	Need	Supply	Demand	Need	Supply	Demand	Need
Cass	11.8	4.9	---	11.8	5.4	---	11.8	7.3	---
Gregg	8.1	5.7	---	8.1	6.4	---	8.1	8.8	0.7
Harrison	13.9	89.5	75.6	13.9	100.2	86.3	13.9	137.8	123.9
Marion	8.9	217.5	208.6	8.9	243.5	234.6	8.9	334.8	325.9
Upshur	10.7	0.5	---	10.7	0.5	---	10.7	0.7	---
Totals	53.4	318.1	284.2	53.4	356.0	320.9	53.4	489.4	450.5

Table 8. Estimated recreation resource requirements (M.D.'s x 1,000) for fishing in freshwater lakes ≥ 250 surface acres in the Cypress Bayou Basin, Texas.

County	1980			1985			2000		
	Supply	Demand	Need	Supply	Demand	Need	Supply	Demand	Need
Cass	456.8	7.9	---	456.8	8.8	---	456.8	11.8	---
Gregg	179.4	23.6	---	179.4	26.5	---	179.4	36.4	---
Harrison	571.5	358.9	---	571.5	401.8	---	571.5	552.4	---
Marion	1442.2	857.1	---	1442.2	959.6	---	1442.2	1319.4	---
Upshur	36.0	5.5	---	36.0	6.1	---	36.0	8.4	---
Totals	2685.9	1253.0	---	2685.9	1402.8	---	2685.9	1928.4	---

Springs during 1973-74 noted an actual expenditure of 14.5 mandays per acre (Toole 1975).

When the supply of stream fishing is compared to demand figures provided by Texas Parks and Wildlife Department for the years 1980, 1985 and 2000, there is a notable need for stream fishing in Harrison and Marion Counties (Table 7). This demand is anticipated to increase in the future as human populations continue growing and stream habitats are further impacted by development activities. However, much of this demand could be satisfied by providing access facilities to the study area streams. Currently, public access is available only at major road crossings, and facilities such as boat ramps, parking, fish cleaning tables, etc. are not available (TPWD 1970).

It appears a surplus of reservoir fishing opportunity exists in all counties of the study area (Table 8). Biologically speaking, study area reservoirs are capable of meeting the current and foreseeable demand for lake fishing recreation. Any needs for lake fishing could be provided through development of additional facilities such as boat ramps, fishing piers, and marinas on existing reservoirs (TPWD 1981).

A preliminary estimate of the sport fishing potential of alternative reservoir sites on Little Cypress and Black Cypress Bayous is provided in Table 9. Anticipated stream fishing losses as a result of impoundment of the sites are also given.

Table 9. Preliminary estimate of potential sport fishing gains and losses (M.D.'s x 1000) from alternative reservoir sites in the Cypress Bayou Basin, Texas.

Alternative Site	Conservation Pool Elevation (ft.msl)	Conservation Pool Area (Acres)	Reservoir Fishing Supply (M.D.'s)	Stream Fishing Losses (M.D.'s)
Little Cypress Bayou:				
Marshall #1	267	40,800	1,836.0	4.1
Marshall #2	267	40,800	1,836.0	4.1
Marshall #3	241	19,800	891.0	2.3
Marshall #4	223	9,450	425.3	1.8
Black Cypress Bayou:				
Black Cypress #1	262	29,200	1,314.0	2.8
Black Cypress #2	262	29,200	1,314.0	2.8
Black Cypress #3	242	14,500	652.5	2.6
Black Cypress #4	229	8,500	382.5	2.4

The gains and losses in sport fishing opportunity are based on the maximum resource capability of the water bodies calculated from the formula presented by Wood (1961). These figures reflect the highest possible use of the reservoirs and streams based upon their biological productivity and estimated levels of harvest.

Actual demands for reservoir fishing would not be as great as the projections displayed in Table 9, however, since there is currently a surplus of reservoir fishing opportunity on other nearby lakes. Fishing on newly-created impoundments would be primarily "transfer-of-use" from the existing reservoirs, rather than new use or demand.

If a specific project plan is selected for future evaluation by the Corps of Engineers, detailed human use and economic studies would be conducted for alternative project futures to further define use-levels and monetary values of fish and wildlife recreation. Procedures developed by the U.S. Fish and Wildlife Service could prove useful for such evaluations (U.S. FWS 1980).

RECOMMENDATIONS

Preliminary aquatic studies indicate several features which should be considered during the Corps of Engineers' feasibility investigations into the water resources of Cypress Bayou Basin.

1. Monthly maintenance flows of 100 cfs from December-June and 75 cfs from July-November should be provided in Little Cypress Bayou or Black Cypress Bayou, if an impoundment is constructed on either of these sites. To meet these flow levels, consideration should be given to reserving or acquiring water rights in the reservoir for downstream release.

2. The feasibility of in-channel, downstream water transfers could be explored as an alternative for maintaining instream flows, in lieu of specific mitigation storage. Since instream flows for fish and wildlife are non-consumptive, capture of the water supply storage at Caddo Lake or other downstream points could meet instream needs without adversely interfering with the water supply function of a project.

3. Alternative project futures should provide stream access as well as traditional reservoir recreation facilities. Stream facilities are needed to satisfy some of the large stream-oriented recreation demands now occurring in the study area.

4. Hydrological and biological studies should be continued on Little Cypress and Black Cypress Bayous in order to refine the seasonal requirements and quantity of instream flows necessary to meet fisheries management objectives.

5. Future studies should consider the effects of any project on the unique fisheries resources and wetland habitats of Caddo Lake, and appropriate mitigatory features developed. Such an analysis is not possible until a specific development plan is available for evaluation.

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APPENDIX A

Composite checklist of fish species collected from Big, Little and Black Cypress Bayous, and small tributary streams within the Cypress Bayou Basin, Texas.[1]

Common Name	Species	Little Cypress	Big Cypress	Black Cypress	Small[2] Tributary Streams
Chestnut lamprey	*Ichthyomyzon castaneus*	X			
Spotted gar	*Lepisosteus oculatus*	X			
Longnose gar	*Lepisosteus osseus*	X	X		
Bowfin	*Amia calva*				X
Gizzard shad	*Dorosoma cepedianum*	X	X	X	
Threadfin shad	*Dorosoma petenense*		X		
Grass pickerel	*Esox americanus vermiculatus*	X	X	X	X
Chain pickerel	*Esox niger*	X	X	X	
Black buffalo	*Ictiobus niger*	X			
Smallmouth buffalo	*Ictiobus bubalus*	X			
Spotted sucker	*Minytrema melanops*	X	X	X	X
Golden shiner	*Notemigonus crysoleucas*		X	X	X
Pugnose minnow	*Notropis emiliae*			X	
Emerald shiner	*Notropis atherinoides*	X	X	X	
Ribbon shiner	*Notropis fumeus*			X	
Redfin shiner	*Notropis umbratilis*	X	X	X	X

Common Name	Species	Little Cypress	Big Cypress	Black Cypress	Small Tributary Streams
Ironcolor shiner	Notropis chalybaeus	X	X	X	
Weed shiner	Notropis texanus	X	X	X	
Pallid shiner	Notropis amnis		X		
Blacktail shiner	Notropis venustus	X	X	X	
Red shiner	Notropis lutrensis	X	X		
Sand shiner	Notropis stramineus	X	X		
Blackspot shiner	Notropis atrocaudalis	X	X	X	X
Striped shiner	Notropis chrysocephalus				X
Silvery minnow	Hybognathus nuchalis	X	X	X	X
Cypress minnow	*Hybognathus hayi*	X	X	X	
Bullhead minnow	*Pimephales vigilax*	X	X		
Creek chubsucker	*Erimyzon oblongus*				X
Channel catfish	*Ictalurus punctatus*	X	X		
Blue catfish	*Ictalurus furcatus*		X		
Black bullhead	*Ictalurus melas*			X	
Yellow bullhead	*Ictalurus natalis*	X		X	
White catfish	*Ictalurus catus*		X		

Common Name	Species	Little Cypress	Big Cypress	Black Cypress	Small Tributary Streams
Flathead catfish	*Pylodictis olivaris*			X	
Tadpole madtom	*Noturus gyrinus*			X	
Freckled madtom	*Noturus nocturnus*		X		
American eel	*Anguilla rostrata*	X			
Golden topminnow	*Fundulus chrysotus*	X		X	
Starhead topminnow	*Fundulus notti*			X	X
Blackstripe topminnow	*Fundulus notatus*	X	X	X	X
Blackspotted topminnow	*Fundulus olivaceous*	X	X		X
Mosquitofish	*Gambusia affinis*	X	X	X	X
Pirate perch	*Aphredoderus sayanus*	X	X	X	X
Brook silversides	*Labidesthes sicculus*	X	X	X	
White bass	*Morone chrysops*		X		
Yellow bass	*Morone mississippiensis*	X			
Spotted bass	*Micropterus punctulatus*	X	X	X	
Largemouth bass	*Micropterus salmoides*	X	X	X	
Warmouth	*Lepomis gulosus*	X	X	X	X
Green sunfish	*Lepomis cyanellus*	X	X		X

Common Name	Species	Little Cypress	Big Cypress	Black Cypress	Small Tributary Streams
Spotted sunfish	*Lepomis punctatus*	X	X	X	
Bantam sunfish	*Lepomis symmetricus*			X	
Redear sunfish	*Lepomis microlophus*	X	X	X	X
Bluegill	*Lepomis macrochirus*	X	X	X	X
Orangespotted sunfish	*Lepomis humilis*			X	
Redbreast sunfish	*Lepomis auritus*		X	X	
Longear sunfish	*Lepomis megalotis*	X	X	X	X
Dollar sunfish	*Lepomis marginatus*	X		X	
White crappie	*Pomoxis annularis*	X	X		
Black crappie	*Pomoxis nigromaculatus*	X	X	X	
Flier	*Centrarchus macropterus*		X		X
Banded pygmy sunfish	*Elassoma zonatum*	X		X	
Black side darter	*Percina maculata*	X		X	
Dusky darter	*Percina sciera*		X	X	
River darter	*Percina shumardi*		X		
Scaly sand darter	*Ammocrypta vivax*		X	X	
Bluntnose darter	*Etheostoma chlorosomum*		X	X	X
Slough darter	*Etheostoma gracile*	X	X	X	

Common Name	Species	Little Cypress	Big Cypress	Black Cypress	Small Tributary Streams
Cypress darter	*Etheostoma proeliare*	X		X	
Goldstripe darter	*Etheostoma parvipinne*	X		X	
Freshwater drum	*Aplodinotus grunniens*	X	X	X	
Totals	71 species	46	48	46	21

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[1] Source: Kemp 1954a; 1954b; Bonn 1956; CSW 1980.

[2] Other small tributary streams surveyed were Beckum Creek, Rainey Creek, Grays Creek, and an unnamed creek (CSW 1980).

APPENDIX B

Checklist of aquatic plants, Cypress Bayou Basin, Texas. [1]

Common Name	Scientific Name
American lotus	*Nelumbo lutea*
Arrowhead	*Sagittaria papillosa*
Bladderwort	*Utricularia sp.*
Bulrush	*Scirpus sp.*
Cattail	*Typha sp.*
Coontail	*Ceratophyllum demeraum*
Duckweed	*Lemna sp.*
Duckpotato	*Sagittaria latifolia*
False loosestrife	*Ludwigia leptocarpa*
Fanwort	*Cabomba caroliniana*
Water primrose	*Ludwigia peploides*
Frogbit	*Linmobium spongia*
Pennywort	*Hydrocotyle sp.*
Pondweed	*Potamogeton spp.*
Lizard's tail	*Saururus sp.*
Maidencane	*Panicum hemitomon*
Spikerush	*Elecoharis sp.*
Parrotfeather	*Myriphyllum brasiliense*
Smartweed	*Polygonum sp.*
Rush	*Juncus spp.*
Cyperus	*Cyperus spp.*
Cutgrass	*Zizaniopsis milacea*

Common Name	Scientific Name
Elodea	*Elodea densa*
Water hyacinth	*Eichornia crassipes*
Waterleaf	*Hydrolea sp.*
Watermeal	*Wolffia sp.*
White waterlily	*Nymphaea odorata*
Wild celery	*Vallisneria americana*
Yellow waterlily	*Nuphar luteum*
Watershield	*Brasenia schreberi*
Baldcypress	*Taxodium distichum*
Buttonbush	*Cephalanthus occidentalis*
Waterlocust	*Gleditsia aquatica*
Black willow	*Salix nigra*
Filamentous algae	Chlorophyta
Blue-green algae	Cyanophyta
Muskgrass	*Chara sp.*
Sawgrass	*Cladium mariscoides*
Water milfoil	*Myriophyllum spicatum*

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[1] Source: Toole 1981, 1983a, 1983b

APPENDIX C

Composite checklist of fish species collected from reservoirs within Cypress Bayou Basin, Texas. [1]

Common Name	Scientific Name
Chestnut lamprey	*Ichthyomyzon castaneus*
Spotted gar	*Lepisosteus oculatus*
Longnose gar	*Lepisosteus osseus*
Shortnose gar	*Lepisosteus platostomus*
Alligator gar	*Lepisosteus spatula*
Bowfin	*Amia calva*
Gizzard shad	*Dorosoma cepedianum*
Threadfin shad	*Dorosoma petenense*
Grass pickerel	*Esox americanus vermiculatus*
Chain pickerel	*Esox niger*
Carp	*Cyprinus carpio*
Golden shiner	*Notemigonus crysoleucas*
Blackspot shiner	*Notropis atrocaudalis*
Ironcolor shiner	*Notropis chalybaeus*
Red shiner	*Notropis lutrensis*
Blacktail shiner	*Notropis venustus*
Weed shiner	*Notropis texanus*
Pallid shiner	*Notropis amnis*
Sand shiner	*Notropis stramineus*
Mimic shiner	*Notropis volucellus*
Taillight shiner	*Notropis maculatus*
Pugnose minnow	*Notropis emiliae*
Silvery minnow	*Hybognathus nuchalis*
Bullhead minnow	*Pimephales vigilax*
Lake chubsucker	*Erimyzon sucetta*
Bigmouth buffalo	*Ictiobus cyprinellus*
Smallmouth buffalo	*Ictiobus bubalus*
River carpsucker	*Carpiodes carpio*
Spotted sucker	*Minytrema melanops*
Black bullhead	*Ictalurus melas*
Yellow bullhead	*Ictalurus natalis*
Channel catfish	*Ictalurus punctatus*
Blue catfish	*Ictalurus furcatus*
Tadpole madtom	*Noturus gyrinus*
Freckled madtom	*Noturus nocturnus*
Flathead catfish	*Pylodictis olivaris*
Pirate perch	*Aphredoderus sayanus*
Golden topminnow	*Fundulus chrysotus*
Blackstripe topminnow	*Fundulus notatus*
Mosquitofish	*Gambusia affinis*
Brook silverside	*Labidesthes sicculus*

Common Name	Scientific Name
Inland silverside	*Menidia beryllina*
White bass	*Morone chrysops*
Yellow bass	*Morone mississippiensis*
Hybrid striped bass	*Morone chrysops* x *M. saxatilis*
Warmouth	*Lepomis gulosus*
Bluegill	*Lepomis macrochirus*
Redbreast sunfish	*Lepomis auritus*
Green sunfish	*Lepomis cyanellus*
Dollar sunfish	*Lepomis marginatus*
Longear sunfish	*Lepomis megalotis*
Redear sunfish	*Lepomis microlophus*
Spotted sunfish	*Lepomis punctatus*
Bantam sunfish	*Lepomis symmetricus*
Spotted bass	*Micropterus punctulatus*
Largemouth bass	*Micropterus salmoides*
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*
Flier	*Centrarchus macropterus*
Scaly sand darter	*Ammocrypta vivax*
Bluntnose darter	*Etheostoma chlorosomum*
Slough darter	*Etheostoma gracile*
Swamp darter	*Etheostoma fusiforme*
Cypress darter	*Etheostoma proeliare*
Log perch	*Percina caprodes*
Freshwater drum	*Aplodinotus grunniens*

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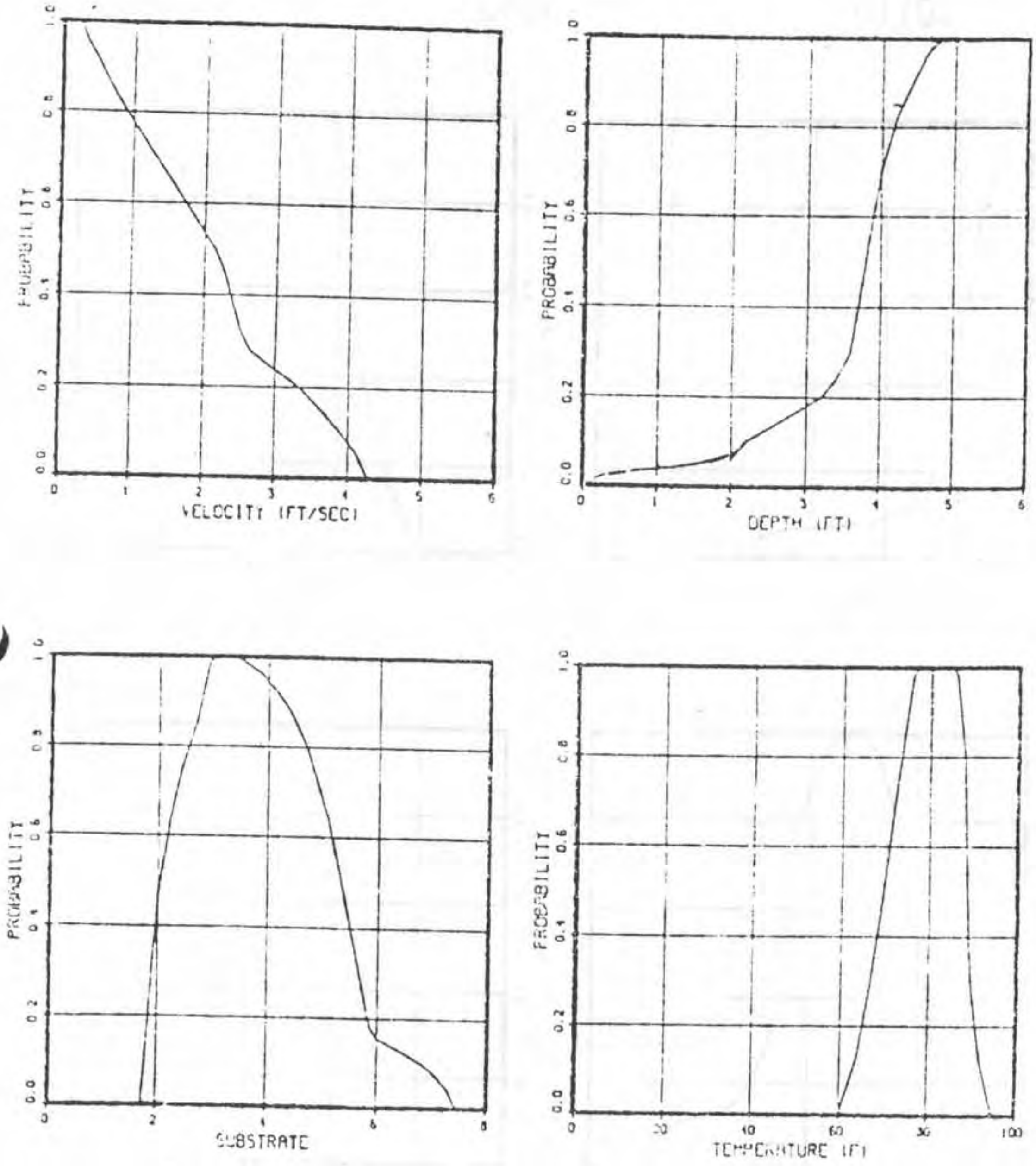
[1] Source: Bonn 1956; Toole 1981, 1983a, 1983b

CHANNEL CATFISH

ADULTS 78/06/23.



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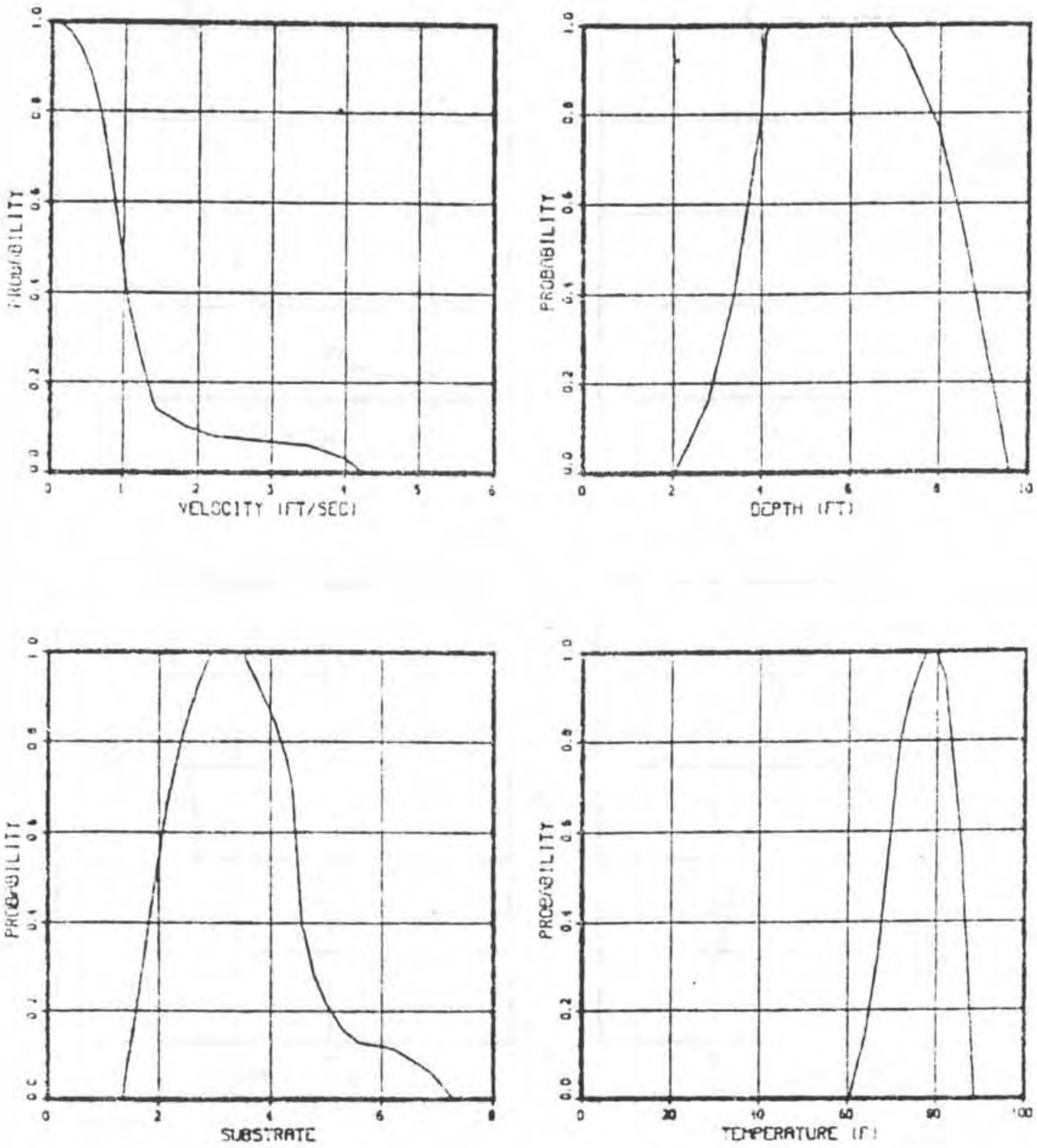

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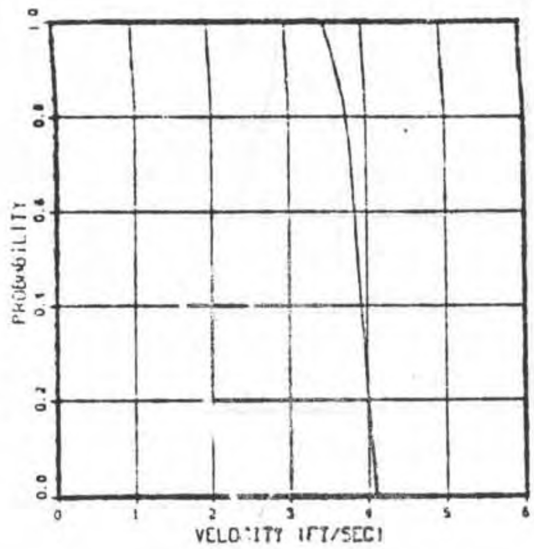

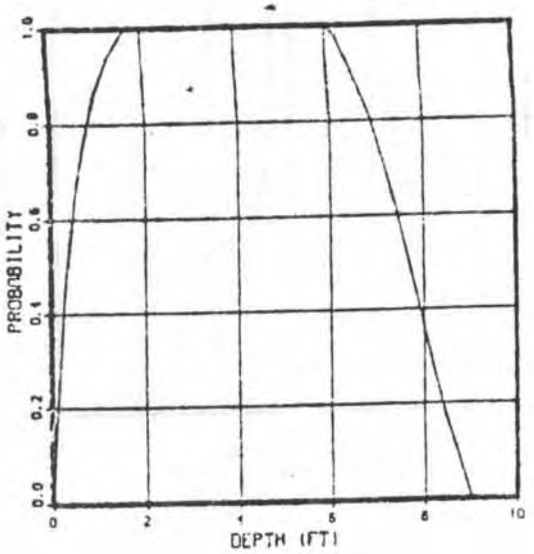

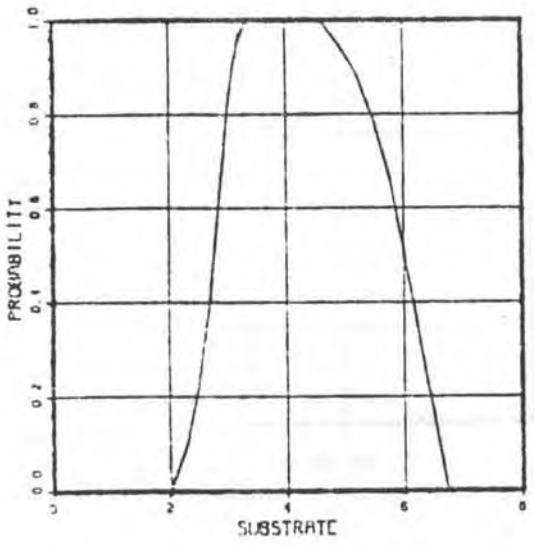

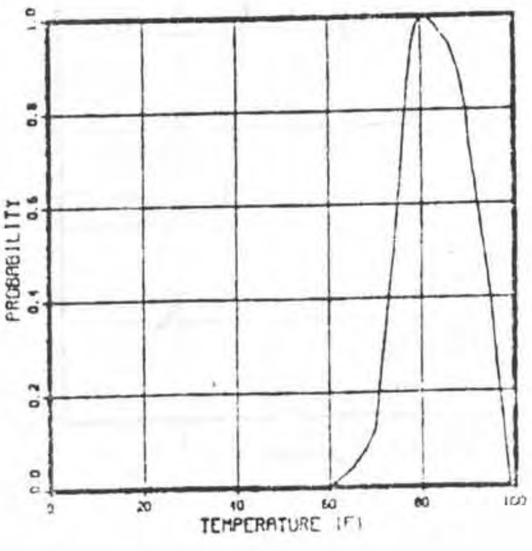

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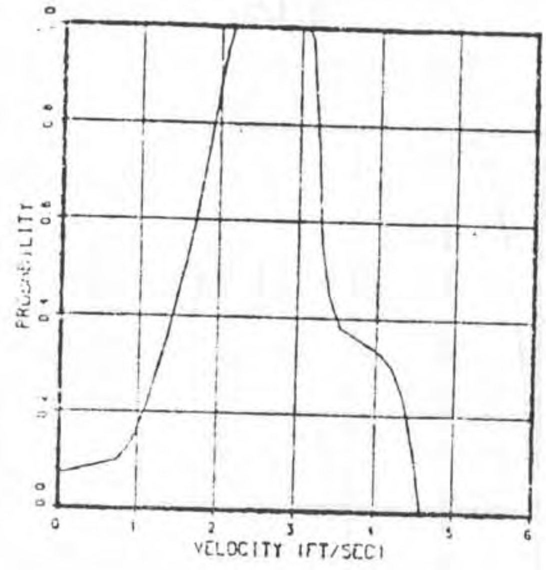

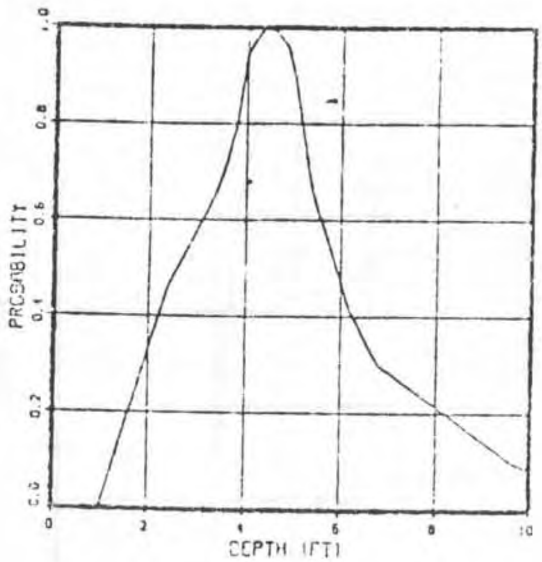

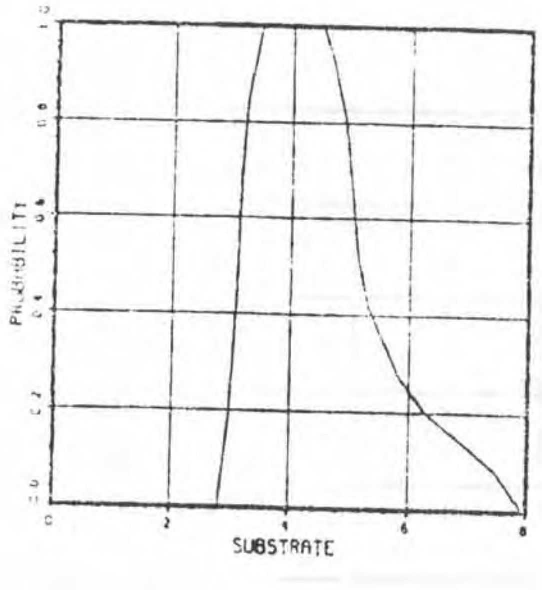

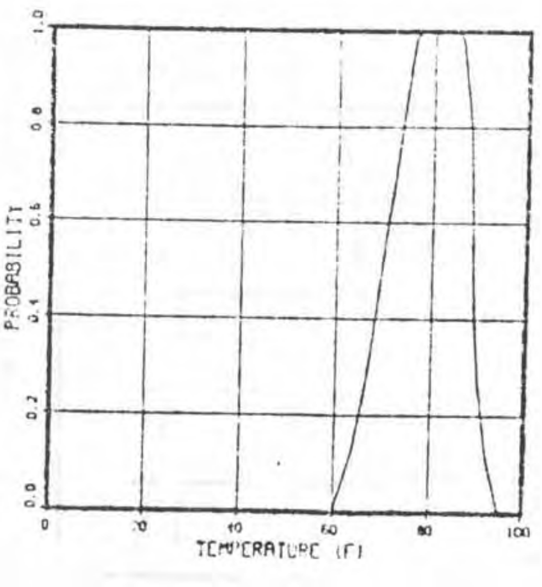

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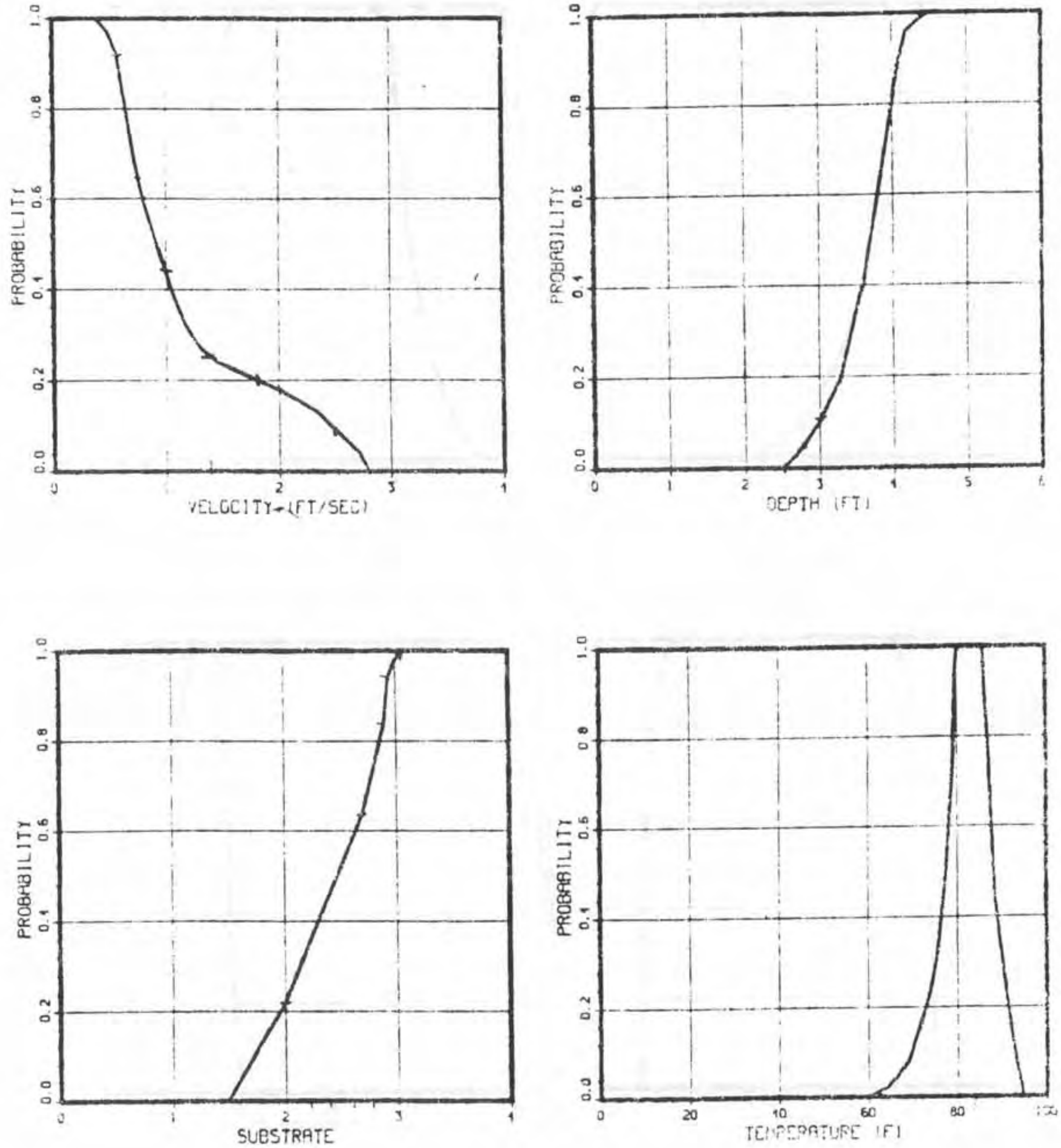

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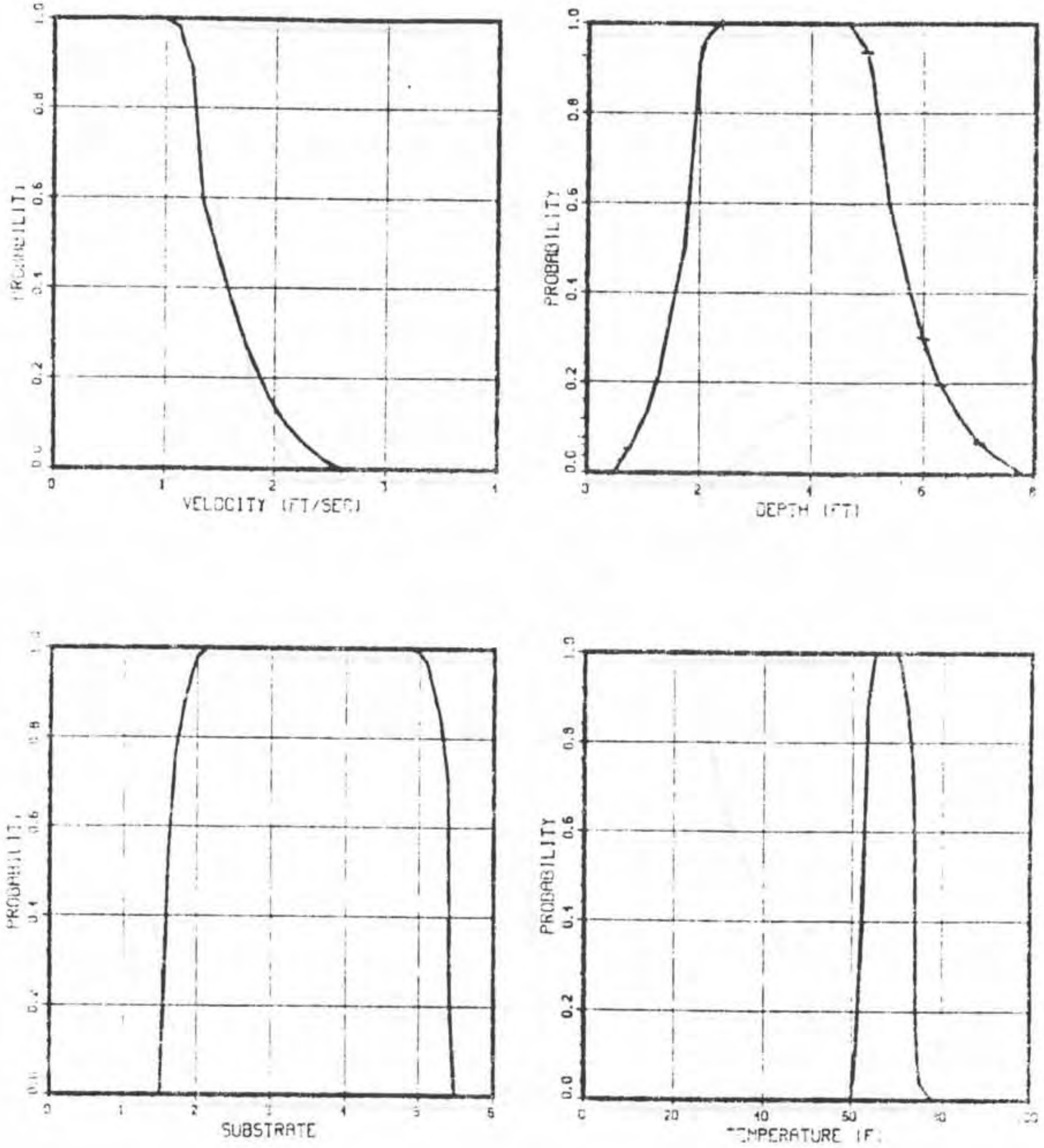

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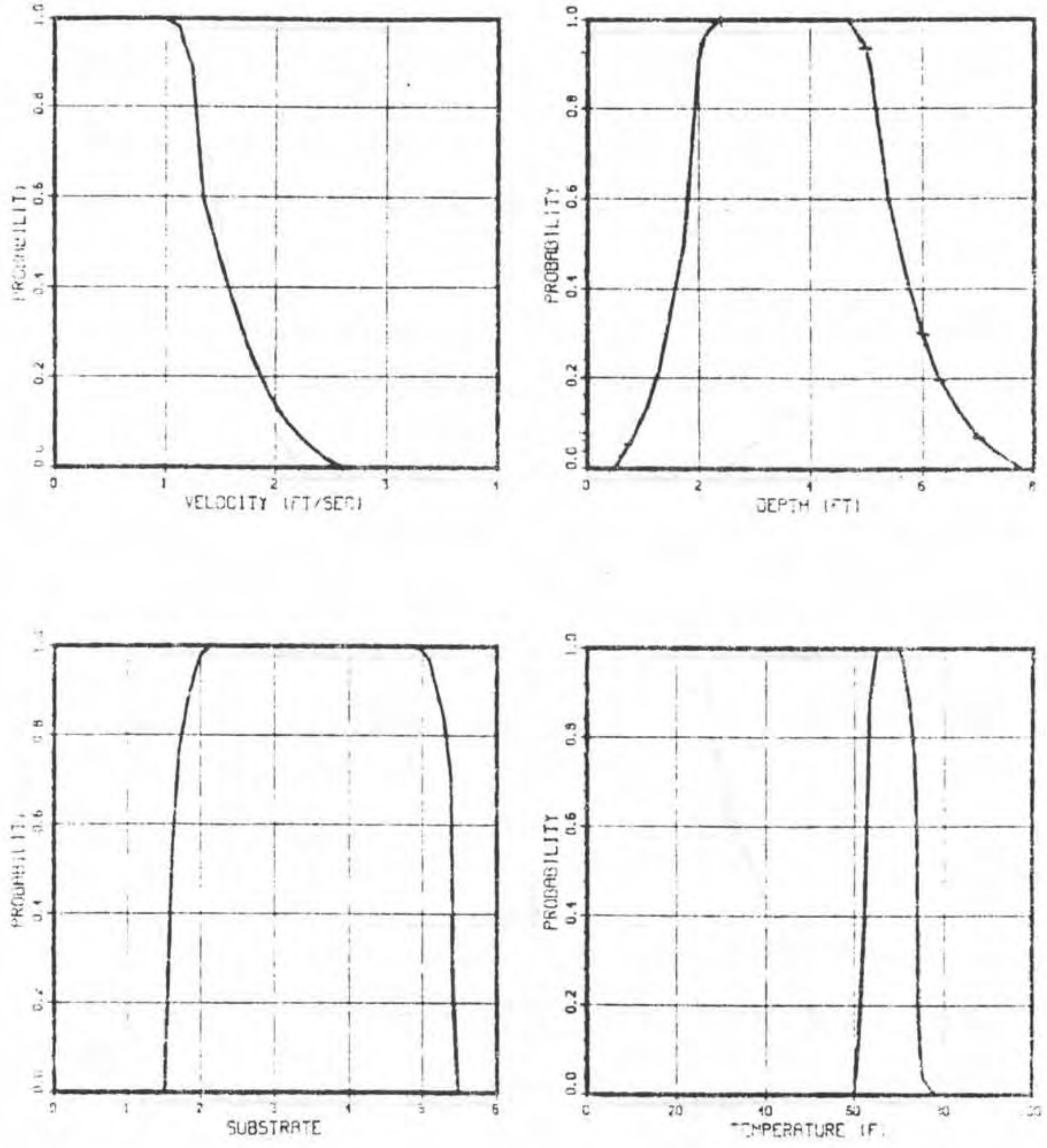

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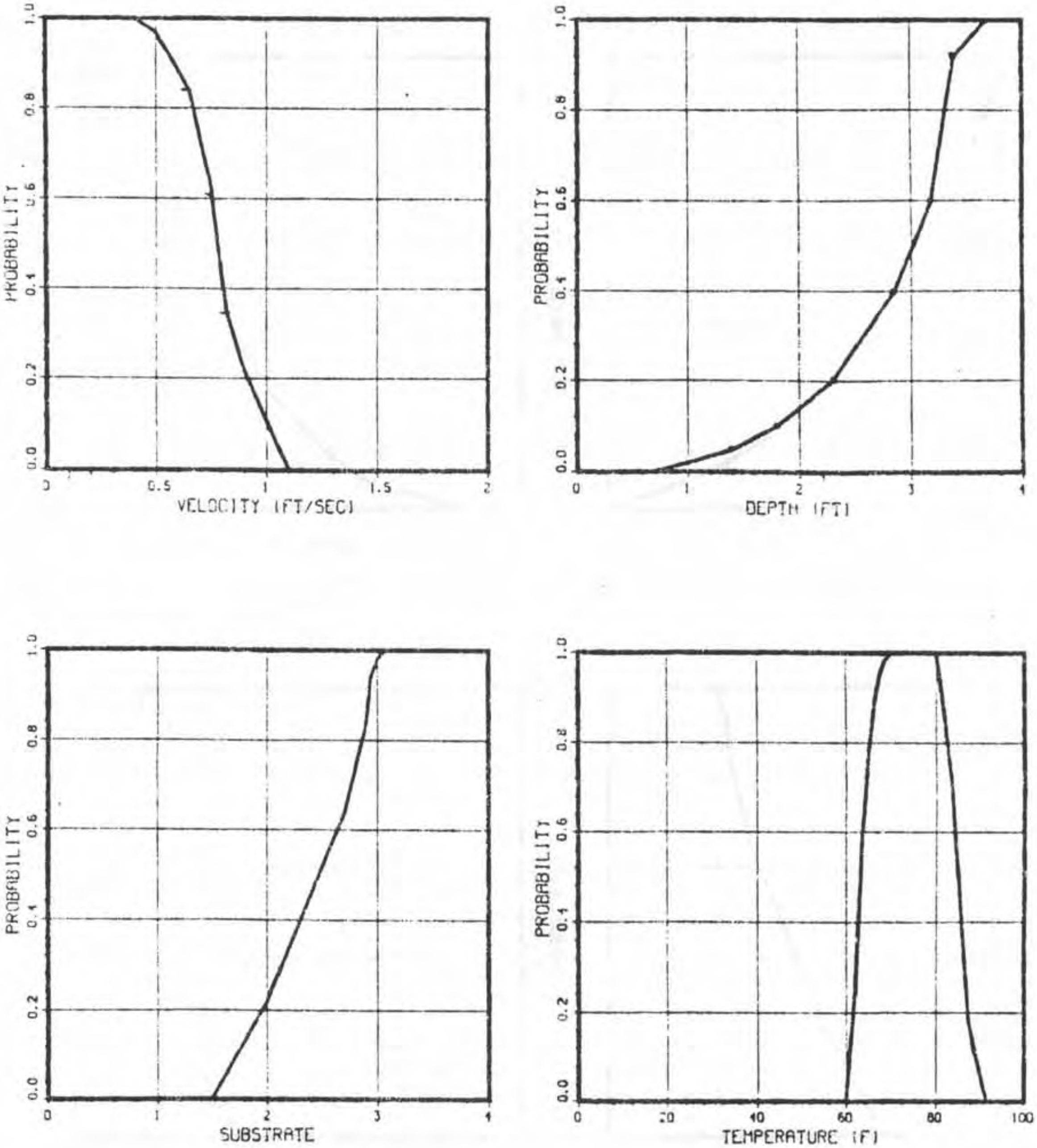

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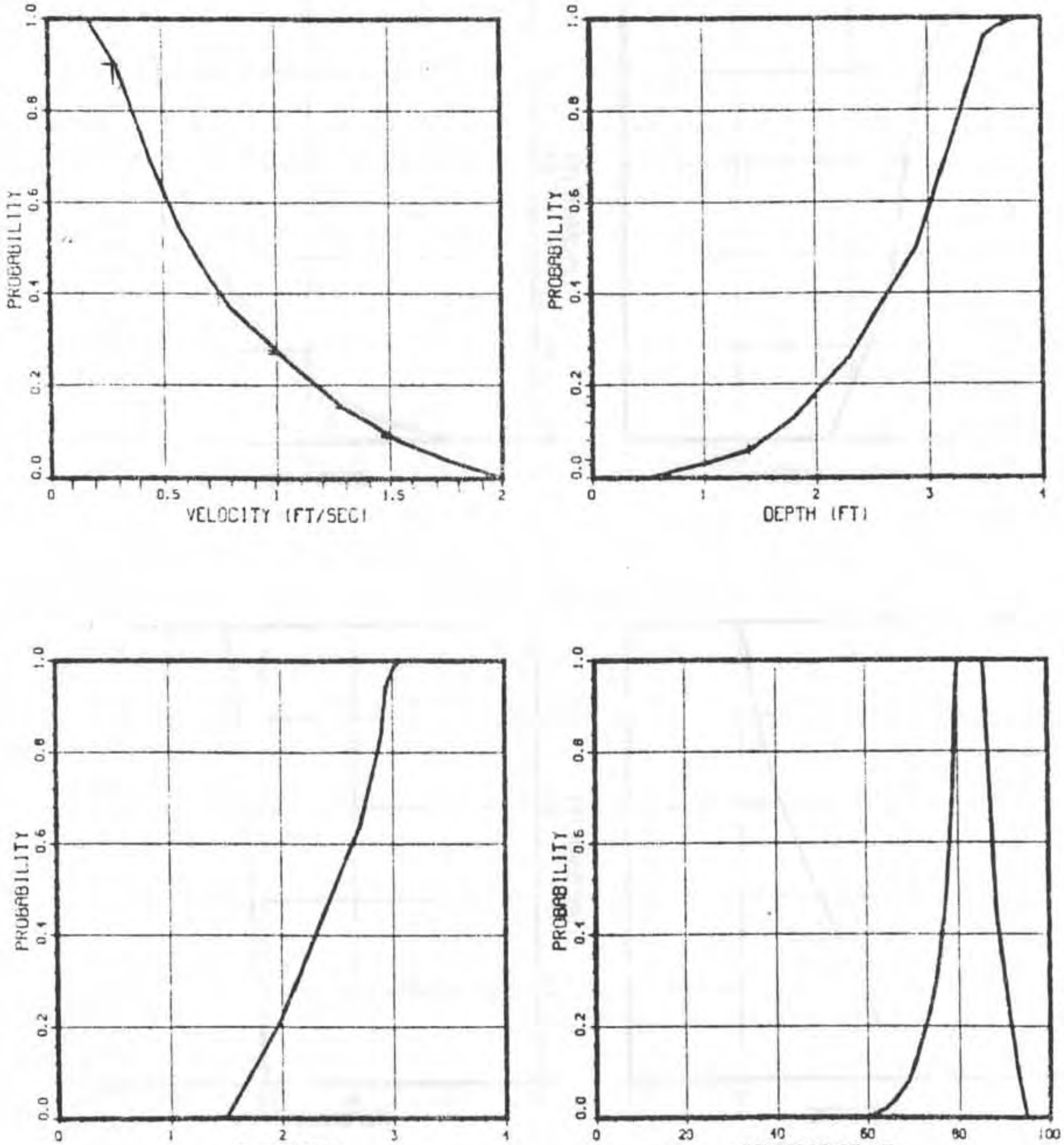

WHITE BASS

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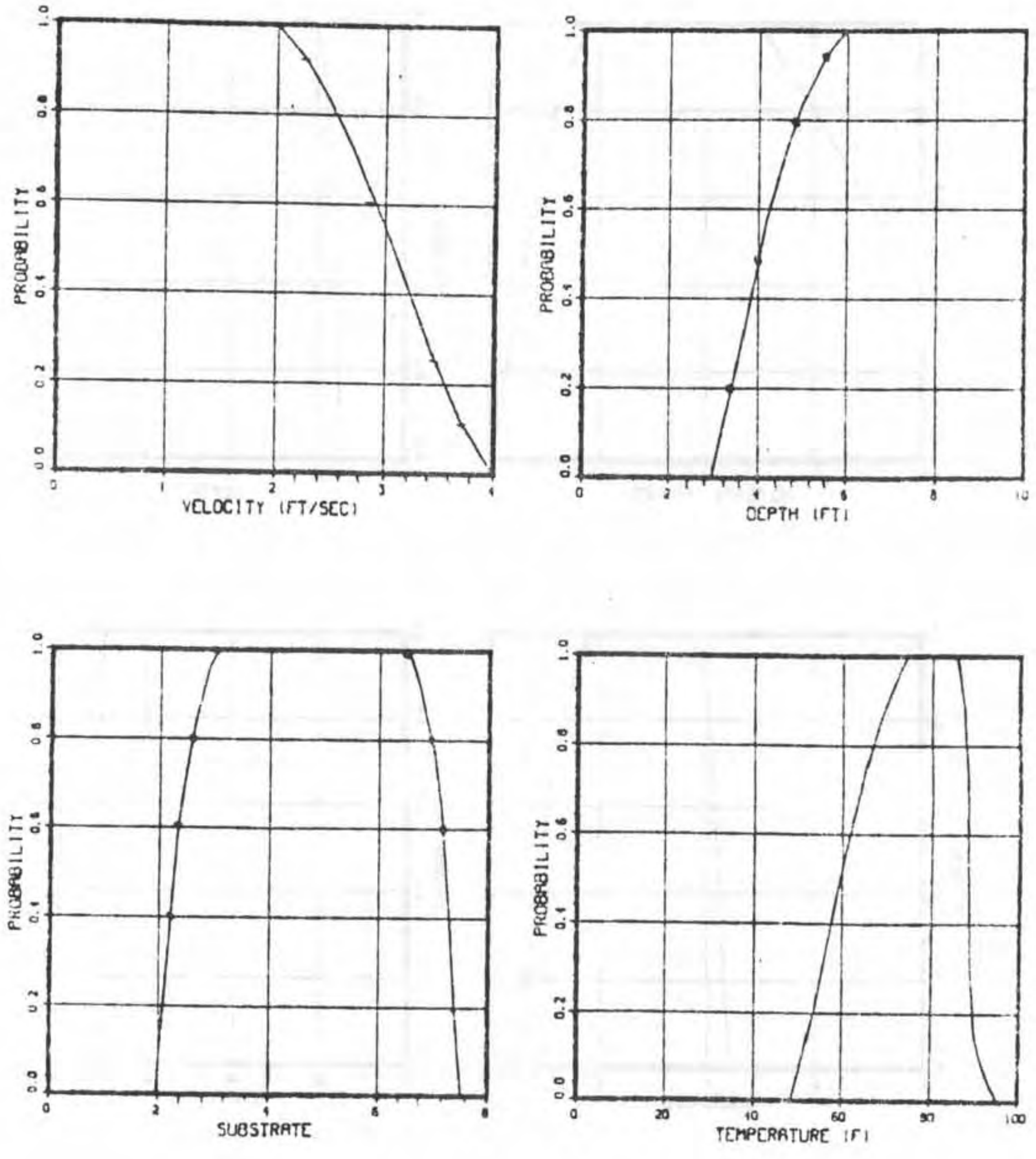

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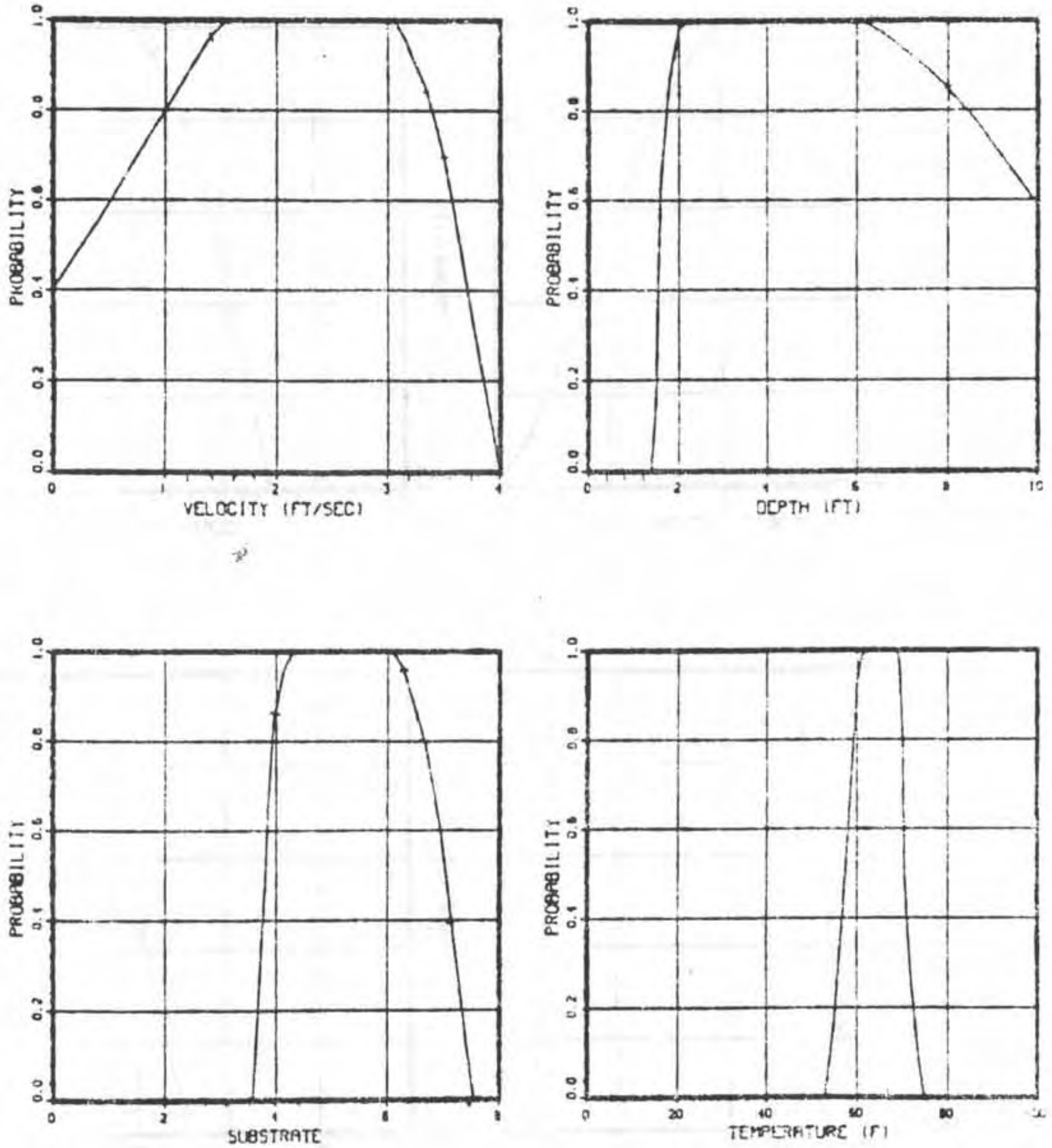

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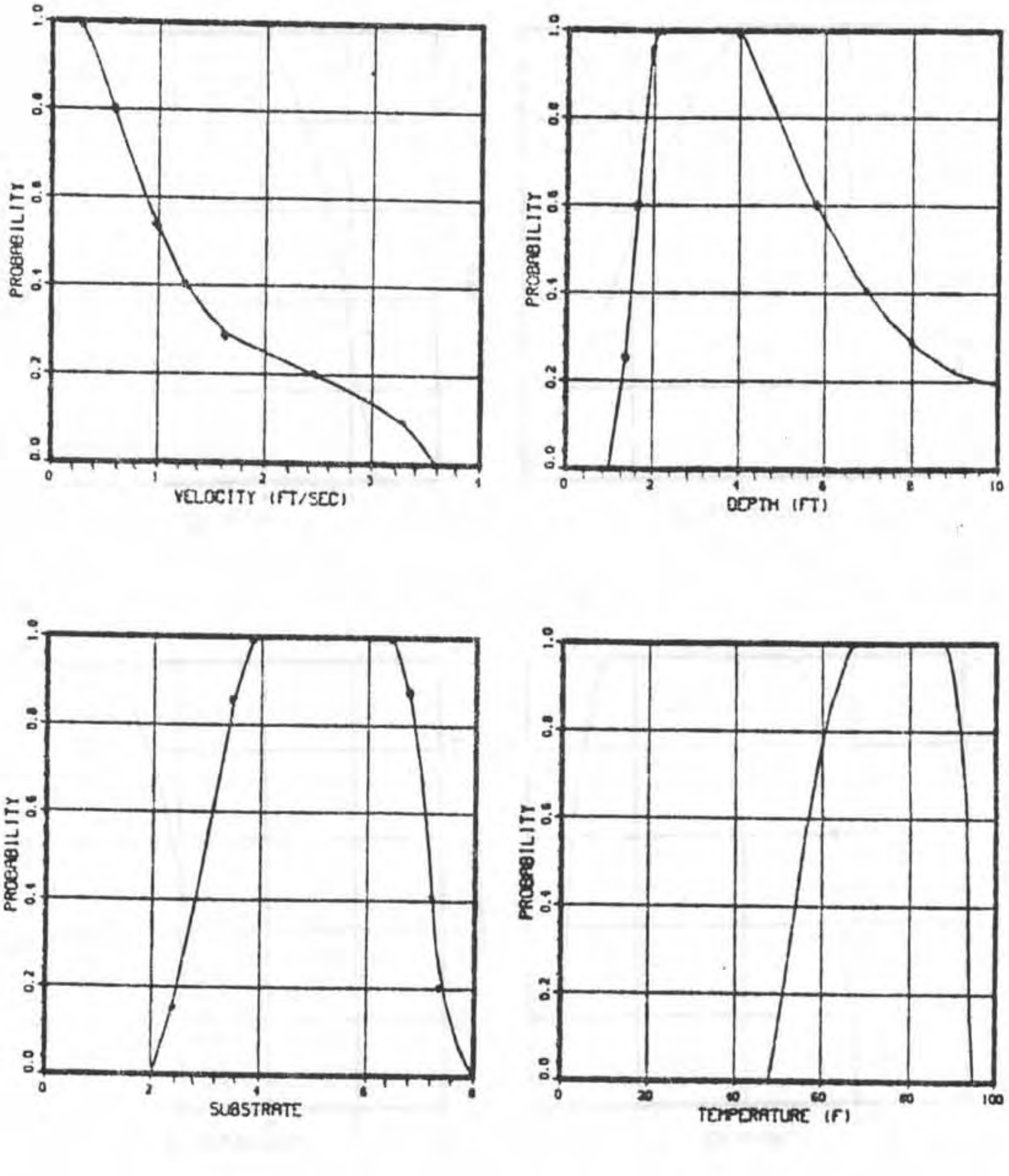

WHITE BASS

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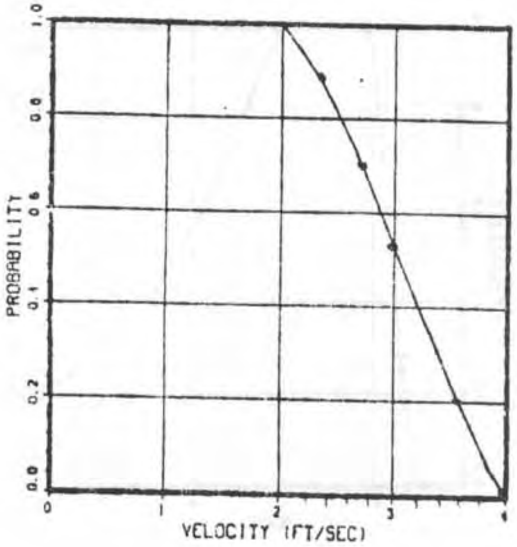
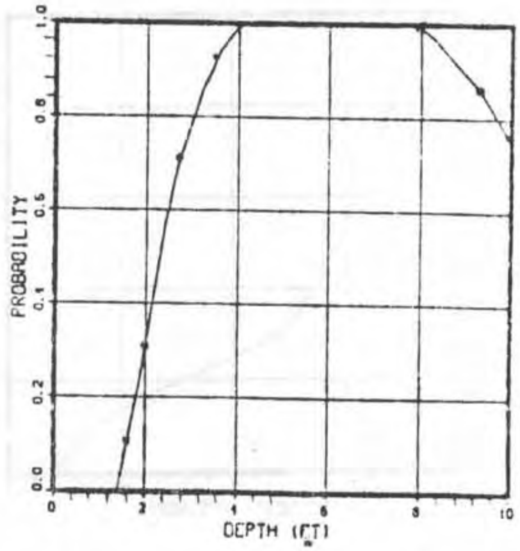
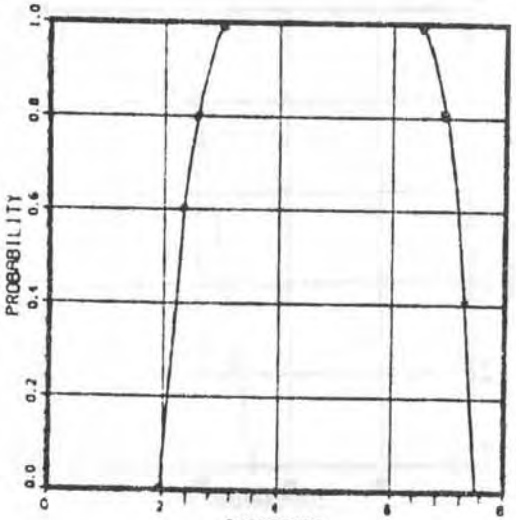
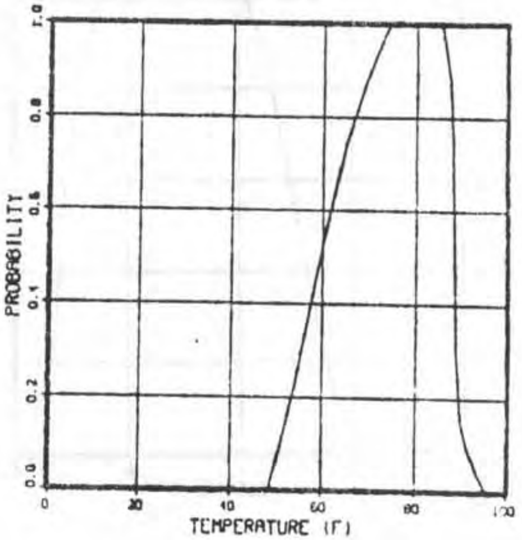
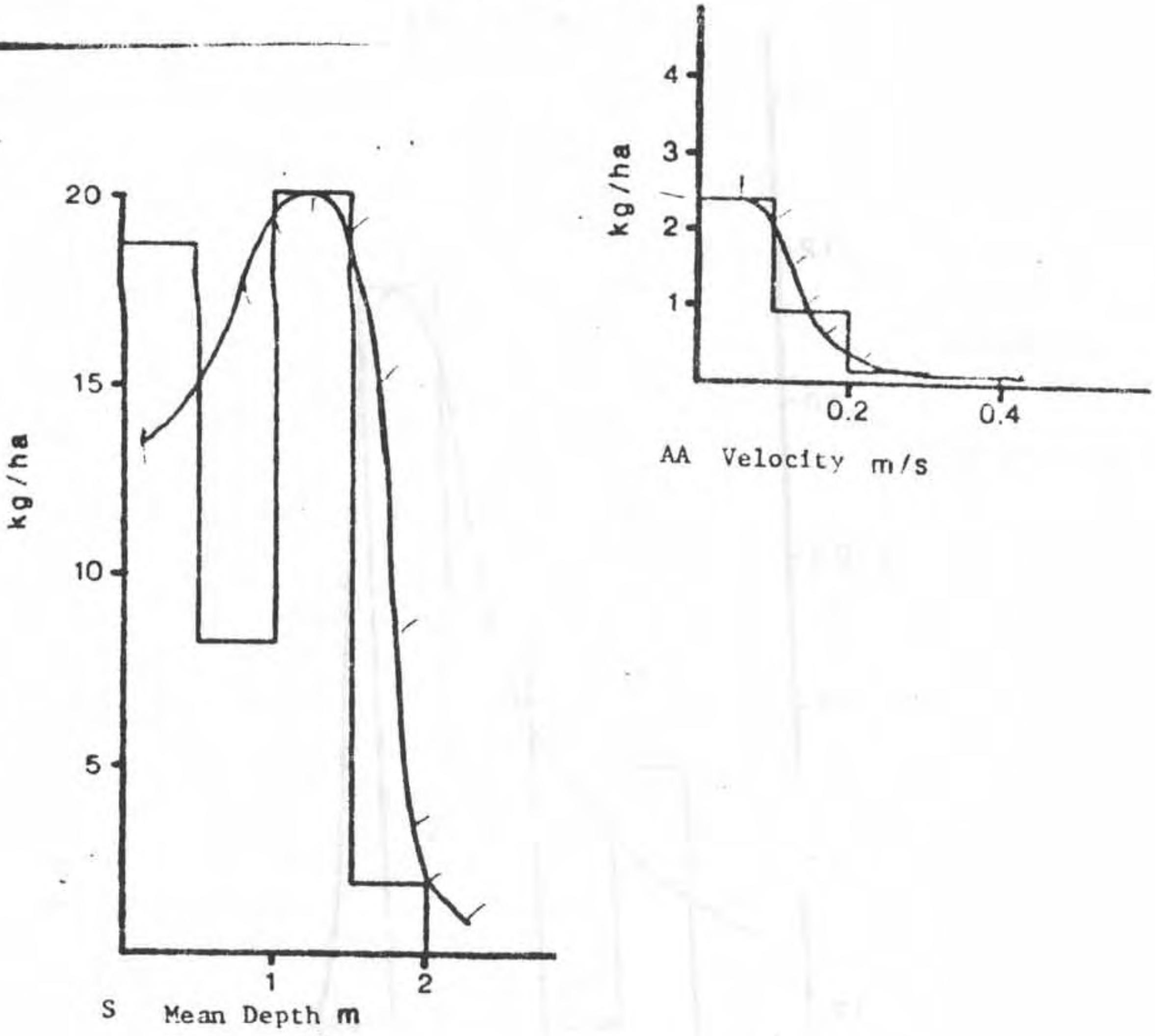








Longear Sunfish



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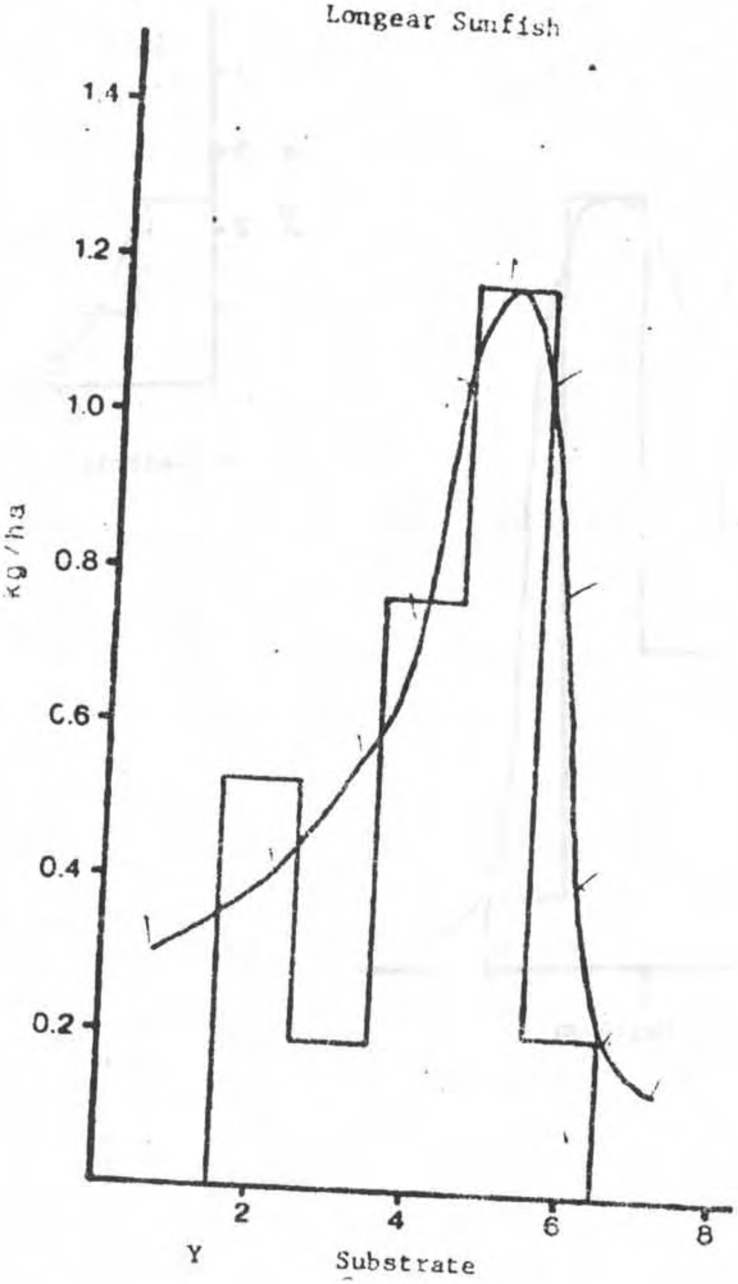

RIVER DARTER

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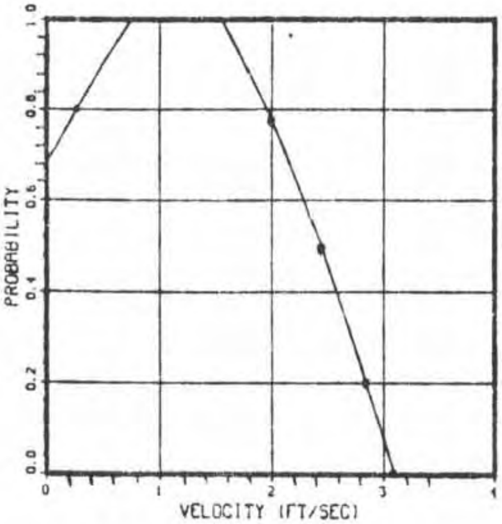
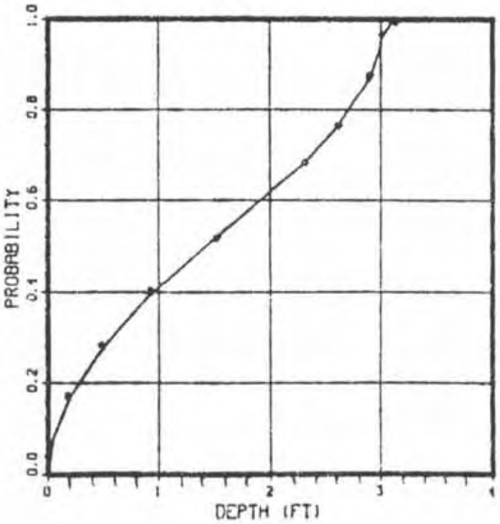
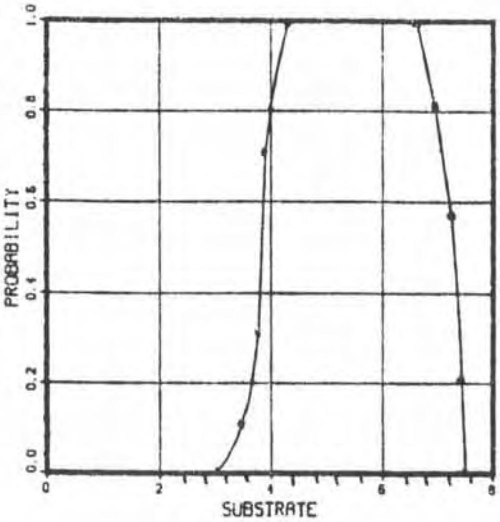
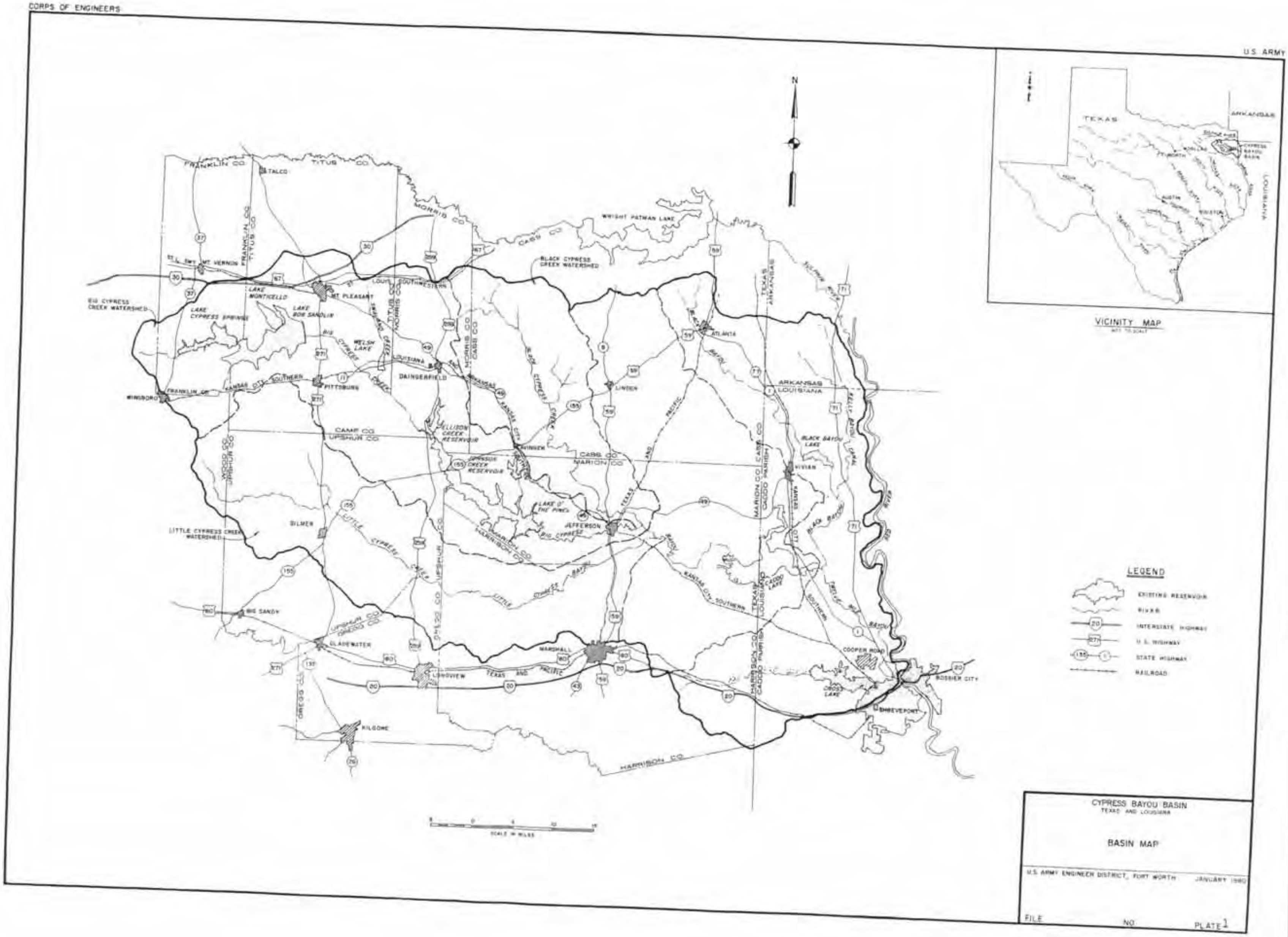






CORPS OF ENGINEERS U.S. ARMY



CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

BASIN MAP

U.S. ARMY ENGINEER DISTRICT, FORT WORTH JANUARY 1960

FILE NO PLATE 1

A. Riffle-run sequence, Black Cypress Bayou near Berea, Marion County, TX. 12-1-83.

B. Stream run with abundant bank and overhanging cover, Little Cypress Bayou, near FM 450, Harrison County, TX. 12-1-83.

Plate 2. Stream habitat features of Cypress Bayou Basin, Texas.

Plate 4. Canopy and instream cover provided by woody vegetation, Big Cypress Bayou, TX. 4-19-84.

A. Transect number 2, streamflow approximately 75 cfs. 1-31-84.

B. Study reach looking downstream, water muddy from runoff, approximately 250 cfs. 4-16-84.

Plate 6. Streamflow study reach on Little Cypress Bayou, immediately downstream from Highway 154, Harrison Co., Texas.

A. Pool area immediately upstream of study transects, estimated streamflow 40 cfs. 12-1-83.

B. Transect number 1, streamflow 100 cfs. 2-2-84.

Plate 8. Streamflow study reach on Black Cypress Bayou, near Berea, Marion Co., Texas.

A. Trail boat collects habitat data (velocity, depth, substrate, cover) at location of collection site.

B. Hydrolab and other instrumentation is used to collect water quality data at study reaches.

Plate 10. Field techniques being used on the Cypress Bayou Basin Cooperative Fishery Study to collect additional fisheries data and develop species preference curves.

A. Electrofishing is used to collect fish in representative stream habitats; collection locations are marked by buoy for habitat parameter measurements.

B. Pertinent data (e.g., length, weight, sex) are gathered to determine life history stage and condition factors.

Plate 9. Field techniques being used on the Cypress Bayou Basin Cooperative Fishery Study to collect additional fisheries data and develop species preference curves.

A. Study reach looking upstream, streamflow approximately 40 cfs. 12-1-83.

B. Study reach looking upstream, streamflow about 250 cfs, water muddy from runoff. 4-17-84.

Plate 7. Streamflow study reach on Little Cypress Bayou, upstream from Highway 3001, Harrison Co., Texas.

A. Stream cross-section data (depths and widths) obtained for each transect.

B. Stream velocities measured across transect.

Plate 5. Techniques used in gathering stream hydrologic data, Cypress Bayou Basin, Texas.

A. Open pool on Little Cypress Bayou, near Highway 3001, Harrison County, TX. 12-1-83.

B. Backwater off main channel of Little Cypress Bayou, near Highway 134, southeast of Jefferson, Marion County, TX. 12-1-83.

Plate 3. Stream habitat features of Cypress Bayou Basin, Texas.

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX H - COORDINATION WITH THE U.S. FISH AND WILDLIFE SERVICE

SECTION 2

JUNE 18, 1986 PLANNING AID LETTER FOR THE LITTLE CYPRESS BAYOU STUDY

IN REPLY REFER TO:

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Ecological Services
9A33 Fritz Lanham Building
819 Taylor Street
Fort Worth, Texas 76102

June 18, 1986

Colonel A. J. Genetti, Jr.
District Engineer
Corps of Engineers, U.S. Army
P.O. Box 17300
Fort Worth, TX 76102

Dear Colonel Genetti:

This letter transmits wildlife planning information for the Little Cypress Bayou study. It is provided pursuant to Section 2(a) of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and the fiscal year 1986 Transfer Funding Agreement, Appendix A Scope of Work.

On May 28, 1986, your agency requested the Scope of Work be modified to require planning assistance from the Fish and Wildlife Service in lieu of a Fish and Wildlife Coordination Act (FWCA) report. This change was necessitated by the lack of a Federal interest in the selected plan of development, Marshall Lake, and the Corps' decision to defer further water resources planning studies.

The Service has submitted four planning assistance reports on the fish and wildlife resources of Cypress Bayou Basin within the past five years. Our report of January 22, 1981, provided instream flow data for Big Cypress Bayou below Lake O' the Pines and was prompted by the Corps' consideration of re-regulating scheduled releases from the lake. Planning reports, dated March 16, 1982 and June 23, 1983, provided fish and wildlife information on several alternative development plans during the Corps' reconnaissance studies of the basin. Our last planning report, submitted July 11, 1984, characterized aquatic resources of the basin and provided preliminary instream flow recommendations for use by the Corps during plan formulation activities.

This report summarizes the current status of wildlife habitat evaluations on Little Cypress Bayou, Marshall Lake site, which was selected for detailed feasibility studies during plan formulation. It provides a synopsis of our habitat evaluation methodology, our baseline assessment of habitat conditions, and a preliminary analysis of habitat compensation requirements should this reservoir project be constructed. If planning is reinitiated on this project at some future date, it would be necessary to evaluate various mitigation areas for their suitability to compensate project-induced habitat losses. This would require the continuation of FWCA investigations by our agency.

STUDY AREA

The area currently under study for potential water resources development is Little Cypress Bayou located in Wood, Upshur, Gregg, and Harrison Counties, Texas (Plate 1). The Little Cypress watershed has a drainage area of approximately 712 square miles, a length of about 62 miles, and a maximum width of 17 miles. Little Cypress Bayou is one of three major streams contributing to the Cypress Bayou Basin which feeds Caddo Lake on the Texas-Louisiana border. Of these three streams, Little Cypress, Big Cypress and Black Cypress, only Big Cypress has been significantly impacted by water resource development projects.

PROJECT PLAN

The plan of development currently being evaluated by the Corps of Engineers is Marshall Lake damsite, located at river mile 21.3 of Little Cypress Bayou, approximately nine miles northwest of the City of Marshall (Plate 2). This multiple purpose reservoir would have a drainage area of 617 square miles and provide a yield of 200 cubic feet per second (cfs) from a 15,763 acre conservation pool. Pertinent project data are provided in Table 1.

Table 1. Pertinent Data for Marshall Lake, Little Cypress Bayou, Texas.

Feature	Elevation (ft. msl)	Area (Acres)	Capacity (Acre-ft)
Top of Conservation Pool	233.1	15,763	217,324
Top of Flood Control Pool	-	-	-
Guide-Take Line	241.7	20,172	373,262
Top of Dam	256.5	30,484	745,312

EVALUATION METHODOLOGY

Wildlife evaluations were conducted on the Marshall Lake site using the Fish and Wildlife Service's Habitat Evaluation Procedures (HEP). HEP is a method which permits the documentation of the quality and quantity of available habitat for selected wildlife species at different time intervals and under various development scenarios. Essentially, HEP quantifies and compares habitat in a study area for future with and without project conditions.

HEP is based on the assumption that habitat for selected wildlife species can be described by a Habitat Suitability Index (HSI). This index value, which ranges from 0 to 1.0, is multiplied by the area of available habitat to obtain Habitat Units (HU's), which are used for the alternative future comparisons. HSI's are generally obtained by comparing field measured habitat variables to optimum habitat criteria preferred by each individual evaluation species.

For the Marshall Lake study area, habitats were delineated using high altitude, color infrared aerial photographs transferred to 7 1/2 minute U.S. Geological Survey quadrangle maps. Area for each representative habitat cover-type was then determined through planimetering. The seven cover-types mapped included bottomland hardwood forest, upland hardwood forest, pine forest, shrublands, herbland/savannah, riverine, and lacustrine.

Evaluation species for the HEP analysis were selected through the application of feeding and reproduction guild matrices. Such a selection process permits the evaluation of an entire ecological community through the use of "indicator species" which have varying feeding and reproductive requirements. Whenever possible, species were also selected which have high public interest and economic values. Thirteen evaluation species were utilized in this analysis. These included the gray squirrel, fox squirrel, white-tailed deer, eastern cottontail, swamp rabbit, barred owl, wood duck, hairy woodpecker, carolina chickadee, red-tailed hawk, bobwhite, scissortail flycatcher, and belted kingfisher. HSI models for these evaluation species were obtained from the Terrestrial Habitat Evaluation Criteria Handbook, Big Sandy Creek, Texas, 1980.

Baseline field data were obtained for the Marshall Lake site on March 31-April 3, 1986. Habitat variables were gathered on a total of 57 sample sites in seven representative wildlife habitats. Study team members included representatives of the Fish and Wildlife Service, Texas Parks and Wildlife Department, and U.S. Army Corps of Engineers. Representatives of the local project sponsor, Kindle, Stone & Associates, participated as observers.

Analysis of the HEP field data involved the determination of the average annual habitat units (AAHU's), based on a 100-year period of analysis, which would occur for each evaluation species within the project area. This analysis compared the AAHU's which would exist under with and without project conditions and calculated the amount of wildlife management lands which would be required to compensate for the negative impact of the project on wildlife habitats.

In order to evaluate future habitat conditions, both with and without a project, it was necessary to estimate the acreage of each habitat type and its HSI for each evaluation species for the period of analysis. The criteria used for developing these projections are attached as Appendix A.

WILDLIFE RESOURCES

Habitat

The project site lies entirely within the Pineywoods ecological area of east Texas. This ecological area is characterized by gently rolling to hilly forested lands interspersed with native grasslands, pasture, and farm lands. Major land uses within the Little Cypress Basin include commercial timber operations, ranching, farming, and oil and gas production.

Seven major habitat cover-types have been mapped and evaluated in this report.

The Bottomland Hardwood Forest (BH) cover-type comprised approximately 72 percent (14,524 acres) of the Marshall Lake site. This habitat type consisted predominately of overcup oak, water oak, willow oak, white oak, cherrybark oak, sweetgum, black gum, and bald cypress in the overstory. Common midstory species included sweetgum, water elm, winged elm, American elm, red maple, green ash, American hornbeam, swamp privet, oak saplings, water hickory, and sugarberry. Primary understory included buttonbush, greenbriar, wild grape, poison ivy, crossvine, American holly, sparkleberry, wildrye, rushes, sedges, and broadleaf chasmanthium.

The Upland Hardwood Forest (UH) cover-type comprised only about 1.0 percent of the reservoir basin, or 203 acres. Primary overstory species of the UH's included post oak, blackjack oak, southern red oak, hickory, and sweetgum. Loblolly and short-leaf pines were also common, but comprised less than 50 percent of the overstory. Typical midstory vegetation included saplings of the overstory species, winged elm, persimmon, dogwood, and boxelder. Common understory species included American beautyberry, sassafras, hawthorne, wild plum, greenbriar, yaupon, deciduous holly, poison ivy, wild grape, and herbaceous plants such as ragweed, Texas wintergrass, bluestems, panicgrass, and lovegrass.

The Pine Forest (P) type consisted of greater than 50 percent by composition of loblolly and shortleaf pine in the overstory. Midstory species included immature pine specimens as well as sweetgum, winged elm, post oak, willow oak, persimmon, and dogwood. Common understory species included dewberry, yaupon, deciduous holly, sumac, American beautyberry, red buckeye, poison ivy, peppervine, and bluestem grasses. Pine forest occupied about 1,613 acres or 8 percent of the Marshall Lake project lands.

The Shrubland (S) cover-type consisted predominately of young generation pine forest in both uplands and bottoms which had been clear-cut and were undergoing natural successional processes. Prevalent vegetation included saplings of loblolly pine and sweetgum, blackberry, wild grape, baccharis, and a herbaceous cover dominated by bluestems. This cover-type occurred on 403 acres (2%) of the project area.

The Herbland/Savannah (H/S) type was openland, primarily improved pasture or native rangelands, with an occasional tree or group of trees. Trees associated with this cover-type included shortleaf and loblolly pine, sweetgum, water oak, elm, and southern red oak. Herbaceous species included common and coastal bermudagrass, croton, and paspalums in the pastures with fencerows either clean or comprised of ragweed, oak and sweetgum sprouts, persimmon and hackberry. The H/S cover-type covered about 3,026 acres (15%) of the project area.

The riparian vegetation associated with the Riverine (R) and Lacustrine (L) cover-types was used to evaluate habitat suitability for terrestrial species. Riparian habitat evaluated was associated with Little Cypress Bayou and numerous tributaries, sloughs, and ponds. Vegetation associated with these water bodies is similar to, and comprised of, many of the same plant species as the BH cover-type. The one major exception was river birch which occurred only along streams. Riparian habitats occupied approximately 2% or 404 acres of the project lands.

Wildlife

Numerous species of birds, reptiles and amphibians, and mammals inhabit the project area. High interest species of mammals include white-tailed deer, gray and fox squirrels, and furbearers. The furbearers include bobcat, raccoon, and mink. Deer are abundant in most bottomland areas and moderate to abundant in the uplands. Gray squirrels are dominant in bottomlands and overlap with fox squirrels along transition woodlands. Fox squirrels are abundant in the uplands.

Over 200 species of birds are known to inhabit the area. High interest upland gamebirds include mourning dove and bobwhite quail. Both are found in seasonal abundance throughout the project area. Wintering and breeding waterfowl populations are abundant in the area, especially wood ducks. This is due to the abundance of highly desirable bottomland hardwoods in the project area.

Herptifauna include snakes (aquatic and terrestrial), frogs, toads, salamanders, and lizards.

The bald eagle, Arctic peregrine falcon, interior least tern, and red-cockaded woodpecker are listed endangered or threatened species in the Cypress Basin. Your studies should assess the probable effects of Marshall Lake Project on these species. If you determine the proposed project may affect these listed species, you should initiate a written request for formal consultation to this office, as provided for by Section 7 of the Endangered Species Act of 1973, as amended.

PROJECT IMPACT ANALYSIS

As discussed in Appendix A, wildlife habitats within Little Cypress Bayou Basin are expected to undergo a significant change in the future even without the construction of Marshall Lake. Bottomland hardwoods are being harvested for timber and permanently converted to pasturelands and pine monocultures due to a higher economic return to landowners. Land use information prepared by the East Texas Council of Governments projected about a 5-10% decrease in woodlands during the 20-year period, 1976-1996. At this rate of depletion, it is expected that bottomland hardwood forests will undergo a 25% reduction during the 100-year period of analysis.

Impacts of Marshall Lake on wildlife resources would be more immediate. Project construction and impoundment would eliminate all wildlife habitat within the conservation pool of the reservoir, i.e. 15,763 acres of which

11,350 acres are productive bottomland hardwoods. Remaining habitat on Government fee lands would also be affected. However, it is believed management activities on these lands, including the revegetation of bottomlands and natural succession, would improve their value as wildlife habitat.

The net impact of the project on wildlife resources was determined by comparing the average annual habitat units (AAHU's) which could be expected without a project to the AAHU's remaining in the project area with the construction of the project. The results of this analysis is provided for each evaluation species by habitat cover-type in Table 2.

Table 2. Comparison of Average Annual Habitat Units (AAHU's) at Marshall Lake, Texas, under With and Without-Project Conditions.

Evaluation Species		AAHU's With Action	AAHU's Without Action	Net Change
ID#	Name			
1	G. Squirrel-BH	3241.85	12602.45	-9360.60
2	Barred Owl-BH	3176.36	12347.85	-9171.50
3	Wood Duck-BH	2357.71	9165.42	-6807.71
4	S. Rabbit-BH	1604.55	6237.58	-4633.02
5	WT Deer-BH	1113.36	4328.11	-3214.75
6	H. Woodpecker-BH	1571.81	6110.28	-4538.47
7	Barred Owl-UH	234.48	153.52	80.96
8	WT Deer-UH	209.80	137.36	72.44
9	H. Woodpecker-UH	46.28	30.30	15.98
10	F. Squirrel-UH	67.88	44.44	23.44
11	Barred Owl-P	300.35	1603.67	-1303.31
12	WT Deer-P	235.41	1256.93	-1021.52
13	H. Woodpecker-P	36.53	195.04	-158.51
14	C. Chickadee-P	93.35	498.44	-405.08
15	WT Deer-S	26.60	43.62	-17.02
16	RT Hawk-S	132.99	218.08	-85.09
17	Bobwhite-S	154.27	252.98	-98.70
18	Cottontail-S	220.77	362.02	-141.25
19	RT Hawk-HS	48.03	1439.21	-1391.18
20	Cottontail-HS	141.26	4232.97	-4091.72
21	Scissortail-HS	135.60	4063.66	-3928.05
22	Wood Duck-R	33.88	149.48	-115.60
23	B. Kingfisher-R	23.35	103.02	-79.67
24	Wood Duck-L	242.75	153.52	89.23
25	B. Kingfisher-L	210.81	133.32	77.49

As can be observed from Table 2, the greatest losses will occur to bottomland hardwoods (BH), which comprise the majority of the reservoir site and possess the greatest overall wildlife value. A positive impact of the reservoir on wildlife would be the creation of additional lacustrine (L) habitat (i.e., open water). The littoral zone of the lake would provide more lacustrine habitat for wood ducks and belted kingfishers than currently exists within the project area. Increased public ownership and management of lands surrounding the reservoir could also be expected to slightly increase upland hardwood (UH) habitat values. Representative wildlife habitats and HEP sample sites are presented in Appendix B.

COMPENSATION ANALYSIS

In accordance with the Fish and Wildlife Service's Mitigation Policy (Federal Register, Vol. 46, No. 15, pp. 7644-7663, January 23, 1981), the Service assigns "resource categories" to fish and wildlife resources based on their value, relative abundance or scarcity, and their susceptibility to development. The purpose of this designation is to guide mitigation planning goals and policies during water resources evaluation and planning activities.

For the Marshall Lake site, bottomland hardwood forests have been designated a resource category 2 due to their habitat value for wildlife evaluation species, scarcity within the Pineywoods ecoregion, and vulnerability to agricultural, forestry, and water development. The mitigation planning goal for resource category 2 bottomland hardwoods is no net loss of "in-kind" habitat value. In essence, this goal requires that "losses" of bottomland hardwood habitat values be replaced with "gains" in bottomland hardwood habitat values. This can only be accomplished through the acquisition and intensive management of bottomland hardwoods remaining in the basin following construction and operation of the reservoir project.

Riverine habitats associated with Little Cypress Bayou, and its numerous sloughs and tributaries, are similarly classified as resource category 2. In-kind compensation of these "wetland" areas would also require acquisition and management of remaining habitats not impacted directly through project construction.

Other habitats in the project area (upland hardwood forest, pine forest, shrubland, herbland/savannah, and lacustrine) have either limited acreages in the reservoir basin or do not provide wildlife benefits equivalent to the bottomlands. With the exception of herbland/savannah, each of these habitats have been classified as resource category 3. This category of habitat has a high to medium value for wildlife evaluation species, but is relative abundant within the planning region. The mitigation planning goal for this category is no net loss of habitat value. If warranted, losses of resource category 3 habitats can be replaced "out-of-kind", i.e., more ecologically important habitats such as bottomland hardwoods can be substituted during development of the mitigation plan. Herbland/savannah or pastureland has been classified as a resource category 4, which has a medium to low value for wildlife. Losses to this resource category should be minimized.

For the purposes of our compensation analysis only resource category 2 bottomland hardwoods and riverine habitats were evaluated, since these habitat types comprise approximately 73% of the project site and represent the most significant habitats impacted by the proposed reservoir. We recommend losses to the more abundant upland habitats be compensated through acquisition and management of bottomlands due to their higher wildlife value, scarcity within the ecoregion, and their vulnerability to development. Since resource category 2 riverine habitats are directly associated with the bottomland hardwoods, this important habitat would likewise be mitigated "in-kind" from the acquisition of bottomland tracts.

In order to perform the compensation analysis, it is necessary to evaluate one or more candidate areas which could be managed for wildlife mitigation purposes. Per our Mitigation Policy, first priority for the identification of a mitigation site should be within the general planning area, which normally includes lands upstream, downstream, or adjacent to the project. Second priority is given to the identification of potential mitigation sites in proximity to the planning area and in the same ecoregion. Finally, third priority is given to recommending a mitigation site elsewhere within the ecoregion.

An area of 6,288 acres, designated Mitigation Area A, was identified downstream of the Marshall Lake damsite and above U.S. Highway 59. This area essentially corresponds to the Little Cypress floodplain downstream of the proposed lake. A second mitigation site, designated Mitigation Area B, was also analyzed. This site consists of approximately 13,034 acres of the Little Cypress floodplain upstream of the project and downstream of State Highway 155. These mitigation areas were evaluated for their future condition using the same land use assumptions and criteria applied to the reservoir lands. However, it was assumed the habitat quality (HSI) of the mitigation lands could be increased to optimum for all evaluation species in assessing their suitability to compensate for project impacts. In reality, differing habitat requirements for each evaluation species would limit this management potential. Appendix A details the procedures utilized in estimating the future habitat conditions of the mitigation sites.

Table 3 displays results of the compensation analysis conducted on the Marshall Lake Project. Information provided in this table includes the net loss of average annual habitat units (AAHU's) which would occur for each evaluation species in the resource category 2 habitats with the construction of the lake, the net gain of AAHU's which would occur with implementation of either Mitigation Plan A or B, the net change in AAHU's, and the management area required to compensate for the AAHU losses. Finally, the average amount of lands required to fully (100%) compensate "in-kind" for the evaluation species representative of the resource category 2 habitats is provided.

As can be observed from Table 3, the most severe impacts will occur to gray squirrel and barred owl due to the loss of high quality, mast producing hardwoods such as water oak, willow oak, overcup oak, and blackgum. Significant impacts will also occur to the other bottomland hardwood and riverine evaluation species, because of the destruction of high quality food and reproductive habitats.

Table 3. Net Change in Average Annual Habitat Units (AAHU's) for Marshall Lake with Mitigation Plans A and B and Acres Required for Compensation.

Evaluation Species ID #	Species	Plan Alternative (AAHU's)	Mitigation Plan A (AAHU's)	Net Change (AAHU's)	Compensation Area Required (AC)	Mitigation Plan B (AAHU's)	Net Change (AAHU's)	Compensation Area Required (AC)	Average Compensation Area Required (AC)
1.	G. squirrel-BH	-9360.60	1014.31	-8346.29	58028.80	2990.54	-6370.60	40797.30	49413.05
2.	Barred owl-BH	-9171.50	1033.42	-8138.08	55805.10	3011.37	-6160.13	39696.60	47750.85
3.	Wood duck-BH	-6807.71	1397.03	-5410.68	30641.30	3516.24	-3291.47	25234.80	27938.05
4.	S. rabbit-BH	-4633.02	732.63	-3900.39	39764.00	1952.40	-2680.62	30929.60	35346.80
5.	WT deer-BH	-3214.75	509.26	-2705.49	39693.30	1351.91	-1862.84	30994.00	35343.65
6.	H. woodpecker-BH	-4538.47	1848.41	-2690.06	15439.20	4213.90	-324.57	14037.90	14738.55
								Average	35088.49
22.	Wood duck-R	-115.60	40.64	-74.96	17885.60	56.54	-59.06	26646.80	22266.20
23.	B. kingfisher-R	-79.67	86.66	+6.99	5780.52	120.58	+40.91	8612.11	7196.32
								Average	14731.26

On the average, approximately 35,088 acres of bottomland hardwood forest and 14,731 acres of riverine habitat would be required to fully compensate for the adverse impacts of Marshall Lake. Therefore, neither Mitigation Area A (6,288 acres) nor Mitigation Area B (13,034 acres) would adequately compensate for the project. These mitigation areas would need to be greatly expanded or other candidate areas identified which could more fully compensate for project-induced wildlife habitat losses. In either case, it is likely losses to riverine habitats could not be adequately compensated, since they cannot be developed from other habitats through management or land use conversions, as can be accomplished for bottomland hardwoods.

DISCUSSION AND RECOMMENDATIONS

The bottomland hardwoods and riverine habitats of Little Cypress Bayou Basin provide a valuable fish and wildlife resource. Our HEP evaluations of the proposed Marshall Lake site indicate the bottomlands provide near optimum habitat for gray squirrel and barred owl, two primary indicators of mature bottomland hardwood forest. Relatively high habitat values for wood ducks were also observed for these habitats.

In 1985, the Fish and Wildlife Service published the final concept plan for the Texas Bottomland Hardwood Preservation Program (U.S. FWS, Albuquerque, NM, May 1985). This document identified and evaluated 62 bottomland hardwood sites in east Texas for their value to waterfowl species. Bottomland hardwoods of the lower Mississippi River delta and Red River Basin including east Texas are considered vital to the welfare of waterfowl in North America, since they provide a significant portion of the breeding and wintering wood duck population and winter 30% of the North American mallard population. East Texas bottomlands also provide critical habitats for a variety of migratory and resident game and non-game species, including endangered species.

Little Cypress Bayou was classified as a Priority 2 site in the Preservation Program document. This classification indicates the site has good quality bottomlands with moderate waterfowl benefits. The Service is currently exploring alternatives for the preservation of this bottomland site, which may include acquisition with migratory bird (duck) stamp monies, conservation easements, leasing, zoning, or other appropriate measures.

Data on losses of bottomland hardwoods in eastern Texas are not well documented. However, it is apparent that losses have been significant due to human activities such as reservoir development, clearing for agriculture, forestry practices, mining and petroleum extraction, and residential, urban, and industrial development. The U.S. Forest Service's status and trend reports indicate that commercial bottomlands decreased by approximately 18% between 1935 and 1975; a 10% decrease has occurred in the past 10 years. Desirable oak-gum-cypress bottomlands declined 13.8%, while elm-ash-cottonwood (an early successional type with lesser wildlife values) increased by 163.1%. From this statistic it is apparent the amount of mature bottomlands in east Texas are decreasing at the expense of pioneer forest types. Of the 1.8 million acres of east Texas bottomlands, it is estimated that only 46,100 acres are at least "medium stocked" with desirable trees.

The above discussion points out the importance and vulnerability of bottomland hardwoods within the project planning area. We believe the economic benefits of any development action, such as the construction of Marshall Lake, should be carefully examined in light of its environmental costs.

Our HEP analysis indicates that approximately 35,000 acres of bottomland hardwood forests would have to be acquired and managed to fully compensate for the adverse impacts of Marshall Lake. It is unlikely this amount of mitigation land could be identified or economically acquired during project planning. Therefore, we recommend the Corps of Engineers not construct Marshall Lake and pursue other more environmentally-sensitive and economically feasible alternatives for flood control and water supply within the Cypress Bayou Basin. One alternative deserving future consideration would be the reallocation of reservoir storage capacity in Lake O' the Pines or other existing reservoirs.

If future planning determines there is a Federal interest in development of the Marshall Lake site, regardless of the environmental costs, it would be necessary to initiate detailed fish and wildlife studies to identify and evaluate potential mitigation sites. Detailed investigations would also be required by the Fish and Wildlife Coordination Act on any other water development alternatives pursued within the basin.

We hope this report provides adequate information for your current planning efforts on Little Cypress Bayou. Please feel free to contact me, if you have any comments or questions concerning our studies.

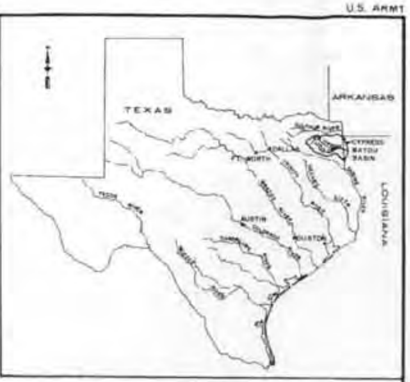
Sincerely,

Jerome L. Johnson

Jerome L. Johnson
Field Supervisor

cc:
Regional Director, FWS, Albuquerque, NM (AHR)
Executive Director, Texas Parks and Wildlife Department, Austin, TX

U.S. ARMY



VICINITY MAP
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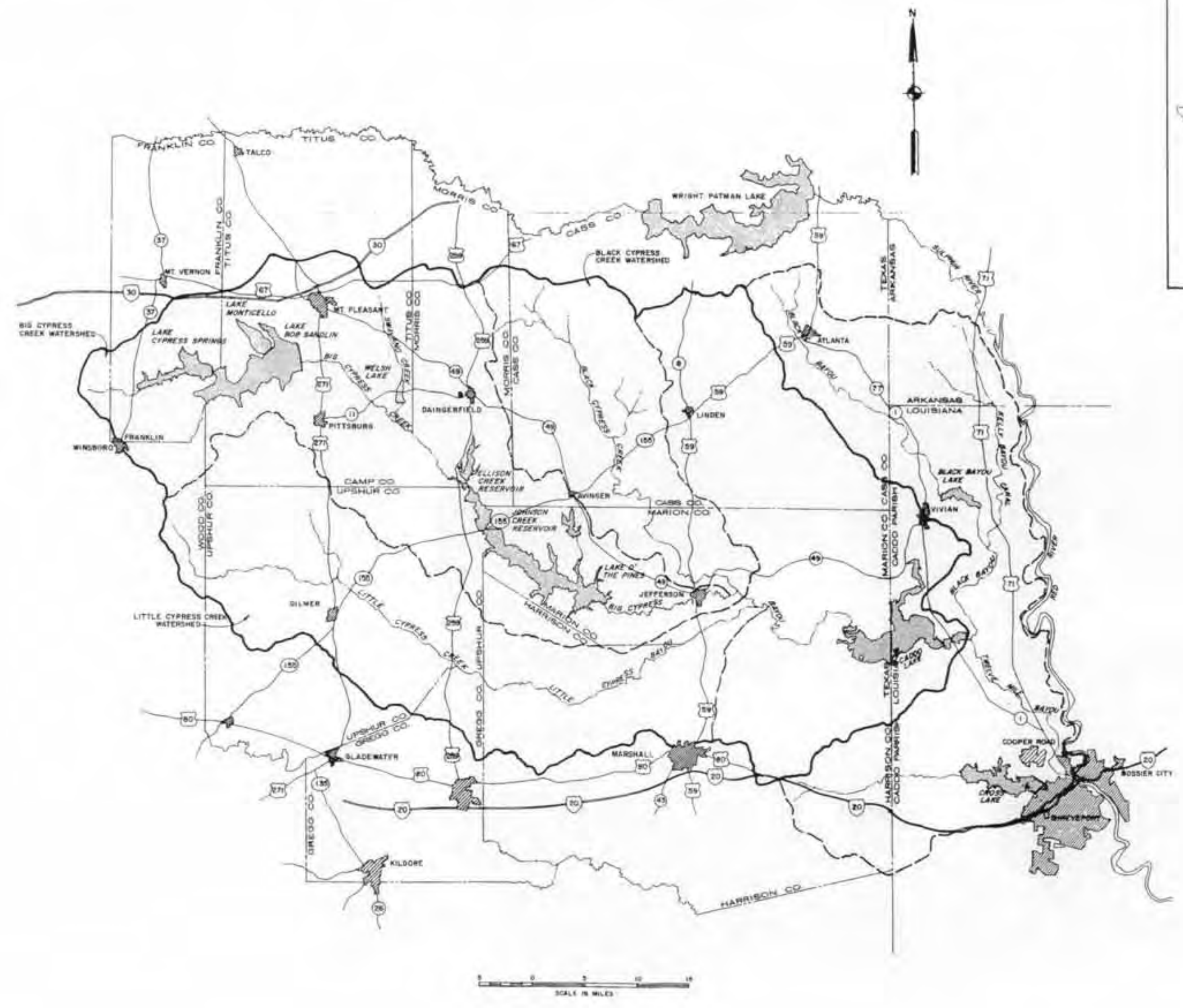
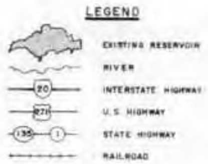




LEGEND

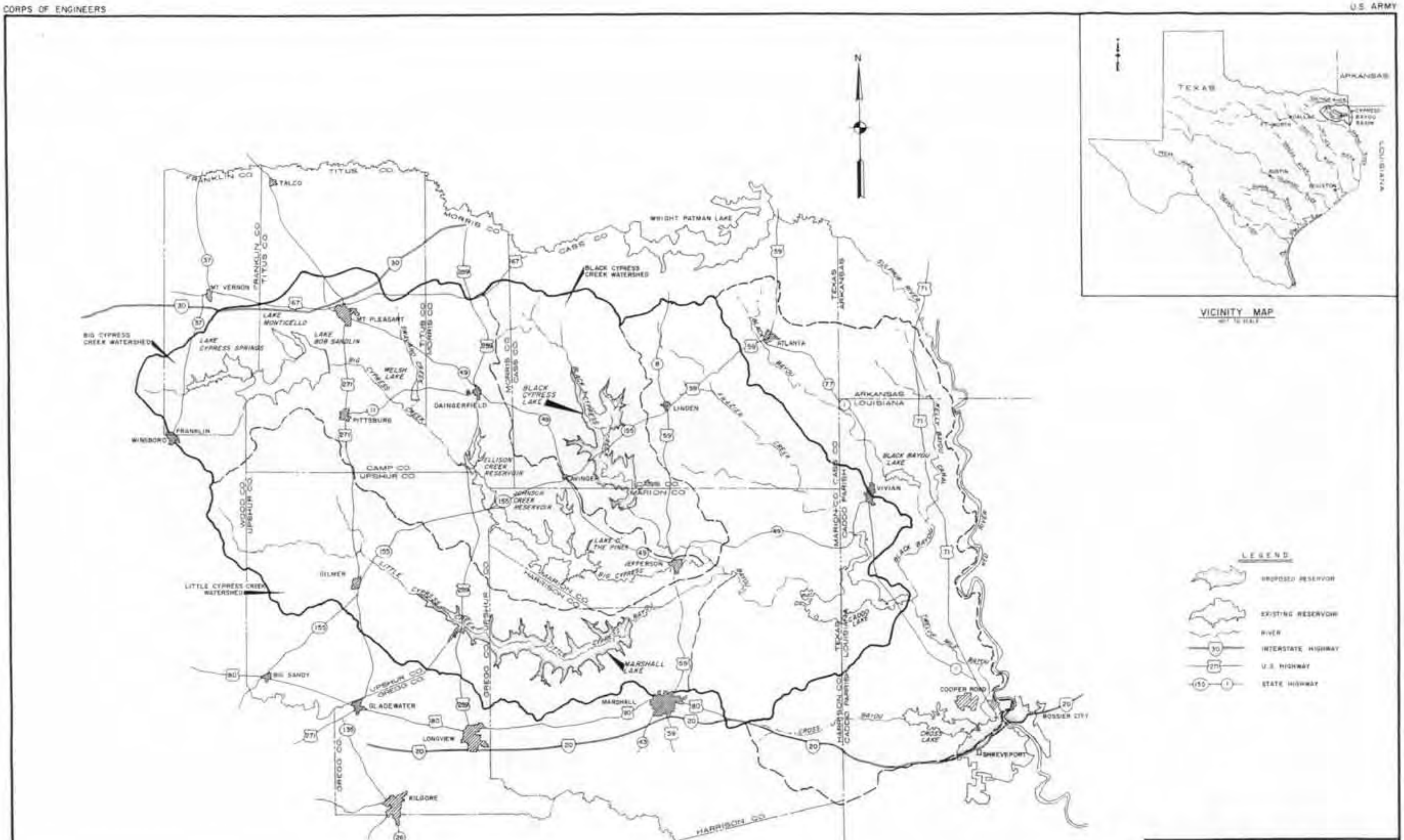
EXISTING RESERVOIR
RIVER
INTERSTATE HIGHWAY
U.S. HIGHWAY
STATE HIGHWAY
RAILROAD

CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

BASIN MAP

U.S. ARMY ENGINEER DISTRICT, FORT WORTH JANUARY 1980

FILE NO. PLATE 1



CYPRESS BAYOU BASIN
TEXAS AND LOUISIANA

LOCATION OF MARSHALL AND BLACK CYPRESS DAMSITES

U.S. ARMY ENGINEER DISTRICT, FORT WORTH JULY 1981

FILE NO PLATE 2

Appendix A
Marshall Lake Impact Analysis
HEP Assumptions

I. Marshall Lake

A. Future Without Project (PA1)

1. Current logging, agricultural, and energy production activities within the basin will result in approximately a 25% reduction in bottomland hardwood forests (BH) over the 100-year period of analysis. These BH's will be converted primarily to herbland/savannah (H/S) and pine forest (P) habitat types, with the pine preceeded in its early successional stages by shrubland (S). It is anticipated that about 67% of the BH's will be converted to H/S and 33% to P. Since most H/S on-site is intensively managed for hay production or cattle grazing, it will not undergo a sere during its conversion from BH, as would be expected from the other habitat types. Estimated habitat acreages by target years for the conservation pool and total project fee lands are displayed in Tables A-1 and A-2, respectively.

2. No significant changes in evaluation species' HSI's are expected during the period of analysis, due to the maintenance of current land use patterns and private land ownership with restricted public access. Changes in wildlife habitat will result primarily from reductions in habitat quantity (i.e., acreage) rather than quality.

B. Future With Project (PA2)

1. Conservation Pool. The reservoir basin will be filled immediately at TY1 with a 100% loss of all habitats. The only exception is lacustrine habitat which will be created by the impoundment. Only the shallow, littoral zone of the lake will be useful as habitat for terrestrial evaluation species such as the wood duck and belted kingfisher (Table A-3).

2. Government Fee Lands - Habitats within the Government property line, but above the conservation pool, will also undergo a significant change over the life-of-the-project. Removal of logging and agricultural practices (i.e., cattle grazing and haying) will result in a longterm change in vegetative structure. H/S and S cover types will be replaced by UH, P and BH through natural successional processes and revegetation with woody plantings. Minor acreages of H/S would be maintained in or near developed recreation/public use areas or project structures.

Estimated habitat acreages for Government fee lands by target year are displayed in Table A-4. Habitat acreages for all project lands are provided in Table A-5.

Natural succession and management activities on fee project lands will also improve their quality as wildlife habitats. However, this will generally be offset through increased public access and human use of these habitats. Therefore, no significant changes in evaluation species' HSI's area anticipated over the period of analysis.

II. Mitigation Area A (Downstream Corridor)

A. Future Without Project and Management (MP1)

1. In the absence of a project, land use patterns downstream of Marshall damsite would be comparable to those experienced upstream. Therefore, over the period of analysis, it is anticipated that about 25% of the BH's would be converted to P and H/S cover types. Of this conversion, approximately 67% would be converted to H/S and the remaining 33% to P (Table A-6).

2. As with project lands, no significant changes in evaluation species HSI's are expected over the period of analysis.

B. Future with Management (MP2)

1. Natural vegetative succession and management practices on mitigation lands will improve the quantity and quality of habitats for evaluation species. It is anticipated management activities would stress the restoration of ecologically important BH's through the conversion of the H/S and P cover types. During the period of analysis, it is estimated that 75% of the H/S and 50% of the P cover types would be converted to BH. About 25% of the P will also be converted to UH's. Each forested habitat would undergo an intermediate shrubland (S) stage (Table A-7).

2. Management activities on the mitigation area will improve habitat quality for evaluation species. In the BH, UH, and P cover types, trees will become more mature, canopy closure will increase, and shrubs and herbaceous vegetation will be reduced. In the H/S and S cover types, shrub/herbaceous canopy closure will occur, height of the vegetation will increase, tree cover will increase, and the distance to woody cover will be reduced. Specific management practices will dictate the quality of the habitat for each target species; however, for the purpose of this impact evaluation, it is assumed optimum quality could be established for each species in its preferred habitat by the end of the period of analysis. Table A-8 displays projected changes in species HSI's based on the above assumptions.

III. Mitigation Area B (Upstream Corridor)

A corridor upstream of the Marshall Lake damsite was evaluated as Mitigation Area B. Future habitat conditions without the project (MP3) and with the project and management (MP4) were compared using the same HSI's and land use projections previously used for Marshall Lake and Mitigation Area A. Tables A-9 and A-10 display habitat acreages by target year for without and with management conditions for Mitigation Area B.

Table A-1. Habitat acreages by target year for Marshall Lake site, without project conditions, conservation pool (PA1).

Habitat Type	TY0 (Baseline)	TY1 (Impoundment)	TY25	TY100
BH	11,350	11,350	10,635	8,500
UH	157	157	157	157
P	1,262	1,262	1,439	2,202
S	315	315	374	315
H/S	2,365	2,365	2,844	4,275
R	157	157	157	157
L	157	157	157	157
Total	15,763	15,763	15,763	15,763

Table A-2. Habitat acreages by target year for Marshall Lake site, without project conditions, total project lands (PA1).

Habitat Type	TY0 (Baseline)	TY1 (Impoundment)	TY25	TY100
BH	14,524	14,524	13,650	10,893
UH	202	202	202	202
P	1,613	1,613	1,815	2,824
S	403	403	470	403
H/S	3,026	3,026	3,631	5,446
R	202	202	202	202
L	202	202	202	202
Total	20,172	20,172	20,172	20,172

Table A-3. Habitat acreages by target year for Marshall Lake site, with project conditions, conservation pool (PA2).

Habitat Type	TY0 (Baseline)	TY1 (Impoundment)	TY25	TY100
BH	11,350	0	0	0
UH	157	0	0	0
P	1,262	0	0	0
S	315	0	0	0
H/S	2,365	0	0	0
R	157	0	0	0
L*	157	275	275	275
Total	15,763	275	275	275

* Lacustrine habitat useful for wildlife evaluation species would consist only of the narrow band of shallow water, littoral zone around the 75 mile shoreline of the reservoir.

Table A-4. Habitat acreages by target year for Marshall Lake site, with project conditions, Government fee lands (PA2).

Habitat Type	TY0 (Baseline)	TY1 (Impoundment)	TY25	TY100
BH	3,174	3,174	3,205	3,250
UH	45	45	197	545
P	351	351	412	400
S	88	88	455	74
H/S	661	661	50	50
R	45	45	45	45
L	45	45	45	45
Total	4,409	4,409	4,409	4,409

Table A-5. Habitat acreages by target year for Marshall Lake site, with project conditions, total project lands (PA2).

Habitat Type	TY0 (Baseline)	TY1 (Impoundment)	TY25	TY100
BH	14,524	3,174	3,205	3,250
UH	202	45	197	545
P	1,613	351	412	400
S	403	88	455	74
H/S	3,026	661	50	50
R	202	45	45	45
L	202	320	320	320
Total	20,172	4,684	4,684	4,684

Table A-6. Habitat acreages by target year for downstream Mitigation Area A without management (MP1).

Habitat Type	TY0 (Baseline)	TY1 (Impoundment)	TY25	TY100
BH	4,613	4,613	4,322	3,450
UH	0	0	0	0
P	1,120	1,120	1,298	1,504
S	7	7	15	7
H/S	310	310	415	1,089
R	230	230	230	230
L	8	8	8	8
Total	6,288	6,288	6,288	6,288

Table A-7. Habitat acreages by target year for downstream Mitigation Area A with management (MP2).

Habitat Type	TY0 (Baseline)	TY1 (Impoundment)	TY25	TY100
BH	4,613	4,613	4,870	5,406
UH	0	0	80	280
P	1,120	1,120	800	280
S	7	7	70	7
H/S	310	310	230	77
R	230	230	230	230
L	8	8	8	8
Total	6,288	6,288	6,288	6,288

Table A-8. Future HSI's for evaluation species at Mitigation Area A, with management (MP2).

Habitat Type	TY0 (Baseline)	TY1 (Impoundment)	TY25	TY100
BH				
1. Gray squirrel-BH	.99	.99	.99	1.00
2. Barred owl-BH	.97	.97	.97	1.00
3. Wood duck-BH	.72	.72	.85	.90
4. Swamp rabbit-BH	.49	.49	.50	.60
5. White-tailed deer-BH	.34	.34	.40	.35
6. Hairy woodpecker-BH	.48	.48	.70	.90
UH				
7. Barred owl-UH	.76	.76	.85	.90
8. White-tailed deer-UH	.68	.68	.60	.50
9. Hairy woodpecker-UH	.15	.15	.50	1.00
10. Fox squirrel-UH	.22	.22	.60	1.00
P				
11. Barred owl-P	.74	.74	.80	1.00
12. White-tailed deer-P	.58	.58	.50	.40
13. Hairy woodpecker-P	.09	.09	.50	.80
14. Carolina chickadee-P	.23	.23	.60	1.00
S				
15. White-tailed deer-S	.10	.10	.80	1.00
16. Red-tailed hawk-S	.50	.50	.60	.80
17. Bobwhite-S	.58	.58	.70	.90
18. Cottontail-S	.83	.83	.90	1.00
H/S				
19. Red-tailed hawk-HS	.34	.34	.60	.90
20. Cottontail-HS	1.00	1.00	.90	.90
21. Scissortail flycatcher-HS	.96	.96	1.00	1.00
R				
22. Wood duck-R	.74	.74	.90	1.00
23. Belted kingfisher-R	.51	.51	.90	1.00
L				
24. Wood duck-L	.76	.76	.90	1.00
25. Belted kingfisher-L	.66	.66	.90	1.00

Table A-9. Habitat acreages by target year for downstream Mitigation Area B, without management (MP3).

Habitat Type	TY0 (Baseline)	TY1 (Impoundment)	TY25	TY100
BH	8,544	8,544	7,400	6,408
UH	90	90	90	90
P	1,204	1,240	1,500	1,909
S	51	51	183	51
H/S	2,721	2,721	3,437	4,152
R	320	320	320	320
L	104	104	104	104
Total	13,034	13,034	13,034	13,034

Table A-10. Habitat acreages by target year for downstream Mitigation Area B, with management (MP4).

Habitat Type	TY0 (Baseline)	TY1 (Impoundment)	TY25	TY100
BH	8,544	8,544	9,800	11,187
UH	90	90	300	391
P	1,204	1,240	602	301
S	51	51	708	51
H/S	2,721	2,721	1,200	680
R	320	320	320	320
L	104	104	104	104
Total	13,034	13,034	13,034	13,034

APPENDIX B

Representative Wildlife Habitats
and
HEP Sample Sites

Logged Bottomland Hardwood (BH) Forest, in vicinity of State Highway 154, mid-lake area.

HEP Site #BH5. Overcup oak dominated BH on Little Cypress Bayou immediately downstream of Marshall Lake damsite.

HEP Site #BH9. Overcup-water oak dominant BH on tributary slough to Little Cypress Bayou near damsite.

HEP Site #BH19. Water-willow oak dominant BH along Little Cypress Bayou, upper lake area.

HEP Site #BH22. Overcup oak flat in mid-lake area.
Note high water mark on trees.

HEP Site #BH23. Water oak dominated BH in mid-lake area.

HEP Site #UH3. Upland Hardwood (UH) forest cover-type dominated by southern red oak, mid-lake area near FM 450.

HEP Site #P1. Pine forest (P) on south ridge of Little Cypress Bayou, adjacent to damsite. Loblolly pine dominant.

HEP Site #S1. Shrubland (S) site dominated by regenerating sweetgum saplings and pine. Clear cut site in upper lake area.

HEP Site #H/S1. Herbland/Savannah (H/S) cover-type north of proposed dam embankment consisting of native bluestem grasses and forbs.

HEP Site #H/S7. Well managed coastal bermudagrass - bahiagrass pasture in mid-lake area.

HEP Site #R6. Riverine (R) habitat of Little Cypress Bayou immediately below damsite. Water elm-bald cypress-river birch dominated.

HEP Site #R8. Overcup dominated R habitat in upper lake area.

HEP Site #L4. Open water marsh in mid-lake area. Shallows dominated by smartweed, buttonbush, and willow.

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX I - HABITAT EVALUATION PROCEDURES IN THE CYPRESS BAYOU BASIN, TEXAS

ENVIRONMENTAL IMPACT RESEARCH PROGRAM

MISCELLANEOUS PAPER EL-86-

APPLICATION OF THE HABITAT EVALUATION PROCEDURES IN THE CYPRESS BAYOU BASIN, TEXAS

by

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Construction of a dam on either the Little or Black Cypress Bayou, Texas, is being evaluated by the US Army Engineer District, Fort Worth, to provide water resource benefits (flood control, water supply, recreation) in the Cypress Bayou Basin. The Habitat Evaluation Procedure (HEP) was used to determine fish habitat gains in the proposed reservoirs, estimate losses in fish habitat resulting from inundation of portions of the Little and Black Cypress bayous, and recommend methods to compensate for habitat losses caused by the project.

Habitat Suitability Index (HSI) models composed of three physical habitat variables (depth, velocity, and cover) were developed from field and literature data for nine species of riverine fishes including: spotted bass, longear sunfish, grass pickerel, flathead catfish, blacktail shiner, ironcolor shiner, brook silverside, spotted sucker, and slough

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19. Abstract (Continued).

darter. These species were selected from biological guilds, and they represented 87 percent of the species community. The longear sunfish, grass pickerel, ironcolor shiner, and slough darter preferred shallow, nonflowing water with abundant instream cover, whereas the spotted bass, flathead catfish, blacktail shiner, and spotted sucker liked relatively deeper, fast-flowing water usually associated with large instream objects such as cypress trees and log-jams. The brook silverside was often found in both types of habitat.

Habitat units (HU) were calculated for each species and river at flows ranging from 0 to 1,000 cfs. Trends in the HU-discharge curves were similar for all evaluation species, although the relative amounts of usable fish habitat varied considerably among species. HU's increased with discharge up to approximately 200 cfs, tapered off or slightly decreased, and then increased again at overbank flows. HU discharge curves were similar among species; so to simplify data interpretation, a single composite HU discharge curve was developed from the average of all species curves and was used in determining baseline habitat and compensation criteria.

Monthly flows that would maintain the historic fish community were identified from the HU discharge curves. In most cases, the maintenance flows corresponded to the 60 percent exceedance value on the monthly flow duration tables. Monthly compensation flows below the proposed damsites were determined to replace fish habitat lost from inundation. Compensation flows during the late winter and spring corresponded to overbank flows (i.e., > 400 cfs), which would replace the majority of fish habitat lost from the project during these months, maximize suitable spawning areas, and ensure fry survival. Compensation flows during the summer and fall months, which are characterized by low flows including prolonged periods when there is no flow in the rivers, ranged from 10 to 100 cfs.

Evaluation of lake habitat was conducted using regression equations based on the standing crop of selected fishes. Habitat gains for four lake species (bluegill, largemouth bass, black crappie, and white bass) as well as total sportfish and total species were determined for both reservoirs. HU's lost from inundation ranged from 333 to 1,502, whereas HU's for total species gained from the reservoir were 21,741. The lake proposed on the Little Cypress Bayou provided more fish habitat than the Black Cypress Reservoir provided.

Preface

This report describes an aquatic resource evaluation of a proposed water resource project in the Cypress Bayou Basin, Texas, and contributes to the overall feasibility study being prepared by the US Army Engineer District, Fort Worth (SWF). Funding for this project was provided by SWF; partial funding for development of the Suitability Index Curves was provided by the Environmental Impact Research Program (Work Unit 32390).

The study was completed by the Aquatic Habitat Group (AHG), Environmental Resources Division (ERD), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). The report was prepared by Messrs. K. Jack Killgore (AHG) and Paul M. Hathorn (SWF). Mr. Tom Cloud (US Fish and Wildlife Service, Fort Worth), Mr. Mike Ryan (Texas Parks and Wildlife Department), Dr. Andrew Miller (WES), Dr. William Matthews (University of Oklahoma), Mr. Kenneth Conley (WES), and Mr. Frank Ferguson (WES) contributed to the conduct of this study. The report was prepared under the supervision of Dr. Thomas Wright, Chief, AHG; Dr. Conrad J. Kirby, Chief, ERD; and Dr. John Harrison, Chief, EL. This report was edited by Ms. Lee T. Byrne of the WES Information Technology Laboratory.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

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Contents

List of Tables

List of Figures

Conversion Factors, Non-SI to SI (Metric)
Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic feet	0.02831685	cubic metres
feet	0.3048	metres
miles (US statute)	1.609347	kilometres
square feet	0.09290304	square metres

Application of the Habitat Evaluation Procedure in the Cypress Bayou Basin, Texas

Introduction

1. The US Army Engineer District, Fort Worth (SWF), is investigating the feasibility of providing flood control, water supply, recreation, and other water resource benefits for the Cypress Bayou Basin, located in northeast Texas. Of the alternative plans considered, construction of a dam on either the Little Cypress Bayou (Marshall Lake) or Black Cypress Bayou (Black Cypress Lake) appears to be the most feasible approach to accommodate the various water resource needs in the basin. Aquatic resource studies of the project were initiated in 1984 by a team of biologists representing SWF, US Fish and Wildlife Service (USFWS), Texas Parks and Wildlife Department (TPWD), and Waterways Experiment Station (WES). The Habitat Evaluation Procedure (HEP) was selected as one method to evaluate the impacts of the project on aquatic resources. The study approach follows the format described in the HEP manual (USFWS 1980) with modifications specific-to-project requirements. An overview of the steps taken in the HEP analysis appears in Table 1.

Table 1

Overview of the Steps Taken to Conduct an Aquatic HEP for the Cypress Bayou Basin Project

Step 1:	Delineate the river and future lake habitat and describe the hydraulic and morphometric features.
Step 2:	Select evaluation fish species and construct the Habitat Suitability Index (HSI) models.
Step 3:	Select representative reaches, collect hydraulic and morphometric data, and estimate physical habitat conditions at target discharges using hydraulic mathematical relationships.
Step 4:	Construct habitat duration curves and define maintenance flows.
Step 5:	Determine habitat units lost in the river due to inundation and develop a plan to compensate for lost habitat.
Step 6:	Determine habitat gains of the project created by the reservoirs.

Purpose and Objectives

2. The purpose of this document is to provide SWF with a comprehensive analysis of fish habitat gains and losses resulting from the construction of a dam on either Little or Black Cypress Bayou. The objectives are:

a. To determine baseline habitat conditions that would maintain the historic fish community structure.

b. To recommend techniques to compensate for the loss of inundated fish habitat.

c. To identify gains in new fish habitat created by the reservoir.

Methods

Study area

3. The study area included the Little and Black Cypress bayous located in northeastern Texas (Figure 1). Both rivers are lowland, meandering, warmwater streams that are relatively undisturbed by water resource development. The rivers have abundant instream cover such as logjams, rootwads, undercut banks, and cypress trees. Substrate composition is relatively uniform ranging from clayey sand to silty clay. Based on data from the US Geological Survey (USGS) gaging stations located on both rivers near Jefferson, Texas, water quality (Appendix A) is adequate to sustain viable fish populations at any flow and therefore was not used in the HEP analysis. The average annual discharge for the Little and Black Cypress bayous is 527 and 333 cfs*, respectively. Discharge ranges from 0 during August through October to greater than 1,000 cfs during the spring months (Appendix B).

4. Three major study areas were used in the HEP: the rivers below the damsites, the lakes, and the portion of rivers that would be inundated (Table 2). The river habitats below the dams extend from the damsite downstream to the confluence with the Big Cypress Creek. The river reaches that would be inundated by the project are between the damsite and the conservation pool elevation (US Army Engineer District, Fort Worth (SWF) 1985).

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

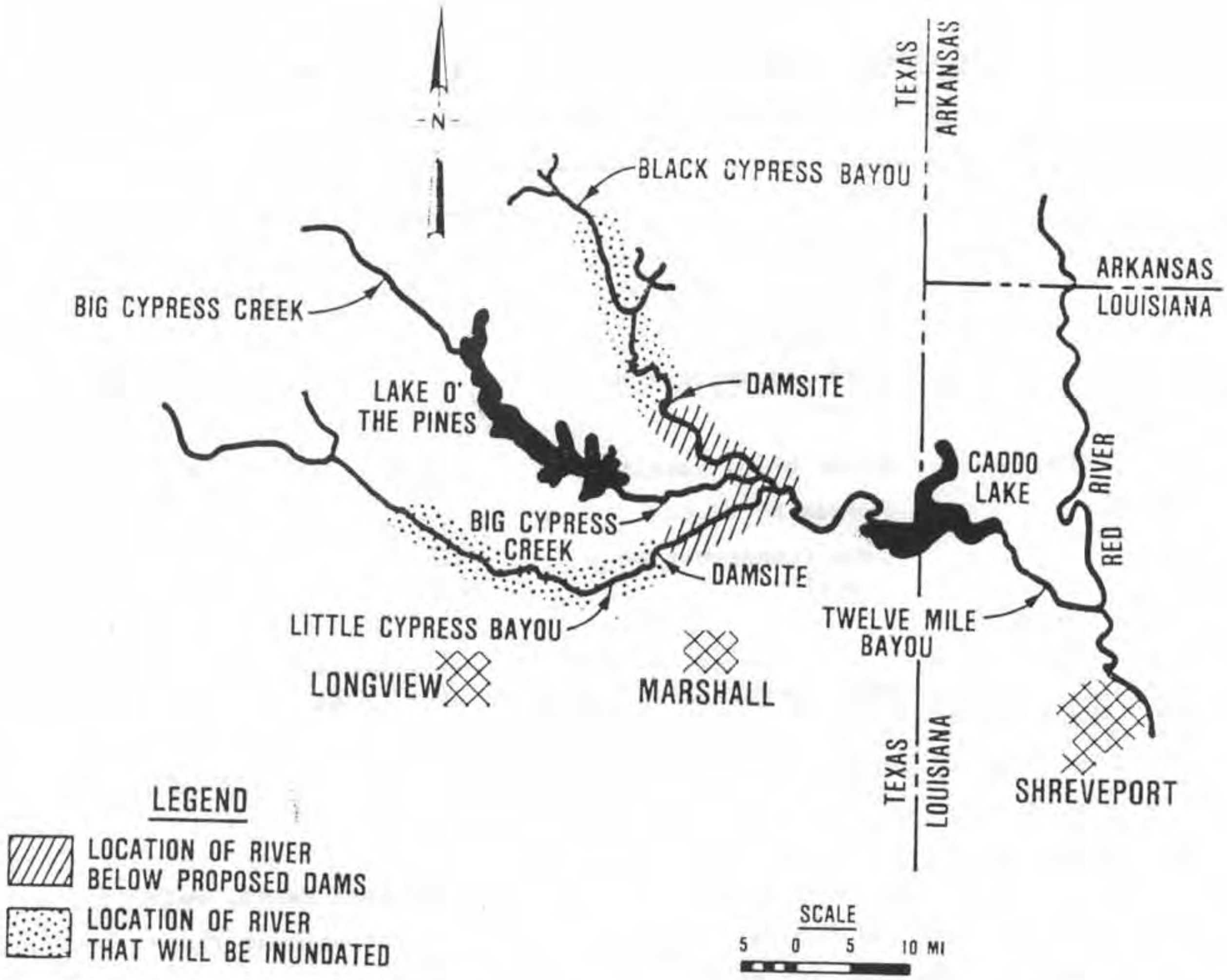

Figure 1. Location of study sites in the Cypress Bayou Basin, Texas

River models

5. From a total of 67 species of fishes known to occur in both rivers (Appendix C), nine evaluation species were chosen for the HEP. These were spotted bass, grass/chain pickerel, flathead catfish, longear sunfish, spotted sucker, blacktail shiner, ironcolor shiner, brook silverside, and slough darter. These species were selected from biological guilds (Appendix D) that considered adult feeding preferences and reproductive strategies and represented 87 percent of the fish community. All evaluation species were considered to be equally important to the stream ecosystem. A periodicity table (Appendix E) was constructed to relate the presence of life stages (spawning, fry, juvenile, and adults) to changes in discharge and water temperature.

Table 2

Delineation Between the River and Lake Habitat for the Little and Black Cypress Bayous

River	Type of Habitat	River Channel miles	Elevation ft	acres
Little Cypress	River below damsite	1-20.3	170-195	646*
	Inundated river	20.3-41.3	195-255	132**
	Lake (conservation pool)	--	195-255	28,988
Black Cypress	River below damsite	1-17.0	175-200	194*
	Inundated river	17-44.0	200-253	--
	Lake (conservation pool)	--	200-253	21,951

* Calculated at annual median flow occurring at USGS Gage near Jefferson, Texas.

** Calculated at annual median flow occurring at USGS Gage near Ore City, Texas.

6. The variables used to assess fish habitat were depth, velocity, and cover. These physical habitat variables are important because they: (a) regulate the carrying capacity of a river system if water quality is within the tolerance limits of the species, (b) are directly impacted by water resource development, (c) can be manipulated to provide optimum habitat conditions, and (d) are easily measured in the field. Suitability Index (SI) Curves for these variables were developed from field data for all evaluation species except the flathead catfish and slough darter. Curves for these species were developed from the literature. Because of the lack of field data on nonadult life stages, only adult life stages were used in the HSI models. Juveniles generally occurred in habitats similar to those of adults. Requirements for spawning and for survival of fry were accounted for by the occurrence of overbank flows.

7. Fish habitat utilization was determined by measuring water depth, water velocity, and the presence or absence of instream cover at each location where an evaluation species was captured by electrofishing. Length and weight

of each evaluation species were recorded at the time of capture to separate the species into adults, juveniles, and fry. To the extent possible, an equal amount of time was spent at each type of habitat (channel, side channel, and shoreline). Field data were collected seasonally for both rivers during 1984.

8. SI curves were prepared for each evaluation species (Appendix F). These curves summarize the frequency of capture for each of the three habitat variables and for each evaluation species. The Y-axis, or SI Score, ranges from 0.0 (poor habitat) to 1.0 (optimum habitat) and is a qualitative measure of habitat value. An average HSI score for each species was derived from the geometric mean of all variables using the following formula:

$$HSI = (V_1 \cdot V_2 \cdot V_3)^{0.333} \quad (1)$$

where

HSI = Habitat Suitability Index value for physical habitat
V_1 = depth, ft
V_2 = velocity, ft/sec
V_3 = cover, percent

Lake models

9. The following fishes were evaluated for the proposed lakes: largemouth bass, bluegill, black crappie, white bass, total sport fishes, and total fishes. Predicted standing crops for each species were determined using regression equations prepared by the USFWS (Table 3) and were converted to HSI scores using the technique described in Aggus and Morais (1979).

Field methods--rivers

10. Prior to field sampling, a reconnaissance of both rivers was made by boat, and two representative sites were selected at each river. The sites on the Little Cypress Bayou were located at river mile 2 (Elevation 170 ft, represented 13 river miles) and near the Highway 154 Bridge crossing (Elevation 210 ft, represented 7.3 river miles). Sites on the Black Cypress Bayou were located at river miles 1.5 (Elevation 175 ft, represented 10.5 river miles) and near Berea Bridge crossing (Elevation 200 ft, represented 6.5 river miles). At each site, a metal tag line was positioned across the river at two locations separated by 0.1 mile, and depth, velocity, and

Table 3

Summary of Regression Equations and Variables Used to Calculate HSI Values for Lake Evaluation Species

			Lake Habitat Variables							
Species	Regression Equation to Predict Standing Crop	R^2	Lake	Dissolved Solids mg/ℓ	Growing Season days	Outlet Depth ft	Area of Conservation Pool ft^2	Mean Depth ft	Water Level Fluctuation ft	Age years
Largemouth bass	0.5743 − 0.3120 (log water level fluctuations) + 0.2594 (log dissolved solids) + 0.0046 (age)	0.244	Little Cypress (Marshall Lake)	150	213	60	28,988	23	10	1
Bluegill	−821.4815 + 366.5507 (log growing season) − 0.0688 (dissolved solids) + 0.00006 (dissolved solids squared)	0.244	Black Cypress	50	213	60	21,951	20	10	1
Black crappie	2.7778 − 0.0088 (dissolved solids) − 0.00001 (dissolved solids squared)	0.500								
White bass	5.1756 − 0.9512 (log area) − 2.9939 (log mean depth) + 0.0309 (outlet depth) + 1.2550 (log dissolved solids)	0.172								
Total sport fish	0.9809 − 0.0056 (mean depth) + 0.3877 (log mean depth) + 0.9944 (log growing season)	0.094								
Total species	4.9397 + 0.1614 (log area) − 0.0090 (mean depth) − 1.2663 (log growing season) −2 × 10^{-8} (dissolved solids squared)	0.292								

cover were measured at regular intervals (number of intervals = 10 percent of the cross-sectional width) that divided the cross section into cells. Water depth was measured to the nearest 0.1 ft using a leveling rod. Water velocity was measured to the nearest 0.1 ft/sec using a Marsh-McBirney model 201 current meter. If the total depth (TD) was less than or equal to 3.0 ft, then velocity was measured at 0.6 TD. If TD exceeded 3.0 ft, then velocity was measured at both 0.2 and 0.8 TD, and an average was obtained. Cover was classified as "present" or "not present" in each cell and converted into the percentage of cells with cover. In addition, the slope and distance from the water's edge to the high- water mark were measured with a hand-held level and tape measure respectively. Collectively, these sites represented habitat below the damsites. In addition, the downstream transect site at Highway 154 represented habitat features above the damsite for the Little Cypress Bayou.

Data analysis

11. A noncomputerized method of determining depth, velocity, cover, and other morphometric features of the cross sections at a range of discharges, partially modified from Dunham and Collotzi (1975) and Bovee and Milhous (1978), was used to predict physical habitat conditions at unmeasured flows. The water surface profile measured in the field was plotted on graph paper (Figure 2), and unmeasured hydraulic geometric features of the cross sections were extracted from these graphs in order to calculate velocity and to determine the water depth and percentage of cover for a range of discharges. A detailed description of this procedure for the Little Cypress Bayou is shown in Appendix G.

12. HU's were determined from the following equation:

$$HU = HSI \times Acres \qquad (2)$$

where

HSI = Habitat Suitability Index
Acres = Acres of river at a given discharge
HU = Habitat units

This equation was applied to each discharge of interest (10 to 1,000 cfs) for each species at each representative reach. An SI was assigned to the value of each variable (depth, velocity, cover) that occurred at the target discharges.

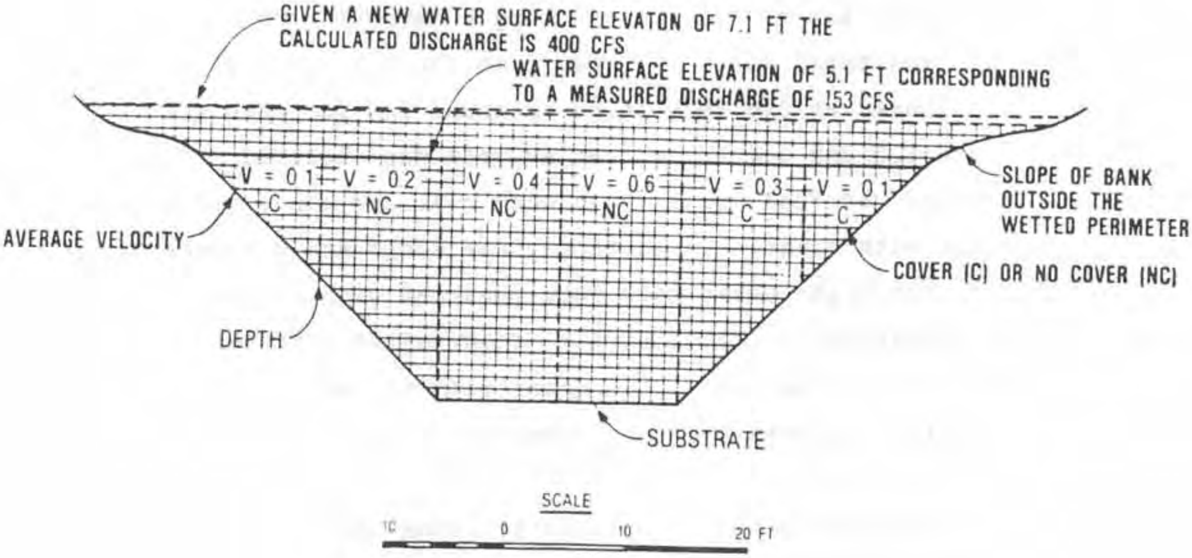

Figure 2. Schematic drawing of procedure to estimate habitat availability for unmeasured flows

The SI values were aggregated into the HSI model to obtain a value between 0.0 to 1.0 that indicated the suitability of the conditions of depth, velocity, and cover to the evaluation species. The product of the HSI equation was multiplied by the acres of river that occur at each target discharge to obtain HU's. Total HU's for the river were calculated by adding the HU's of the representative reaches for each target discharge.

Results

13. An increase in discharge usually resulted in a positive change in HU's for all species (Figures 3 and 4). HU's increased most rapidly between 0 and 200 cfs, and either tapered off or slightly decreased at discharges greater than 200 cfs. Decreases in HU's were due to high velocities without any substantial addition of cover. HU's increased at overbank flows (i.e., 425 and 460 cfs for the Little and Black Cypress bayous, respectively) because of an increase in cover, shallow depths, and surface area. The Little Cypress Bayou provided more fish habitat than the Black Cypress Bayou provided at all

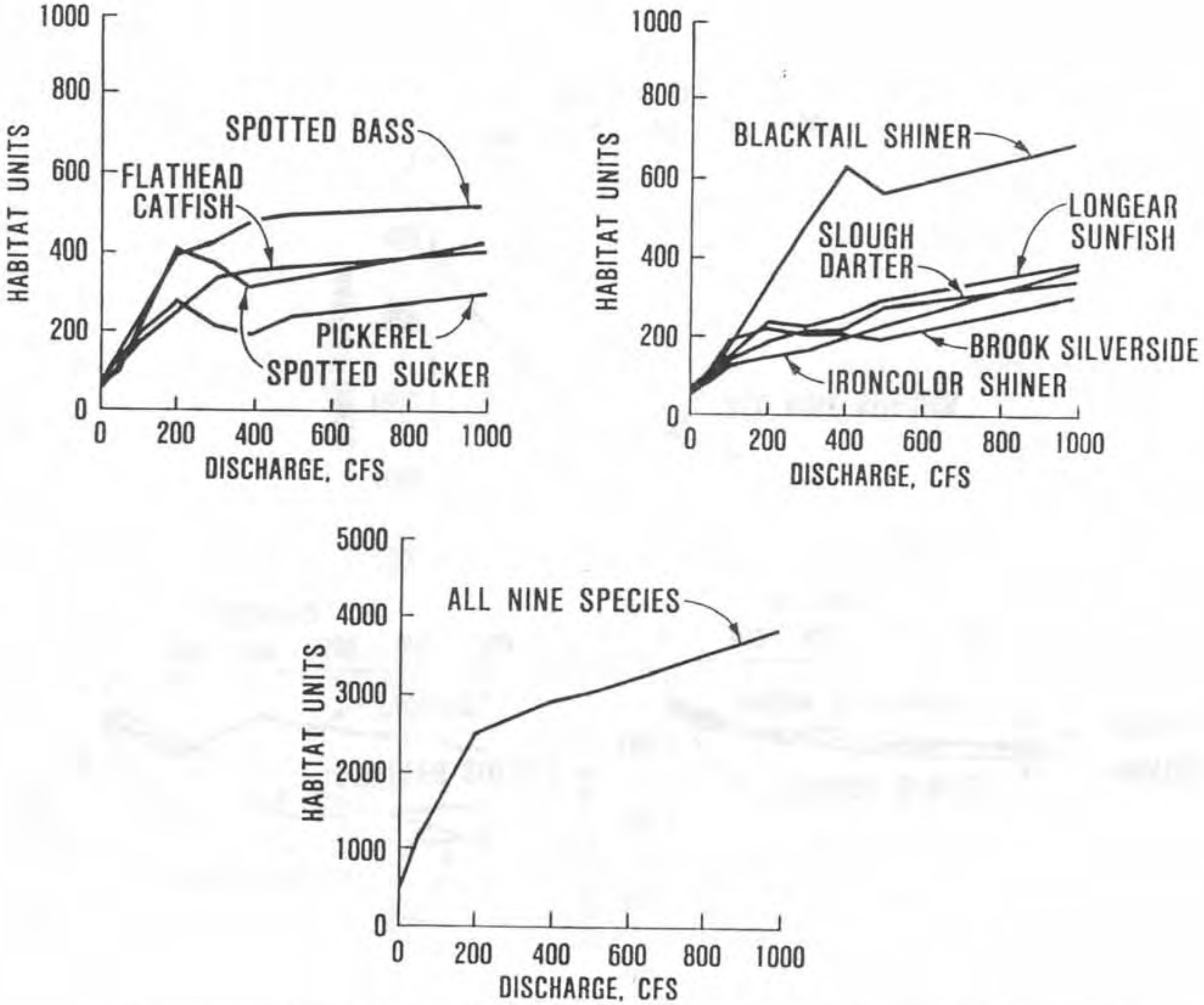

Figure 3. Habitat unit (HU) discharge plots of the evaluation species for the Little Cypress Bayou

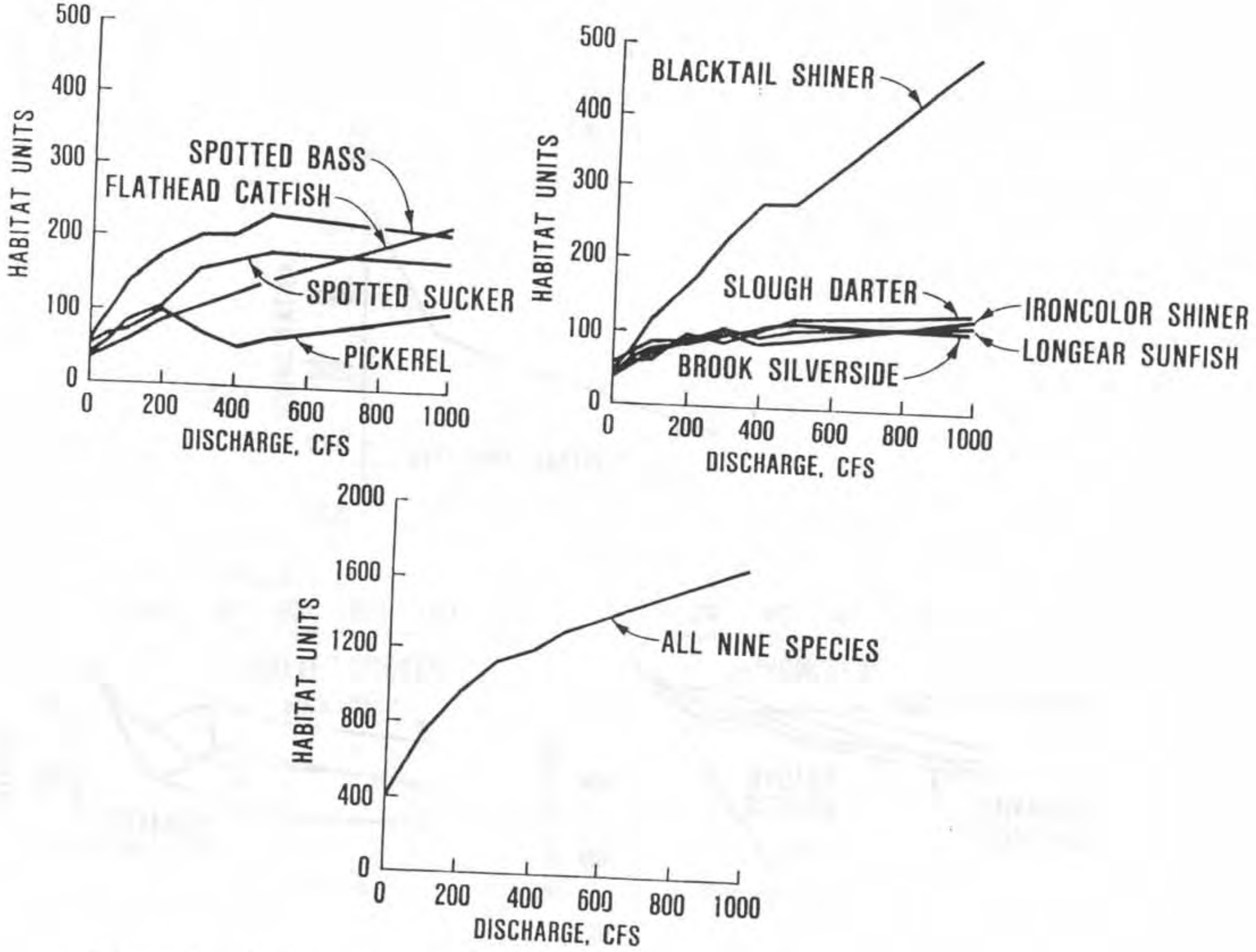

Figure 4. Habitat unit (HU) discharge plots of the evaluation species for the Black Cypress Bayou

discharges. Species that preferred or could tolerate high-velocity, deep water (such as the blacktail shiner, spotted bass, spotted sucker, and flathead catfish) had higher amounts of HU's than did species that usually inhabited shallow, slow-moving water with substantial amounts of instream cover (such as the pickerel, longear sunfish, brook silverside, ironcolor shiner and slough darter). Even though the amounts of HU's were different among species for a given discharge, the trend of the HU discharge curves was similar. Therefore, to simplify data interpretation, a composite HU discharge curve was developed from the average of all nine individual species curves and was used to determine baseline conditions and compensation requirements (Figures 3 and 4).

14. Maintenance flows have been defined for this study as the positive, inflection point on an HU duration-discharge curve and are considered to be those baseline conditions that would maintain the historic fish community structure for a specific time period. An HU duration curve is a cumulative frequency plot that shows the percentage of a certain amount of habitat being equalled or exceeded during a given time period, as described in Bovee (1982). A 10-percent value indicates HU's that occur infrequently, whereas a 90-percent value indicates HU's that occur frequently. For each river, the 10- through 90-percent HU duration values were plotted on the y axis, and the flows that corresponded with each HU value were indicated on the x axis (Figures 5 and 6). The inflection points were visually interpreted from these figures and from a table of these data (Appendix H). Table 4 shows the monthly maintenance flows for each river. The maintenance flows for most months occurred around the 60-percent HU exceedance value maintenance flows during the late winter and spring ranged from 190 to 270 cfs in both rivers and declined to near 0 cfs in the summer and early fall.

15. The Little and Black Cypress bayous are classified by USFWS as resource category 2 (in-kind replacement, no trade-offs); therefore, habitat gains from the lake were not included in the compensation analysis. Due to a determination late in the study that a damsite on Black Cypress Bayou was not economically feasible, a compensation plan was conducted for only the Little Cypress Bayou. Loss in HU's at the 50-percent exceedance flow was determined by month to represent the portion of the Little Cypress lost as the result of inundation. The monthly 50-percent exceedance flows were obtained from the

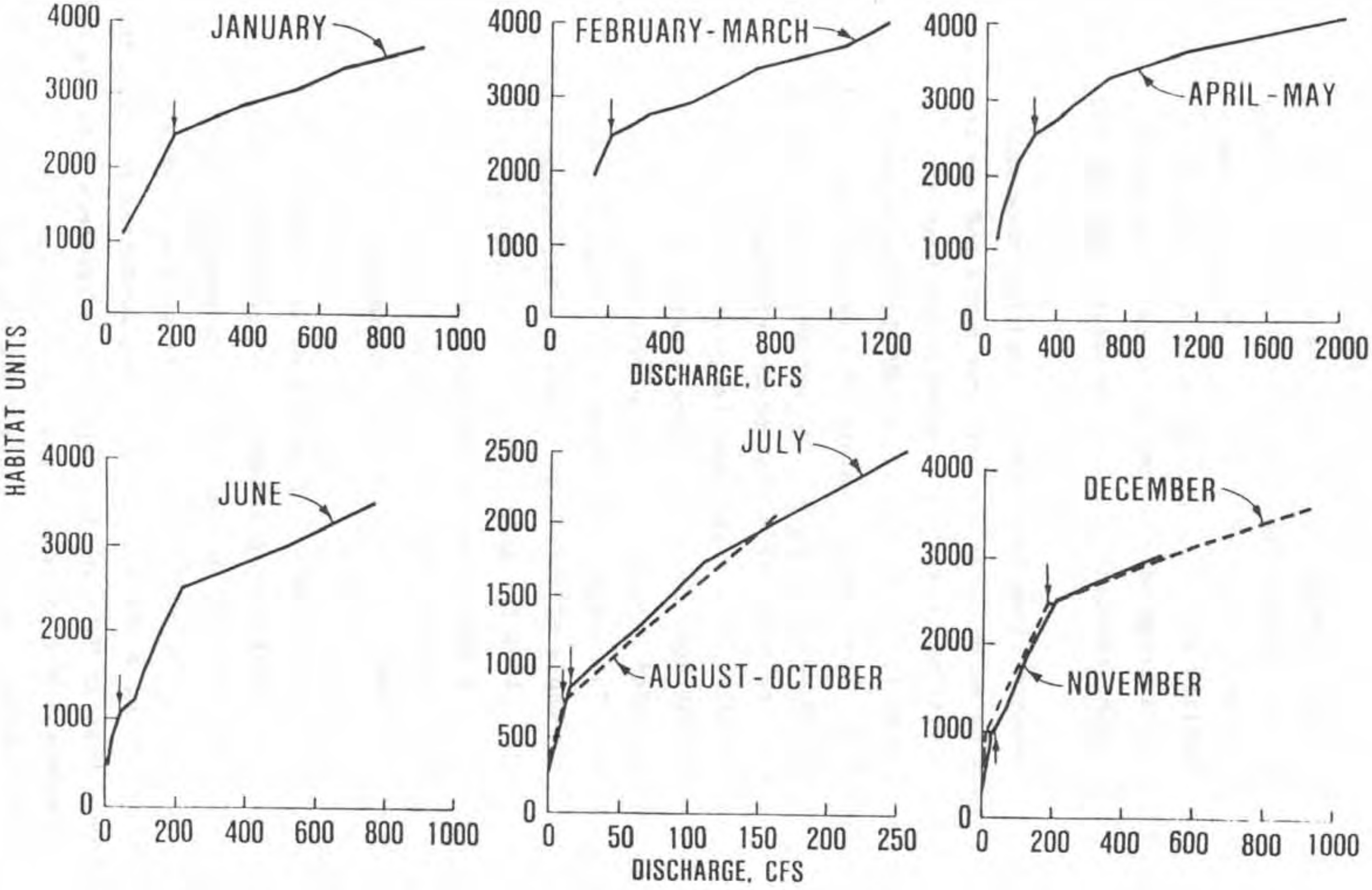

Figure 5. Plots of the habitat unit (HU) duration values and flow for the Little Cypress Bayou. (Arrows indicate the inflection point corresponding to the maintenance flow)

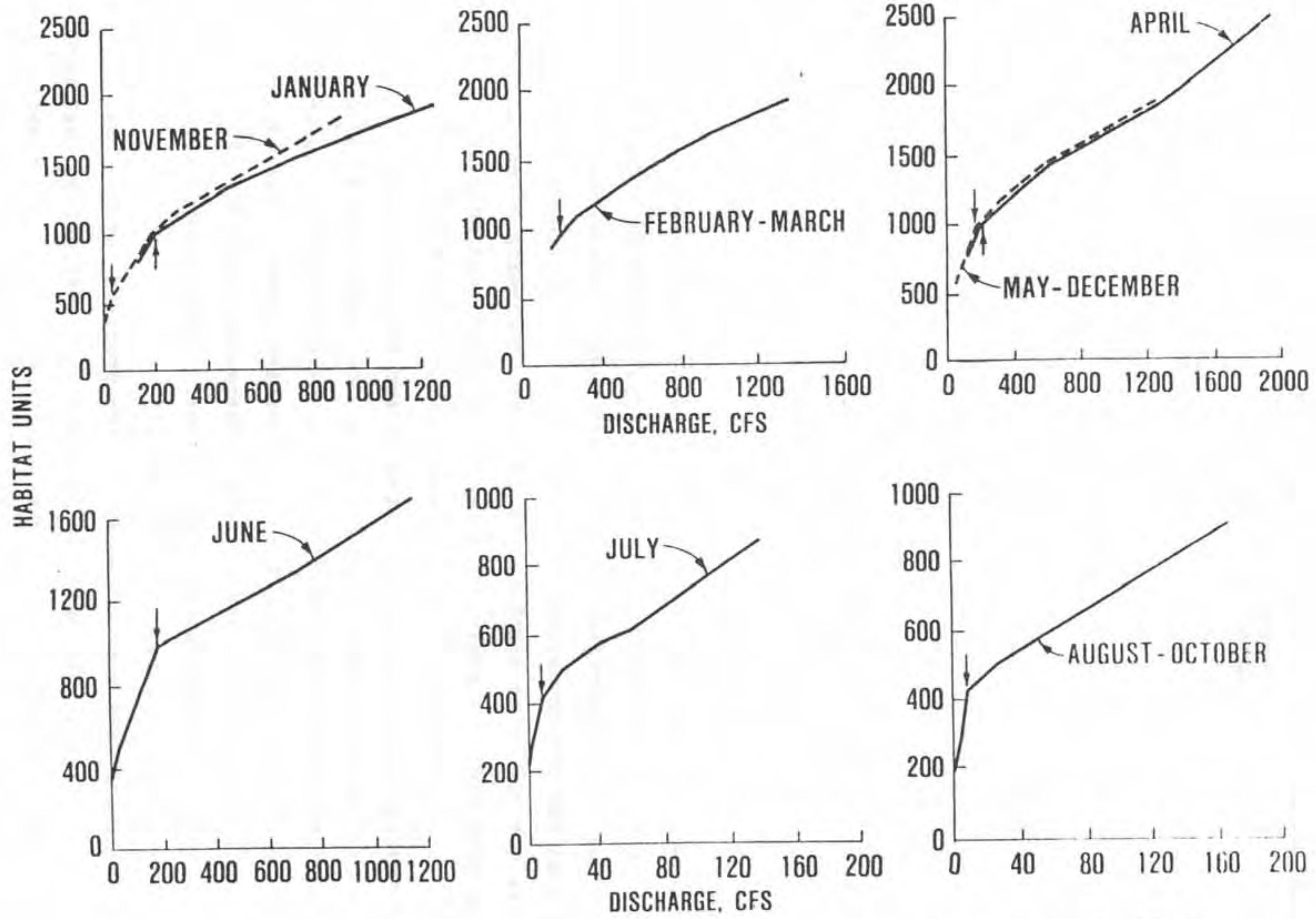

Figure 6. Plots of the habitat unit (HU) duration values and flow for the Black Cypress Bayou. (Arrows indicate the inflection point corresponding to the maintenance flow)

Table 4

Maintenance Flows for the Little and Black Cypress Bayous

Month	Maintenance Flow, cfs	
	Little Cypress Bayou	Black Cypress Bayou
January	190	190
February	215	210
March	215	270
April	270	210
May	270	180
June	40	55
July	14	7
August	3	3
September	3	3
October	3	3
November	16	65
December	55	180

USGS gaging station at Highway 259 near Ore City, because it more accurately represented the flows occurring in the overall river segment that would be inundated than did the downstream gaging station (i.e., Highway 59). Furthermore, HSI values and other morphometric features, including acres, that occurred at each median monthly discharge at the USGS gage near Ore City were determined from the Highway 154 downstream transect (see Table C3), which was considered representative of the inundated stream habitat of the Little Cypress Bayou. The total HU's lost to lake habitat ranged from 333 to 1,502 depending upon the season (Appendix J). It was determined that compensation flows of 10 to greater than 425 cfs (i.e., overbank flows) would be needed below the dam to achieve full and in-kind compensation for habitat lost to inundation (Table 5) and to maintain the historic fish community from the damsite to the mouth of the Little Cypress Bayou.

16. An aquatic HEP was conducted for the proposed Marshall and Black Cypress lakes (Table 6). The analysis includes a 10-year period beginning immediately after dam closure and assumes that the physical and chemical variables used in the lake HSI models (Table 3) would not significantly change

Table 5

Compensation Flows for the Little Cypress Bayou

Month	Maintenance Flow Below the Dam		Monthly Median Flow at USGS Gage near Ore City	Habitat Units Lost from Inundation	Compensation Flow	
	cfs	HU's			cfs	HU's
January	190	2,420	149	1,011	>425*	>3,000
February	215	2,500	253	1,448	>425	>3,000
March	215	2,500	298	1,502	>425	>3,000
April	270	2,600	206	1,212	>425	>3,000
May	270	2,600	193	876	>425	>3,000
June	40	1,010	45	487	100	1,500
July	14	850	6	314	50	1,160
August	3	400	2	333	10	700
September	3	400	2	333	10	700
October	3	400	3	333	10	700
November	16	990	33	442	85	1,400
December	55	1,110	92	760	150	1,900

* Overbank flows.

during this time period. Marshall Lake had the highest amount of habitats for all species except bluegill. These data were prepared to define habitat gains from the project and were not intended to facilitate trade-off analysis. With either lake, however, these gains would occur and should be considered as intangible benefits of the lake. These values can also be used in determination of economic man-days (recreation) benefits attributable to the lake project.

Discussion

17. Rivers in the Cypress Bayou Basin undergo extreme seasonal water level fluctuations. Summer drought accompanied by high-water temperatures and low dissolved oxygen (see Appendix A) drastically decreases usable fish habitat. These conditions can increase spatial competition for food and habitat

Table 6

Average Annual Habitat Units (HU's) of Lake Species for Marshall and Black Cypress Lake During the Time Period of 1 to 10 Years

Lake	Species	Area of Habitat acres	Habitat Suitability Index	Average Annual HU's
Marshall Lake (Little Cypress)	All Species	28,988	0.75	21,741
	Bluegill	28,988	0.45	13,045
	Largemouth Bass	28,988	0.40	11,595
	Black Crappie	28,988	0.50	14,494
	White Bass	28,988	0.78	22,610
	Sportfish	28,988	0.58	16,813
Black Cypress Lake	All Species	21,951	0.77	16,902
	Bluegill	21,951	0.71	15,585
	Largemouth Bass	21,951	0.35	7,683
	Black Crappie	21,951	0.62	13,609
	White Bass	21,951	0.65	14,268
	Sportfish	21,951	0.55	12,073

(Cowx, Young, and Hellawell 1984) and can also increase foraging efficiency by predators because of clear water and concentrated prey (Stevens and Miller 1983). In contrast, high flows during spring increase usable fish habitat and ensure adequate spawning, survival, and nursery habitat for fishes. Instream flow releases, particularly during the summer drought, would moderate standing crop fluctuations in downstream reaches and compensate for in-kind habitat lost from inundation.

18. The HEP is a flexible procedure to assess changes in habitat from water resource projects. A variety of species-oriented assessment techniques have been developed that are conceptually similar to HEP but differ in expertise (training) requirements, time and resource constraints, data requirements, and objectives pursued (Schuytema 1982, Coulombe 1978). The HEP is ideally suited for analyzing lake habitat, although limited by one's ability to predict future habitat conditions. This method is specifically tailored to

facilitate trade-off analysis and to develop compensation plans. The HEP was selected to analyze river habitat to minimize the requirements for data acquisition and analysis as well as to provide a quantitative and relatively rapid approach in determining changes in fish habitat as a function of flow. An important advantage in using the hydraulic procedures described in this report was the ability to extrapolate the amount of usable fish habitat to a flow range of 0 to 1,000 cfs in a relatively short time. Six working days were required to complete the river analysis, including the collection of field data (physical habitat), and to determine maintenance plus compensation flows.

Conclusions and Recommendations

19. Usable habitat for nine species of fish increased with discharge up to 200 cfs, moderated or decreased at flows from 200 to 400 cfs, and again increased at overbank flows.

20. The longear sunfish, ironcolor shiner, grass/chain pickerel, and slough darter preferred shallow, slow-moving water with abundant instream cover, whereas the spotted bass, blacktail shiner, spotted sucker, and flathead catfish liked deeper water with moderate to fast flow usually associated with large instream objects such as cypress trees and logjams. The brook silverside was found in both types of habitat.

21. To maintain the status quo of the fish community structure below the proposed damsite, the monthly maintenance flows that appear in Table 5 should be released.

22. To compensate for the inundated fish habitat, the compensation flows that appear in Table 6 should be released. Overbank flows should be released periodically during the spring spawning season to maximize spawning areas and to ensure fry survival.

23. Marshall Lake will create more fish habitat than will Black Cypress Lake.

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Appendix A: Summary of Water Quality Variables in the Cypress Bayou Basin, Texas

River/Month	Conductivity µmho/cm	Temperature °C	Total Dissolved Solids mg/ℓ	Dissolved Oxygen mg/ℓ	Turbidity JTU
		Little Cypress Bayou			
January	178 ± 58(11)	5.9 ± 2.6(11)	110 ± 30(11)	10.9 ± 0.8(7)	8.0 ± 5.0(4)
February	186 ± 54(6)	8.0 ± 3.4(6)	110 ± 25(6)	8.7 ± 1.7(3)	--
March	153 ± 43(9)	15.4 ± 1.7(9)	94 ± 25(9)	7.2 ± 1.1(5)	6.0 ± 1.7(3)
April	146 ± 56(8)	17.7 ± 1.8(8)	86 ± 30(8)	6.9 ± 0.9(6)	15.0 ± 2.8(2)
May	185 ± 99(8)	22.2 ± 1.5(7)	111 ± 56(8)	6.1 ± 0.3(4)	26.0 ± 1.4(2)
June	150 ± 76(7)	24.7 ± 2.4(7)	93 ± 45(7)	5.5 ± 1.3(7)	14.0 ± 12.7(2)
July	207 ± 59(8)	27.5 ± 1.5(8)	125 ± 26(8)	4.3 ± 1.1(5)	23.5 ± 10.6(2)
August	296 ± 206(9)	27.1 ± 2.3(9)	213 ± 148(9)	5.2 ± 0.6(5)	24.0 ± 25.4(2)
September	182 ± 55(8)	24.5 ± 2.9(7)	109 ± 29(8)	5.4 ± 0.7(4)	14.0(1)
October	220 ± 82(9)	17.5 ± 3.0(9)	127 ± 47(9)	6.9 ± 1.6(5)	5.0(1)
November	225 ± 91(9)	11.3 ± 4.0(9)	133 ± 48(9)	8.8 ± 2.4(4)	7.5 ± 0.7(2)
December	189 ± 104(9)	8.5 ± 2.1(9)	109 ± 54(9)	9.9 ± 2.0(4)	--
		Black Cypress Bayou			
January	52 ± 4(5)	7.6 ± 1.1(4)	45 ± 4(5)	--	--
February	56 ± 11(7)	8.2 ± 4.3(7)	45 ± 8(7)	--	--
March	57 ± 15(4)	16.6 ± 0.7(4)	42 ± 5(4)	--	--
April	56 ± 12(6)	16.1 ± 4.3(6)	43 ± 9(6)	--	--
May	53 ± 11(6)	20.2 ± 1.7(6)	43 ± 10(6)	--	--
June	62 ± 15(8)	25.1 ± 2.5(8)	48 ± 10(8)	--	--
July	69 ± 14(7)	27.4 ± 1.8(7)	50 ± 5(7)	--	--
August	86 ± 34(6)	26.8 ± 2.4(6)	58 ± 15(6)	--	--
September	86 ± 41(3)	28.3 ± 3.5(3)	63 ± 19(3)	--	--
October	63 ± 8(6)	18.4 ± 4.1(6)	50 ± 4(6)	--	--
November	82 ± 62(7)	10.2 ± 3.4(7)	59 ± 28(7)	--	--
December	59 ± 18(5)	7.7 ± 3.8(5)	46 ± 14(4)	--	--

Appendix B: Flow Duration Table for the Little and Black Cypress Bayous, Texas

Site/Percent Exceedance	Discharge by Month, cfs January	February	March	April	May	June	July	August	September	October	November	December
					Little Cypress Bayou*							
10	1,560	1,750	1,950	2,070	2,430	1,090	352	100	226	251	801	1,360
20	1,010	1,300	1,430	1,320	1,520	618	158	43	84	111	300	853
30	782	997	1,060	941	1,030	315	95	27	38	49	159	511
40	581	807	870	702	720	194	54	17	21	31	104	317
50	409	658	689	555	531	135	30	9	9	15	72	227
60	277	543	546	413	371	89	18	4	2	6	47	163
70	205	407	411	282	238	54	11	1	0	1	23	112
80	120	245	289	192	135	30	4	0	0	0	8	72
90	70	131	192	113	85	14	1	0	0	0	0	45
n	1,178	1,074	1,178	1,140	1,178	1,170	1,209	1,209	1,170	1,178	1,140	1,178
					Black Cypress Bayou*							
10	919	952	1,390	1,560	1,010	737	147	74	221	220	530	962
20	696	760	956	919	675	391	75	29	27	86	292	636
30	531	645	761	614	473	245	49	16	12	44	187	457
40	399	546	632	456	336	167	35	9	6	21	117	324
50	307	465	510	340	244	121	21	5	2	11	78	231
60	236	384	394	256	179	72	8	2	0	3	49	169
70	182	312	321	208	138	40	3	1	0	1	31	133
80	194	237	253	159	99	16	1	0	0	0	13	100
90	111	161	187	102	51	4	0	0	0	0	4	75
n	496	452	496	480	496	480	496	496	480	527	480	496

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* Flow calculated from USGS gages at Highway 59 near Jefferson, Texas.

Appendix C: Fish Species List of the Little and Black Cypress Bayous, Texas

Checklist of Fish Species Collected from the Little and Black Cypress Rivers, Texas. Collected by Ryan, Matthews, Killgore (1984) - 0; collected by Kemp (1954) - X; not collected - NC

Common Name	Species	Little Cypress	Black Cypress
Chestnut lamprey	*Ichthyomyzon castaneus*	X	NC
Spotted gar	*Lepisosteus oculatus*	O	NC
Longnose gar	*Lepisosteus osseus*	X	NC
Bowfin	*Amia calva*	O	O
Gizzard shad	*Dorosoma cepedianum*	O	O
Grass pickerel	*Esox americanus vermiculatus*	O	O
Chain pickerel	*Esox niger*	O	O
Black buffalo	*Ictiobus niger*	X	NC
Smallmouth buffalo	*Ictiobus bubalus*	X	NC
Spotted sucker	*Minytrema melanops*	O	O
Common carp	*Cyprinus carpio*	O	O
Golden shiner	*Notemigonus crysoleucas*	O	X
Pugnose minnow	*Notropis emiliae*	O	O
Emerald shiner	*Notropis atherinoides*	O	X
Ribbon shiner	*Notropis fumeus*	O	O
Redfin shiner	*Notropis umbratilis*	O	O
Ironcolor shiner	*Notropis chalybaeus*	O	O
Weed shiner	*Notropis texanus*	O	O
Pallid shiner	*Notropis amnis*	O	O
Blacktail shiner	*Notropis venustus*	O	O
Red shiner	*Notropis lutrensis*	X	NC
Sand shiner	*Notropis stramineus*	X	NC
Blackspot shiner	*Notropis atrocaudalis*	X	X
Silvery minnow	*Hybognathus nuchalis*	X	X
Cypress minnow	*Hybognathus hayi*	X	X

(Continued)

(Sheet 1 of 3)

(Continued)

Common Name	Species	Little Cypress	Black Cypress
Bullhead minnow	*Pimephales vigilax*	X	O
Channel catfish	*Ictalurus punctatus*	O	O
Black bullhead	*Ictalurus melas*	O	X
Yellow bullhead	*Ictalurus natalis*	O	X
Flathead catfish	*Pylodictis olivaris*	O	O
Tadpole madtom	*Noturus gyrinus*	O	O
American eel	*Anguilla rostrata*	O	O
Golden topminnow	*Fundulus chrysotus*	O	X
Starhead topminnow	*Fundulus blairae*	O	X
Blackstripe topminnow	*Fundulus notatus*	O	X
Blackspotted topminnow	*Fundulus olivaceous*	O	O
Mosquitofish	*Gambusia affinis*	O	O
Pirate perch	*Aphredoderus sayanus*	O	O
Brook silversides	*Labidesthes sicculus*	O	O
White bass	*Morone chrysops*	O	O
Yellow bass	*Morone mississippiensis*	O	NC
Spotted bass	*Micropterus punctulatus*	O	O
Largemouth bass	*Micropterus salmoides*	O	O
Warmouth	*Lepomis gulosus*	O	O
Green sunfish	*Lepomis cyanellus*	O	NC
Spotted sunfish	*Lepomis punctatus*	O	O
Bantam sunfish	*Lepomis symmetricus*	NC	X
Redear sunfish	*Lepomis microlophus*	O	O
Bluegill	*Lepomis macrochirus*	O	O
Orangespotted sunfish	*Lepomis humilis*	NC	X
Redbreast sunfish	*Lepomis auritus*	NC	X
Longear sunfish	*Lepomis megalotis*	O	O
Dollar sunfish	*Lepomis marginatus*	X	X
White crappie	*Pomoxis annularis*	O	O
Black crappie	*Pomoxis nigromaculatus*	O	O

(Continued)

(Sheet 2 of 3)

(Concluded)

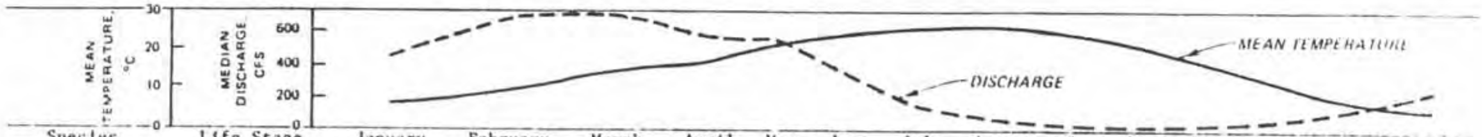
Common Name	Species	Little Cypress	Black Cypress
Flier	*Centrarchus macropterus*	NC	O
Banded pygmy sunfish	*Elassoma zonatum*	O	X
Black side darter	*Percina maculata*	O	O
Dusky darter	*Percina sciera*	NC	X
Log perch	*Percina caprodes*	NC	O
Scaly sand darter	*Ammocrypta vivax*	NC	X
Bluntnose darter	*Etheostoma chlorosomum*	O	O
Slough darter	*Etheostoma gracile*	O	X
Mud darter	*Etheostoma asprigene*	O	NC
Cypress darter	*Etheostoma proeliare*	O	O
Redfin darter	*Etheostoma whipplei*	O	NC
Freshwater drum	*Aplodinotus grunniens*	O	O
Totals	67 species	60	56

(Sheet 3 of 3)

Appendix D: Feeding and Reproductive Guild of Fishes in Cypress Bayou Basin, Texas

ADULT FOOD PREFERENCE	REPRODUCTIVE STRATEGY						
	Nonguarders - No Nest Constructed			Guarders - Nest Spawners		Bearers	
	Pelagophils	Litho-phytophils	Speleophils	Litho-phytophils	Speleophils	External	Internal
Piscivores	*Aplodinotus grunniens*	*Lepisosteus oculatus* *Lepisosteus osseus* *Morone chrysops* *Morone mississippiensis* *Esox vermiculatus* *Esox niger*		*Pylodictis olivaris* *Amia calva* *Micropterus salmoides* *Micropterus punctulatus* *Pomoxis annularis* *Pomoxis nigromaculatus*			
Planktivores and open water insectivores	*Notropis atherinoides*	*Dorosoma cepedianum* *Notemigonus crysoleucas* *Hybognathus nuchalis* *Hybognathus hayi* *Fundulus chrysotus* *Fundulus olivaceus* *Fundulus blairae* *Fundulus notatus* *Labidesthes sicculus* *Notropis emiliae* *Notropis fumeus* *Notropis texanus*	*Notropis venustus* *Notropis lutrensis* *Notropis umbratilus*	*Elassoma zonatum*	*Pimephales vigilax*	*Aphredoderus sayanus*	*Gambusia affinis*
Benthos feeders		*Notropis stramineus* *Notropis chalybaeus* *Notropis amnis* *Notropis atrocaudalis* *Percina caprodes* *Percina maculata* *Percina sciera* *Ammocrypta vivax*	*Etheostoma chlorosomum* *Etheostoma gracile* *Etheostoma asprigene* *Etheostoma proeliare* *Etheostoma whipplei*	*Ictalurus melas* *Centrarchus macropterus* *Lepomis auritus* *Lepomis cyanellus* *Lepomis macrochirus* *Lepomis megalotis* *Lepomis humilis* *Lepomis marginatus* *Lepomis punctatus* *Lepomis symmetricus* *Lepomis gulosus* *Lepomis microlophus*	*Ictalurus natalis* *Ictalurus punctatus* *Noturus gyrinus*		
Detritivores		*Cyprinus carpio* *Ictiobus niger* *Ictiobus bubalus* *Minytrema melanops*					

Appendix E: Monthly Periodicity of Evaluation Species Relative to Temperature and Discharge



Species	Life Stage	January	February	March	April	May	June	July	August	September	October	November	December
Grass/chain pickerel	Spawning		X	X									
	Fry		X	X	X								
	Juvenile	X	X	X		X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Ironcolor shiner	Spawning				X	X	X	X					
	Fry				X	X	X	X	X				
	Juvenile	X	X	X		X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Blacktail shiner	Spawning				X	X	X						
	Fry				X	X	X	X					
	Juvenile	X	X	X		X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X.	X	X	X	X	X	X	X
Spotted sucker	Spawning				X	X							
	Fry				X	X	X	X					
	Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Flathead catfish	Spawning					X	X						
	Fry					X	X	X					
	Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Brook silverside	Spawning				X	X	X						
	Fry				X	X	X						
	Juvenile					X	X	X	X	X			
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Spotted bass	Spawning			X	X	X							
	Fry				X	X	X						
	Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Longear sunfish	Spawning					X	X	X	X				
	Fry						X	X	X	X			
	Juvenile	X	X	X	X		X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Slough darter	Spawning			X	X								
	Fry			X	X	X	X						
	Juvenile	X	X	X	X		X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X

Appendix F: Suitability Index Curves for the Nine Evaluation Riverine Fish Species

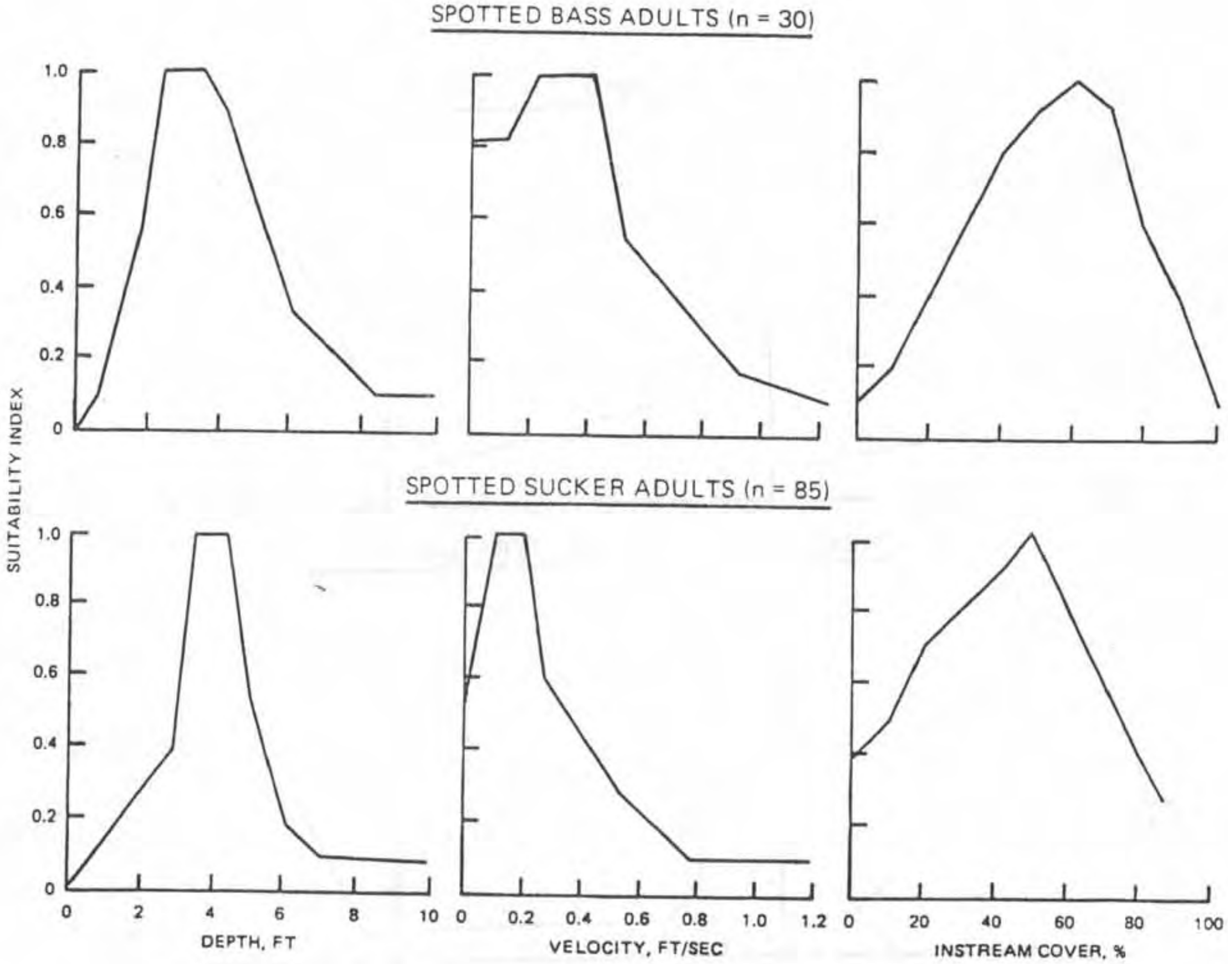


Figure F1. Suitability Index Curves for spotted bass and spotted sucker adults

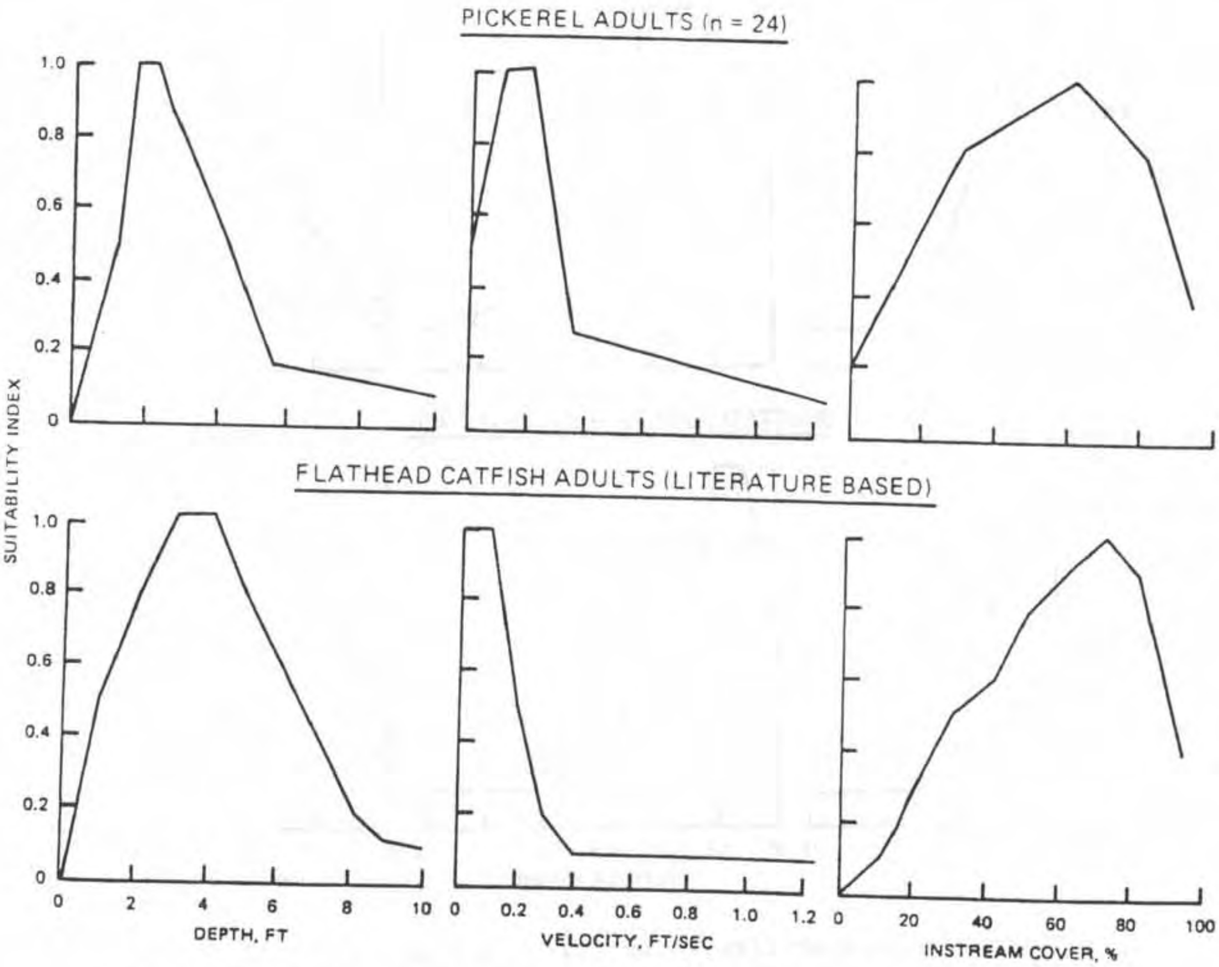


Figure F2. Suitability Index Curves for pickerel and flathead catfish adults

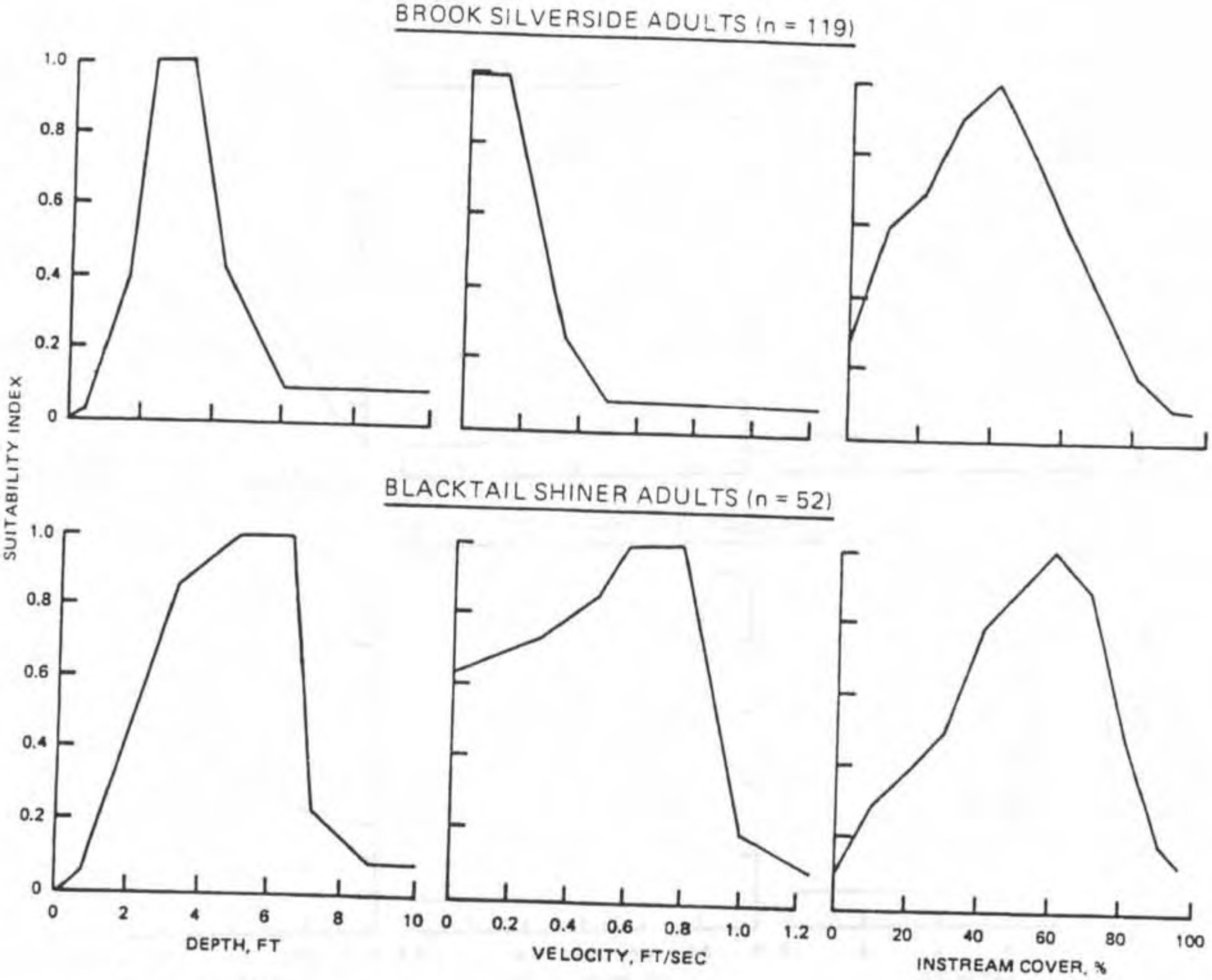


Figure F3. Suitability Index Curves for brook silverside and blacktail shiner adults

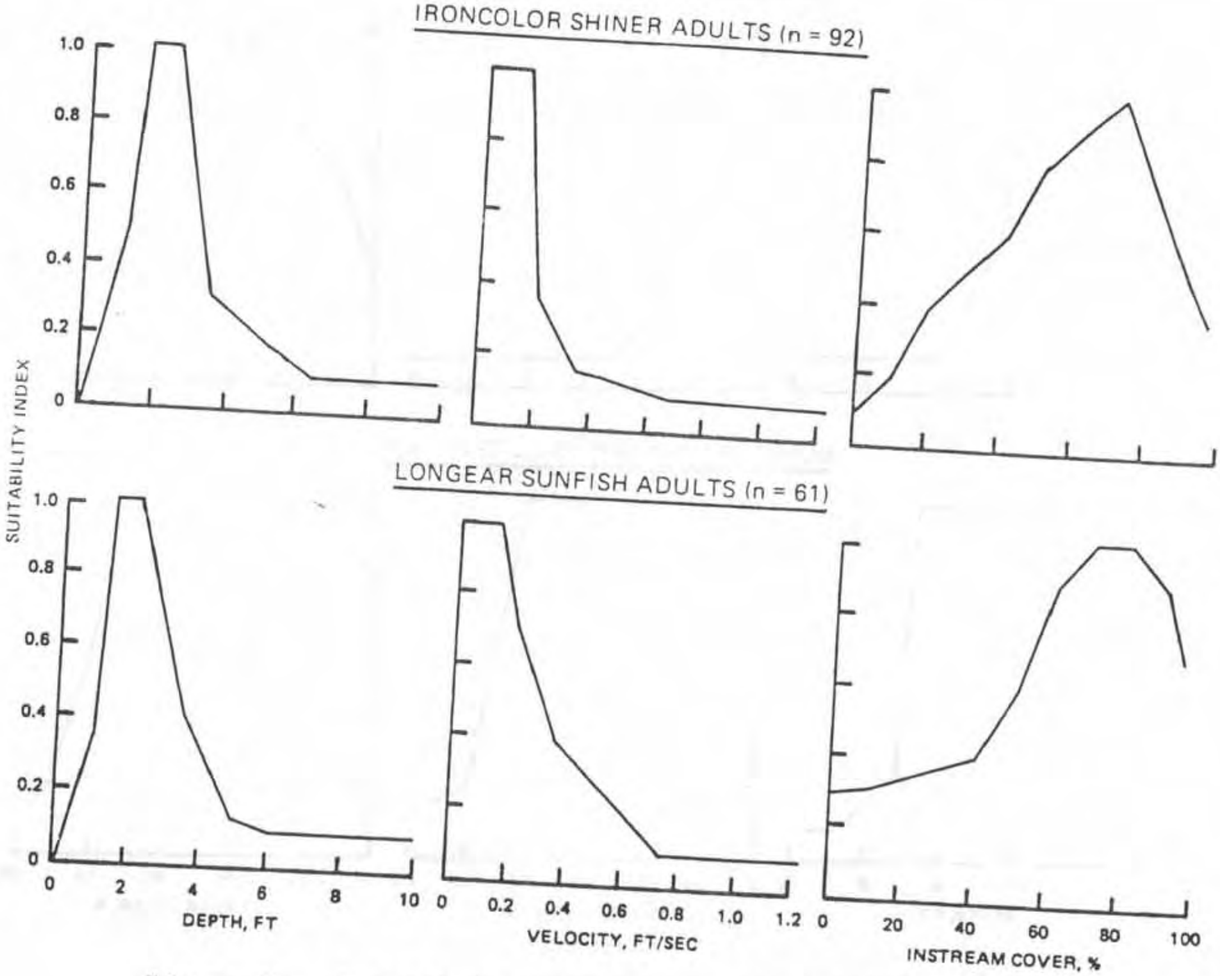


Figure F4. Suitability Index Curves for ironcolor shiner and longear sunfish adults

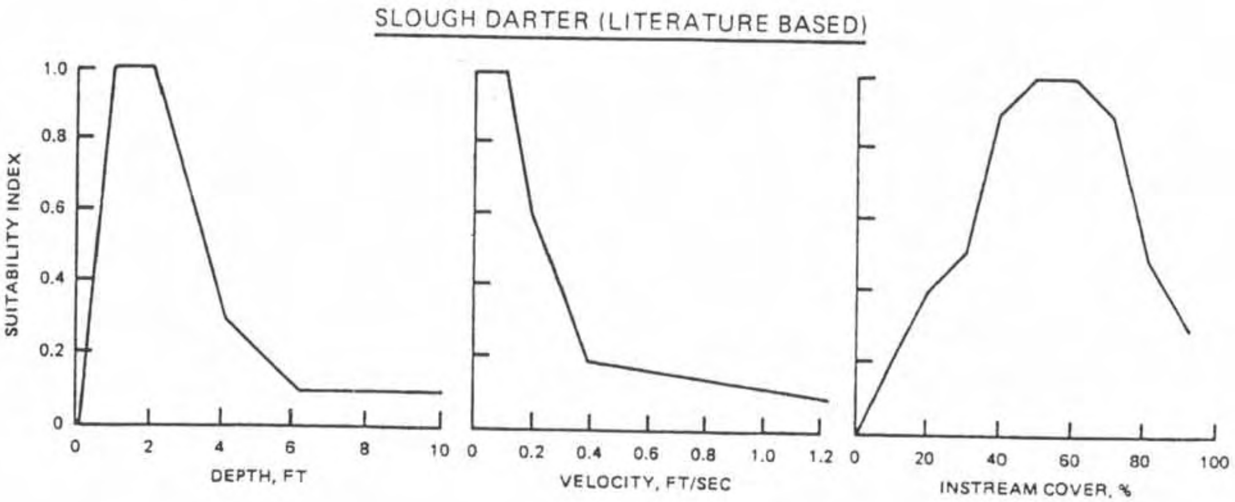


Figure F5. Suitability Index Curves for slough darter

Appendix G: Description of Hydraulic Analysis to Predict Physical Habitat at Unmeasured Flows

1. The purpose of this appendix is to describe the procedure to determine the value of the physical habitat variables (depth, velocity, and cover) and other morphometric features for unmeasured flow conditions in the Little Cypress Bayou. These data are used to calculate HU's to determine maintenance and compensation flows.

2. The first step is to estimate the coefficient of roughness (n) and calculate the slope of the channel (Se) using field data. These values remain constant and are used to determine velocity for unmeasured flows. The coefficient of roughness ranges from 0.025 for clear and straight river channels to 0.150 for weedy and overgrown channels (Bovee and Milhous 1978, Henderson 1966). The coefficient of roughness used in the Little and Black Cypress bayous was 0.075. Once n has been estimated, the slope is calculated from the following equation:

$$Se = \frac{n^2 V^2}{2.22\ R^{4/3}} \qquad (G1)$$

where

V = mean channel velocity measured in the field, ft/sec

n = coefficient of roughness

$R = \text{Hydraulic Radius} = \dfrac{\text{Area, ft}^2}{\text{Wetted Perimeter, ft}}$

The values to calculate hydraulic radius (area and wetted perimeter) are determined from the graphs (Figure 2). Velocity is then calculated for each cell using Manning's equation expressed as follows:

$$V,\ \text{ft/sec} = \frac{1.486}{n} R^{2/3} Se^{1/2} \qquad (G2)$$

The calculated velocities are compared with the field-measured velocities to check the accuracy of the variables used in Manning's equation. If the velocities do not agree, the slope is adjusted. In most cases, either no or small changes in the slope were required for this study. Once the cell velocities were determined, cell discharge was expressed as follows:

$$Q = V \cdot A \qquad (G3)$$

where

Q = discharge, cfs
V = velocity, ft/sec
A = area, ft^2

The cell discharges were summed to obtain a channel discharge that corresponded to the stage height on the graph (Figure 2).

3. Tables G1 and G2 illustrate the steps to determine depth, velocity, and acres of river that occur at the target discharges for the two representative study sites in the Little Cypress Bayou. Target discharges correspond to an incremental range of flows that could be released from the dam. The first step was to calculate the average depth, velocity, and width for each transect at discharges ranging from extreme low flows to overbank flows, using the hydraulic equations and graphs described in the previous paragraph. To accomplish this, new stage heights were drawn on the graph paper (Figure 2). From these graphs, the unmeasured hydraulic components (hydraulic radius and velocity) were determined. Discharge was also calculated for each new stage height. The second step was to calculate regression equations to predict the average depth, velocity, and width for a given discharge. The regression equations were then used to predict average depth, velocity, and width at target discharges of 10, 50, 100, 200, 300, 400, 500, and 1,000 cfs. For cover, a plot was made that related the percentage of cover (i.e., percentage of cells with cover) and discharge for each cross section. An average percentage of cover at each target discharge was then tabulated for each river. These data provided a depth, velocity, and percent cover at each discharge and at each representative site that was used to determine the HSI value. The fourth step was to determine the acres of river that occurred at each discharge by multiplying width times river miles. The final step was to calculate HU's for the study area at each target discharge using the method described in paragraph 12 (Table G3).

Table G1

Procedure to Determine Average Depths, Velocities, and Channel Widths over a Range of Flows Using the Hydraulic Geometry Information from the Graphs. Field Data was Collected from the Little Cypress Bayou at Hwy 154

Step 1: Calculate average depth, velocity, and width for each transect at 4 discharges.

Downstream Transect

Discharge cfs	Channel Width ft	Depth, ft $\bar{x} \pm SD(n)$	Velocity ft/sec $\bar{x} \pm SD(n)$
20	[illegible]	1.0 ± 0.61(6)	0.30 ± 0.13(6)
81	46	2.2 ± 0.92(7)	0.49 ± 0.15(7)
232	43	3.1 ± 1.70(10)	0.62 ± 0.26(10)
449	130	3.7 ± 2.20(13)	0.69 ± 0.30(13)

Upstream Transect (Approximately 530 ft Upstream of Downstream Transect)

Discharge cfs	Channel Width ft	Depth, ft $\bar{x} \pm SD(n)$	Velocity ft sec $\bar{x} \pm SD(n)$
9	41	1.8 ± 0.62(4)	0.11 ± 0.03(4)
81	60	5.3 ± 1.90(6)	0.23 ± 0.08(6)
200	95	6.6 ± 3.90(9)	0.25 ± 0.13(9)
556	430	6.8 ± 5.10(20)	0.27 ± 0.14(20)

Step 2: Calculate regression equations to predict the average depth, velocity, and width for a given discharge.

Downstream Transect

Depth, ft = Q (0.006) + 1.39 $R^2_2 = 0.86$
Velocity, ft/sec = Q (0.0008) + 0.37 $R^2_2 = 0.82$
Width, ft = Q (0.36) + 29.3 $R^2 = 0.93$

Upstream Transect

Depth, ft = Q (0.007) + 3.7 $R^2_2 = 0.51$
Velocity, ft/sec = Q (0.0002) + 0.17 $R^2_2 = 0.52$
Width, ft = Q (0.74) − 0.06 $R^2 = 0.96$

Step 3: Using the regression equations, calculate the average depth, velocity, and width between the upstream and downstream transects over the discharges of interest. Plot percent cover and discharge for each transect and take the average.

Discharge cfs	Depth, ft Downstream Transect	+ Upstream Transect	÷ 2 = Average	Velocity, ft/sec Downstream Transect	+ Upstream Transect	÷ 2 = Average	Width, ft Downstream Transect	+ Upstream Transect	÷ 2 = Average	Cover percent
10	1.4	3.7	2.6	0.37	0.17	0.27	33	30	32	20
50	1.7	4.0	2.8	0.41	0.18	0.29	50	37	43	25
100	2.0	4.4	3.2	0.45	0.19	0.32	71	74	73	33
200	2.5	5.0	3.7	0.53	0.21	0.37	112	148	130	52
300	3.1	5.7	4.4	0.61	0.23	0.42	153	222	187	60
400	3.7	6.4	5.1	0.69	0.25	0.47	194	296	245	65
500	4.2	7.1	5.6	0.77	0.28	0.52	236	370	303	70
1000	7.1	10.5	8.8	1.20	0.38	0.79	442	740	591	80

Step 4: Calculate the acres of river that the two transects represent over the discharges of interest. This site represents 7.3 river miles. Use the following equation to obtain acres: Acres, ft^2 = [Width × (miles × 5,280)] × (2.296×10^{-5}).

Discharge, cfs	Acres, ft^2
10	28
50	38
100	66
200	115
300	165
400	217
500	268
1,000	523

Table [illegible]

Procedure to Determine Average Depths, Velocities, and Channel Widths over a Range of Flows Using the [illegible] Information from the Graphs. [illegible] was Collected from the [illegible]

Step 1: Calculate average depth, velocity, and width for each transect at [illegible] discharges.

Downstream Transect			
Discharge cfs	Channel width ft	Depth, ft $\bar{X} \pm SD(n)$	Velocity ft/sec $\bar{X} \pm SD(n)$
[illegible]	25	1.9 ± 1.1(3)	0.16 ± 0.37(3)
[illegible]	64	3.0 ± 1.9(6)	0.19 ± 0.08(6)
141	124	3.7 ± 2.3(12)	0.23 ± 0.09(12)
289	350	4.3 ± 3.0(19)	0.25 ± 0.13(19)

Upstream Transect, Approximately [illegible] ft Upstream of Downstream Transect			
Discharge cfs	Channel width ft	Depth, ft $\bar{X} \pm SD(n)$	Velocity ft/sec $\bar{X} \pm SD(n)$
5	56	[illegible]	0.07 ± 0.02(3)
82	123	[illegible]	[illegible]
225	147	5.6 ± 2.3(15)	0.22 ± 0.06(15)
398	250	7.3 ± 3.3(13)	0.25 ± 0.19(19)

Step 2: Calculate regression equations to predict the average depth, velocity, and width for a given discharge.

Downstream Transect

Depth, ft = Q (0.008) + 2.25 $R^2 = 0.82$
Velocity, ft/sec = Q (0.0003) + 0.17 $R^2 = 0.88$
Width, ft = Q (1.14) + 3.41 $R^2 = 0.96$

Upstream Transect

Depth, ft = Q (0.014) + 1.90 $R^2 = 0.89$
Velocity, ft/sec = Q (0.0004) + 0.103 $R^2 = 0.82$
Width, ft = Q (0.40) + 80.5 $R^2 = 0.95$

Step 3: Using the regression equations, calculate the average depth, velocity, and width between the upstream and downstream transects over the discharges of interest. Plot the percentage of cover and discharge for each transect and take the average.

Discharge cfs	Depth, ft			Velocity, ft/sec			Width, ft			Cover percent
	Downstream + Transect	Upstream ÷ 2 = Transect	Average	Downstream + Transect	Upstream ÷ 2 = Transect	Average	Downstream + Transect	Upstream ÷ 2 = Transect	Average	
10	2.3	2.0	2.15	0.17	0.10	0.14	15	84	50	35
50	2.6	2.6	2.60	0.18	0.12	0.16	60	100	80	40
100	3.0	3.3	3.15	0.20	0.14	0.17	117	120	119	50
200	3.8	4.7	4.30	0.23	0.19	0.21	231	140	196	60
300	4.6	6.1	5.40	0.26	0.23	0.25	345	200	272	68
400	5.4	7.6	6.50	0.29	0.27	0.28	459	240	349	73
500	6.2	9.0	7.60	0.32	0.31	0.32	573	280	426	78
10,000	10.1	16.1	13.00	0.47	0.52	0.50	1,142	[illegible]	810	40

Step 4: Calculate the acres of river that the two transects represent over the discharges of interest. This site represents 13 river miles.

Discharge, cfs	Acres, ft^2
10	79
50	126
100	187
200	309
300	429
400	550
500	671
1,000	1,276

Table G3

Habitat Suitability Index Values and Habitat Units for the Evaluation Species

in the Little Cypress Bayou

Site Discharge		Total Acres Each Reach	Spotted Bass		Spotted Sucker		Brook Silverside		Blacktail Shiner		Ironcolor Shiner		Longear Sunfish		Pickerel		Flathead Catfish		Slough Darter	
			HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's
Little Cypress	Mile 2*																			
	10	79	0.76	60	0.62	49	0.80	63	0.65	51	0.76	60	0.89	70	0.89	71	0.68	54	0.74	58
	50	126	0.86	108	0.75	94	0.82	103	0.70	88	0.62	78	0.77	97	0.89	113	0.71	89	0.68	86
	100	187	0.90	168	0.93	168	0.89	166	0.76	142	0.56	105	0.66	123	0.86	161	0.75	140	0.60	112
	200	309	0.93	287	1.0	309	0.54	167	0.81	250	0.38	117	0.59	182	0.68	210	0.67	210	0.50	154
	300	429	0.65	279	0.60	257	0.35	150	0.81	347	0.28	124	0.38	163	0.33	142	0.61	262	0.42	180
	400	550	0.62	341	0.36	198	0.28	154	0.76	418	0.27	137	0.34	187	0.27	137	0.49	269	0.33	181
	500	671	0.62	362	0.34	228	0.22	148	0.48	322	0.26	174	0.34	228	0.24	168	0.38	255	0.34	228
	1,000	1,276	0.31	395	0.26	332	0.17	217	0.38	485	0.20	268	0.22	281	0.16	204	0.21	268	0.20	255
Little Cypress	Hwy 154**																			
	10	28	0.67	19	0.46	12	0.45	13	0.52	15	0.38	11	0.45	13	0.48	13	0.38	11	0.38	11
	50	38	0.74	28	0.53	20	0.53	20	0.58	22	0.38	13	0.43	16	0.52	20	0.38	14	0.42	16
	100	66	0.79	52	0.65	43	0.49	32	0.65	43	0.32	21	0.46	30	0.58	38	0.43	28	0.46	30
	200	115	0.89	102	0.79	91	0.50	57	0.80	92	0.33	38	0.50	57	0.55	63	0.45	45	0.33	38
	300	165	0.86	142	0.69	114	0.33	54	0.86	142	0.30	49	0.39	64	0.41	68	0.38	63	0.35	58
	400	217	0.63	137	0.50	108	0.29	63	0.96	208	0.32	69	0.27	59	0.26	56	0.38	82	0.20	54
	500	268	0.49	131	0.40	107	0.19	51	0.90	241	0.21	56	0.25	67	0.23	62	0.38	102	0.21	56
	1,000	523	0.23	120	0.17	89	0.17	89	0.39	204	0.20	105	0.18	94	0.16	84	0.26	136	0.20	105
Little Cypress	Damsite to mouth†																			
	10	107	--	79	--	61	--	76	--	66	--	71	--	83	--	84	--	65	--	69
	50	164	--	136	--	114	--	123	--	110	--	91	--	113	--	133	--	103	--	102
	100	253	--	220	--	204	--	198	--	185	--	126	--	153	--	199	--	168	--	142
	200	424	--	389	--	400	--	224	--	342	--	155	--	239	--	273	--	255	--	192
	300	646	--	421	--	371	--	204	--	489	--	173	--	227	--	210	--	325	--	238
	400	767	--	478	--	306	--	217	--	626	--	206	--	246	--	193	--	351	--	237
	500	939	--	493	--	335	--	199	--	563	--	230	--	295	--	230	--	357	--	284
	1,000	1,799	--	515	--	421	--	306	--	689	--	373	--	375	--	288	--	404	--	360

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* Represents [illegible] river miles.
** Represents [illegible] river miles.
† Represents [illegible] miles.

Appendix H: Composite Habitat Unit--Discharge Table for the Little and Black Cypress Bayous

Discharge cfs	Habitat Units	
	Little Cypress Bayou	Black Cypress Bayou
0	300	200
10	654	440
50	1,025	575
100	1,595	759
200	2,469	986
300	2,658	1,154
400	2,860	1,213
500	2,986	1,326
1,000	3,730	1,699

Appendix I: Habitat Unit Duration Table for the Cypress Bayou Basin HEP Study

Month/Site	Habitat Unit Duration Values, percent*																	
	10%		20%		30%		40%		50%		60%		70%		80%		90%	
	HU	Flow	HU	Flow	HU	Flow	HU	Flow	HU	Flow	HU	Flow	HU	Flow	HU	Flow	HU	Flow
Little Cypress: Mile 1-Damsite																		
January	3,670	900	3,375	670	3,060	530	2,850	390	2,655	290	2,420	190	2,035	155	1,500	90	1,020	45
February-March	4,080	1,200	3,740	1,050	3,450	740	3,260	640	2,965	485	2,810	360	2,650	285	2,500	215	2,000	155
April-May	4,300	2,000	3,775	1,075	3,380	670	3,000	510	2,795	370	2,600	270	2,200	175	1,500	90	1,025	50
June	3,500	760	2,990	510	2,500	215	2,000	155	1,600	105	1,300	75	1,011	40	805	12	580	8
July	2,575	265	1,730	110	1,250	60	1,000	30	850	14	565	7	520	6	350	2	300	0
August-October	2,000	155	1,275	65	810	13	725	11	654	10	400	3	350	2	325	1	300	0
November	3,000	510	2,500	215	1,775	125	1,400	85	1,250	60	990	16	800	12	600	8	375	3
December	3,690	930	3,175	610	2,820	375	2,420	190	2,180	170	1,805	130	1,450	88	1,110	55	950	15
Black Cypress: Mile 0-Damsite																		
January	1,900	1,300	1,705	1,050	1,510	730	1,315	480	1,120	280	975	190	910	170	856	140	800	120
February-March	1,940	1,325	1,800	1,200	1,660	940	1,520	740	1,379	570	1,238	420	1,100	270	975	190	880	145
April	2,500	2,000	1,847	1,250	1,629	900	1,410	600	1,193	370	1,000	210	942	180	882	145	800	120
May-December	1,883	1,270	1,648	930	1,413	600	1,179	340	985	180	914	170	850	135	675	75	564	45
June	1,750	1,150	1,333	500	982	180	890	150	816	130	589	55	530	30	450	11	350	4
July	860	140	600	60	566	45	531	30	492	20	416	7	343	4	284	2	242	1
August-October	900	160	511	25	443	10	427	8	296	3	277	2	258	1	239	1	200	0
November	1,632	910	1,106	275	920	175	825	130	610	65	563	45	513	25	455	12	343	4

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* Percent of time habitat unit (HU) is equalled or exceeded at the given flow (cfs).

Appendix J: Habitat Units Lost from Inundation in the Little Cypress Bayou. The Value of Variables Used to Calculate the HSI Were Determined from the Hwy 154 Downstream Transect According to Table GI

	Month Discharge (cfs)* /Acres**																							
	January 149/211		February 253/305		March 298/346		April 206/262		May 193/252		June 45/114		July 6/79		August 2/76		September 2/76		October 3/76		November 33/104		December 92/158	
Species	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU
Spotted bass	0.79	167	0.79	241	0.65	225	0.76	199	0.77	149	0.67	76	0.62	49	0.62	47	0.62	47	0.62	47	0.67	70	0.79	125
Spotted sucker	0.49	103	0.60	183	0.49	169	0.48	126	0.43	83	0.40	46	0.32	25	0.36	27	0.36	27	0.36	27	0.40	42	0.42	66
Brook silverside	0.43	91	0.37	113	0.34	117	0.41	107	0.41	79	0.45	51	0.38	30	0.38	29	0.38	29	0.38	29	0.41	43	0.45	71
Blacktail shiner	0.79	167	0.90	274	0.90	311	0.89	233	0.82	158	0.56	64	0.52	41	0.52	39	0.52	39	0.52	39	0.56	58	0.73	115
Ironcolor shiner	0.49	103	0.40	122	0.37	128	0.42	110	0.42	81	0.37	42	0.36	28	0.45	34	0.45	34	0.45	34	0.37	38	0.37	58
Longear sunfish	0.48	101	0.42	128	0.34	117	0.38	99	0.41	79	0.43	49	0.43	34	0.49	37	0.49	37	0.49	37	0.43	45	0.49	77
Pickerel	0.45	95	0.43	131	0.42	145	0.45	118	0.43	83	0.62	71	0.60	47	0.60	46	0.60	46	0.60	46	0.62	64	0.65	103
Flathead catfish	0.42	89	0.45	137	0.46	159	0.43	113	0.42	81	0.32	36	0.31	24	0.39	30	0.39	30	0.39	30	0.33	34	0.36	57
Slough darter	0.45	95	0.39	119	0.38	131	0.41	107	0.43	83	0.46	52	0.46	36	0.58	44	0.58	44	0.58	44	0.46	48	0.56	88
Total	--	1,011	--	1,448	--	1,502	--	1,212	--	876	--	487	--	314	--	333	--	333	--	333	--	442	--	760

CPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX J - CULTURAL RESOURCES ASSESSMENT LAKE O' THE PINES POOL RAISE ALTERNATIVE

CPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX J - CULTURAL RESOURCES ASSESSMENT LAKE O' THE PINES POOL RAISE ALTERNATIVE

LIST OF ATTACHMENTS

Number	Description
J-1	April 16, 1986, letter to the Texas Historical Commission
J-2	May 5, 1986, letter from Texas Historical Commission

CYPRESS BAYOU BASIN STUDY

FEASIBILITY REPORT

APPENDIX J - CULTURAL RESOURCES ASSESSMENT LAKE O' THE PINES POOL RAISE ALTERNATIVE

Archeological examinations of the middle reaches of the Big Cypress Creek were conducted in the 1950's in association with construction of the Lake O' The Pines Reservoir (formally named Ferrell's Bridge Reservoir). These investigations concentrated more on excavation of a number of sites and less on survey and recording of archeological sites. Inventory surveys at nearby Lake Bob Sandlin recovered over double the number of sites in less than a third of the area (Thurmond 1981:53). It is certain that many archeological sites in the Lake O' The Pines Reservoir area exist that are as yet unrecorded.

The Ferrell's Bridge project contributed greatly to archeological research in northeast Texas with its intensive investigation of several Caddoan mound and occupation sites belonging to a ceramic complex termed Whelan Phase (Davis 1958). This research added greatly to the formulation of a local chronology (Thurmond 1981:55). Twenty-four sites were tested, five were partially excavated, and one was completely excavated (Thurmond 1981:54). Many of these sites were multicomponent sites. Excavated sites 41MR1,[1] MR2, and MR12, UR10, UR11, and UR12 contain components from late Paleo-Indian (8000-6000 B.C.), early Archaic (6000-4000 B.C.), middle Archaic (4000-2000 B.C.), late Archaic (2000-200 B.C.), early Caddoan (A.D. 800-1400), Bossier Phase (A.D. 1400-1550), Whelan Phase (A.D. 1500-1600), Belcher Phase (A.D. 1550-1700), Titus Phase (A.D. 1600-1700), and early Historic Anglo (A.D. 1830-1900).

Investigations indicate clusters of sites on the Lake O' The Pines Reservoir area for the following chronologic periods: Paleo-Indian, early Archaic, middle Archaic, late Archaic, early Ceramic, and late Caddoan. The presence of springs and springfed streams in addition to Big Cypress Creek afforded a rich biotic habitat and a fairly reliable water supply. Big Cypress Creek flood plain provided fertile soil for horticulture of the later Caddoan occupations. There was a substantially higher number of springs with much higher discharge levels prehistorically (Thurmond 1981:33). These resources undoubtedly added to the desirability of the area for site usage and even occupation. Caddoan settlement/cemetery sites have been recorded and professionally excavated in several areas along Big Cypress Creek.

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[1] The Smithsonian Institution's trinomial site identification system is used to define specific sites within designated counties and states.

Little is known about the historic resources in the area, as only $7,000 was spent on the cultural resources surveys and excavation in the 1950'a and this was primarily spent on prehistoric cultural remains. Both historic and prehistoric sites need to be identified and addressed during a cultural resources survey. Since construction in 1959, there is a substantial on-going impact to the cultural resources. Wave erosion continually exposes and destroys archeological sites on the lake shores. Vandalism of sites is a serious problem at Lake O' The Pines. Vandals have completely destroyed at least three Caddoan cemetery sites on the lake's edge by unearthing the burials for the purpose of obtaining grave goods both for collection and for resale. More than 400 burials are known to have been unearthed by vandals in the immediate project area, and it is likely that the figure is much higher. Destruction of sites in this manner also adds to the erosion problems at the lake because of the open graves or pits left by vandals.

Assessment of cultural resources at Lake O' The Pines Reservoir is incomplete. Recent information suggests that numerous sites on Corps of Engineers property are unrecorded. Site destruction is epidemic due to erosion of sandy soils and intense vandalism pressure. Needed future work includes a shoreline survey and a site stabilization plan. A complete assessment of cultural resources present is necessary for proper management. The need for stabilization measures to combat site destruction must be addressed soon. Resources in the area are disappearing quickly, and adequate controls must be exercised to fulfill Federal cultural resource obligations.

Section 110 of the National Historic Preservation Act of 1966, as amended, charges Federal agencies with the responsibility for identification and nomination of historic properties (both prehistoric and historic sites) that will be affected by Federal undertakings. Section 106 charges Federal agencies with the responsibility of taking into account the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register for Historic Places (NRHP), and affords the Advisory Council on Historic Preservation (ACHP) an opportunity to comment with regard to such an undertaking.

The possible pool raise at Lake O' The Pines will necessitate a cultural resource inventory survey to include identification and nomination to the NRHP and stabilization and/or mitigation measures on those sites believed eligible for inclusion in the NRHP. The entire project area is potentially eligible for nomination as a National Register District because of the abundance of extremely significant prehistoric sites, including occupation areas, mound sites, and cemeteries. Stabilization and mitigation measures could be difficult to perform in some areas because of the limited access due to shallow water, sandy soil, and heavy woods. Because of the sandy soil in the area, mitigation (excavation) may be less expensive than stabilization techniques.

Though recorded and known archeological sites are presently protected under Public Law 96-95, Archeological Resources Protection Act of

1979, looters are presently destroying these archeological sites resulting in a loss of knowledge from invaluable cultural resources. Mitigation (excavation) of significant archeological sites in the Lake O' The Pines project area would result in salvage of a rapidly disappearing resource base.

Dr. LaVerne Herrington, Deputy State Historic Preservation Officer, Texas Historical Commission, was invited to comment regarding adverse impacts to cultural resources by a possible pool raise at Lake O' The Pines. Dr. Herrington (1986) stresses the importance of the cultural resources at the reservoir, and states that these resources are eligible as a District for the National Register of Historic Places. She further indicates that mitigation efforts recommended by the Texas Historical Commission for the adverse effects caused by the raising of the present flood pool would be substantial.

In summary, the location of both historic and prehistoric cultural resources, including an intense Caddo occupation, in the Lake O' The Pines region makes the area critically important and potentially expensive to mitigate for cultural resources.

REFERENCES

Davis, E. M.
1958 The Whelan Site, A Late Caddoan Component in the Ferrell's Bridge Reservoir, Northeastern Texas. Typescript report submitted to the National Park Service by the University of Texas at Austin, Division of Research in Anthropology.

Herrington, Dr. LaVerne
1986 Letter dated May 5, 1986. Texas Historical Commission Texas.

Thurmond, J. P.
1981 Archeology of the Cypress Creek Drainage Basin, Northeastern Texas and Northwestern Louisiana. Master's Thesis, The University of Texas at Austin.

April 16, 1986

Planning Division

Dr. LaVerne Herrington
Deputy State Historic Preservation
Officer
Texas Historical Commission
PO Box 12276
Austin, Texas 78711

Dear Dr. Herrington:

This letter is a follow-up of a telephone conversation of April 14, 1986, between Nancy Kenmotsu of your office and Karen Scott of the Environmental Resources staff regarding a possible pool raise under consideration for Lake O' the Pines reservoir.

The possible pool raise at Lake O' the Pines is an alternative plan for water supply needs of the Cypress Bayou Basin and is being considered under a Feasibility Study at this time.

An assessment of the impact to the cultural resources prepared by this office is enclosed. We welcome your comments regarding the significance of these resources.

Sincerely,

Stephen C. Helfert
Chief, Environmental Resources Branch

Enclosure

KOS
Mrs. Scott/ds/4-2095

HELFERT SWFPL-R

MAIL

RETURN TO: SWFPL-R

ATTACHMENT J-1

CURTIS TUNNELL
EXECUTIVE DIRECTOR

TEXAS HISTORICAL COMMISSION

P.O. BOX 12276
AUSTIN, TEXAS 78711
(512) 463-6100

May 5, 1986

Mr. Stephen C. Helfert, Chief,
Environmental Resources Branch
Department of the Army
Fort Worth District, Corps of Engineers
Post Office Box 17300
Fort Worth, Texas 76102-0300

Re: Cultural Resources, Lake O' the Pines
Marion, Upshur, Morris and Camp
Counties, Texas (FWCOE, D3)

Dear Mr. Helfert:

Thank you for your recent letter concerning cultural resources at the Lake O' the Pines Reservoir. We have reviewed the Cultural Resources Assessment for the Feasibility Study and offer the following comments in accordance with 36CFR800.

We concur with the statements in the Cultural Resources Assessment that the known archeological properties at Lake O' the Pines are significant for the information they contain. Partial excavations carried out in 1958 at the Whelan site (41MR2), Segal site (41MR1), Harroun (41UR10), Jake Martin (41UR12) and other sites in the reservoir prior to inundation revealed rich cultural deposits which were used extensively in establishing the cultural sequences for both Big Cypress Bayou and the general East Texas region. The La Harpe Aspect, defining the Archaic Period of East Texas, waspartly established with the data recovered at the Jake Martin site (41UR12); Whelan site excavations led to the elaboration of the Whelan ceramic complex and the Whelan Phase, a prehistoric period from 1500 to 1600 AD with certain practices and technologies which are unique to that time period. Subsequent to impoundment other sites have been recorded on the lakeshore. Usually these have been prehistoric cemeteries dating from 800-1700 AD, a type of resource which has the potential to yield much new demographic, chronological and socio-economic data. In sum, it is our opinion that the cultural resources at Lake O' the Pines are eligible as a district for the National Register of Historic Places under Criterion D.

We would also like to take this opportunity to express our dismay at the ongoing vandalism of a number of these resources. In 1985 I visited the present reservoir accompanied by Corps personnel to inspect that vandalism. The damage to lakeshore sites, particularly the prehistoric cemeteries, was a tragedy. It is the opinion of this office and the Office of the State Archeologist that within five to ten years all prehistoric Caddoan cemeteries in northeast Texas will be destroyed. These cemetery sites are considered important to the study of pre-history because they contain vast quantities of data relevant to demography, nutrition, social ranking and other cultural processes. While we are aware of efforts by Corps operations personnel to reduce or stop the vandalism, as best we can determine from recent telephone reports and staff visits, vandalism continues unabated and at an accelerated rate.

In summary, then, it is our opinion that the cultural resources at Lake O' the Pines Reservoir are eligible for the National Register of Historic Places. Many of the resources adjacent to and near the lakeshore are being actively vandalized and efforts to date to deter this vandalism have been largely unsuccessful. Given the significance of the resources and the enormity of the vandalism, we would anticipate that mitigation recommended by this office for adverse effects caused by the raising of the present flood pool would be substantial.

Thank you for the opportunity to participate in the review process.

Sincerely,

LaVerne Herrington

LaVerne Herrington, Ph.D.
Deputy
State Historic Preservation
  Officer

NK/LH/lft

PAUL K. RODMAN, P.E., CHIEF
HYDROLOGIC ENGINEERING SECTION
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HYDROLOGY
FILES

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