LEVEL II

(12)

TRINITY RIVER PROJECT, TEXAS

STATUS REPORT OF ENVIRONMENTAL EVALUATIONS

MAIN TEXT

U.S. ARMY ENGINEER DISTRICT, FORT WORTH

CORPS OF ENGINEERS

FORT WORTH, TEXAS

JUNE 1975

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Three volume status report of environmental evaluation of Trinity River Project. This includes (1) Authorized Project Plan that provides for flood control, recreation, water supply, navigation, fish and wildlife programs, hydroelectric power and the Multiple-purpose Channel (2) National Economic Development Plan that is similar to the Authorized Project Plan, but has many features that delete adverse effects to natural resources to reduce cost. (3) Environmental Quality Plan that is a nonstructural multiple-purpose plan of no action in regard to navigation and hydroelectric power for the Corps of Engineers. It

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20. proposes land use regulations for the entire Trinity River flood plain and proposes water conservation in lieu of added development for increasing the water supply. (4) No Action Plan (5) Authorized Project Plan Without Navigation that includes flood control, reservoir regulation channel, strengthen existing agricultural levees, and enlarge Tennessee Colony Lake. This plan reduces some of the adverse effects on natural resources. (6) Authorized Project Plan Without Navigation, Provisions for Future Navigation. This is the same as the previous plan except providing for navigation in the initial stages of design and construction. (7) Authorized Project Plan, Navigation Terminated Downstream from Dallas. Similar to Authorized Project Plan except for the flood control channel. Tax and bond issues were rejected by voters. Congress directed Corps of Engineers to cease further planning for fiscal year 1974 and 1975.

EXECUTIVE SUMMARY

This status report is provided to inform the public of the environmental considerations studied to date with respect to the Trinity River Project. The Corps of Engineers has made extensive studies concerning this project and this report provides information which the public will find useful. Its publication at this time is considered appropriate since the Board of Directors of the Trinity River Authority of Texas (TRA) has announced a number of public hearings to be held throughout their jurisdictional area commencing the week of June 16, 1975, to provide area citizens with the opportunity to participate in the review of the TRA Master Plan.

This status report is not an environmental statement as required by the National Environmental Policy Act of 1969. However, the majority of the data presented in the report are from working papers that were being prepared for a draft environmental statement on the Trinity River Project, and some parts of the report are labeled in various ways to indicate they are a part of an environmental statement or part of a proposed project. The word "proposed" does not infer that the Corps of Engineers is recommending a project, but instead refers to the project authorized by Congress in 1965 as updated by subsequent studies for later conditions.

Our planning studies for the Trinity River Project, specifically called a Phase I General Design Memorandum (Phase I GDM), are not complete. The TRA public hearings may result in changes to its Master Plan that would directly affect the Trinity River Project. Until specific recommendations are received from the TRA, we cannot complete the Trinity River Project Phase I GDM. Without a complete Phase I GDM it is impossible to prepare a draft environmental statement which addresses a recommended project. Following the TRA public meetings, we will receive definitive recommendations on the Trinity River Project from the TRA. The Corps of Engineers will then complete the Phase I GDM, publish a draft environmental statement, and hold its own public meetings, assuming continuance of authority and funding for these activities by the Federal Congress.

The Trinity River Project is being planned as a part of the Comprehensive Survey Report on the Trinity River and Tributaries, Texas, a basinwide plan authorized by the River and Harbor Act of 1965, Public Law 89-298. The survey report was reprinted as House Document No. 276, 89th Congress, 1st Session, entitled "Trinity River and Tributaries, Texas." Preconstruction planning funds were initially appropriated for the Trinity River Project by the Federal Congress for Fiscal Year 1970, exclusive of funds for the economic restudy, with subsequent funding until the present time.

House Document No. 276 included authorization of the following projects: Aubrey, Lakeview, Roanoke and Tennessee Colony Lakes; channel improvements on Elm Fork, Duck Creek, West Fork and adjacent tributaries, and the Trinity River and adjacent tributaries in the Dallas-Fort Worth metropolitan area; levees on the east bank of the Trinity River at Liberty, Texas; Water Conveyance Facilities (84-inch pipeline and pumping facilities) from Tennessee Colony Lake to Benbrook Lake; and a Multiple-Purpose Channel from Fort Worth to the Houston Ship Channel. Because of the timing of technical, administrative, and funding actions and the design and economic interrelationships of some parts of the work authorized by House Document No. 276, the work has been subdivided into the following increments:

PROJECT NAME	LOCAL SPONSOR	CURRENT STATUS
Aubrey Lake	Cities of Dallas & Denton, Texas	Construction authorized
Lakeview Lake	Trinity River Authority of Texas	Construction authorized
Roanoke Lake	Cities of Dallas & Grapevine, Texas & Dallas Co. Park Cities Water Control & Impr. Dist. #2	Inactive
Trinity River Project*	Trinity River Authority of Texas	Preconstruction planning
Elm Fork Floodway	Trinity River Authority of Texas	Preconstruction planning
Duck Creek Channel Improvement	Trinity River Authority of Texas	Construction authorized
Liberty Levee Project	Trinity River Authority of Texas	Inactive**

*Includes Tennessee Colony Lake, Water Conveyance Facilities, Multiple-purpose Channel, West Fork Floodway, and Dallas Floodway Extension.

**Levees constructed by local interests reduced the benefit-cost ratio to less than 1 to 1.

For planning and environmental analysis purposes, the following authorized physically related projects, which are not presently operational, were considered to be operational before the Trinity River Project: Aubrey, Lakeview, and Wallisville Lakes, and the Elm Fork Floodway.

The following multiple-purpose alternatives for the Trinity River Project are presented below in summary chart form as an aid to planning deliberations:

Multiple-purpose Alternatives	Current Status
Authorized Project Plan (as updated by preconstruction planning studies)	Studied and presented in Sections 2 and 3
National Economic Development Plan	Studied and presented in Section 2
Environmental Quality Plan	Studied and presented in Section 2
No Action Plan	Studied and presented in Section 2
Authorized Project Plan Without Navigation (as updated by preconstruction planning studies)	Studied and presented in Section 4 as related to the Authorized Project Plan
Authorized Project Plan Without Navigation; Provisions for Future Navigation	Variation of Authorized Project Plan that could be studied if authority and funds were provided in the future.
Authorized Project Plan, Navigation Terminated Downstream from Dallas	Variation of Authorized Project Plan that could be studied if authority and funds were provided in the future.

Scope of Multiple-purpose Alternatives:

Authorized Project Plan (as updated by preconstruction planning studies)	This plan includes the West Fork Floodway and the Dallas Floodway Extension for flood

control and recreation, Tennessee Colony Lake for flood control, water supply, navigation, recreation, fish and wildlife programs, and hydroelectric power, and the Multiple-purpose Channel for flood control, navigation, hydroelectric power, recreation, and fish and wildlife.

National Economic Development Plan	This plan includes the same structural features as the Authorized Project Plan but differs materially in that numerous features to reduce adverse effects on viable natural resources would be deleted in order to reduce cost; some of the major deletions would include the "Greenway" or "Parkway" concepts in the metropolitan area flood plain, multilevel hydropower and outlet works structures, shaping of excess excavation materials and tree revegetation procedures, lands for wildlife conservation, preservation of existing streambank vegetation wherever possible, relocation of Tennessee Colony Lake to prevent inundation damage to the Catfish Creek watershed, etc.
Environmental Quality Plan	This plan is essentially a nonstructural multiple-purpose plan and proposes no Corps of Engineers action in regard to navigation and hydroelectric power. It proposes comprehensive land use regulations and controls for the entire Trinity River flood plain, including zoning, fee and easement acquisition, and flood plain management in lieu of structures for flood control. It proposes water conservation programs in lieu of additional structural development for increasing the total available water supply. It proposes environmentally compatible riverine-orientated recreation facilities designed to accommodate primitive-type recreation pursuits.
No Action Plan	This plan proposes no action on any aspect of the authorized Trinity River Project by the Corps of Engineers.

Authorized Project Plan Without Navigation (as updated by preconstruction planning studies)	This plan includes the West Fork Floodway and the Dallas Floodway Extension for flood control and recreation in the Dallas-Fort Worth metropolitan area, a reservoir regulation channel (for upstream regulated releases from five flood control lakes) and strengthening of existing agricultural levees from the metropolitan area to Tennessee Colony Lake for flood control and recreation, and an enlarged Tennessee Colony Lake for water supply, flood control, hydroelectric power, and recreation and fish and wildlife programs. This plan would include measures to reduce some adverse effects on viable natural resources included in the Authorized Project Plan, but to a more limited degree because of reduced project scope. No Trinity River Project construction would occur below Tennessee Colony Dam.
Authorized Project Plan Without Navigation; Provisions for Future Navigation	This plan would be the same as the previous plan except that provisions for future navigation would be included in the initial project design and construction and would include flood control and reservoir regulation channels on a navigation alignment, single-stage bridge and utility relocations to provide for ultimate navigation without further reconstruction of these facilities, and structural tie-in provisions for future locks at Tennessee Colony Dam.
Authorized Project Plan, Navigation Terminated Downstream from Dallas	This plan would be essentially the same as the Authorized Project Plan except that navigation would be terminated downstream from Dallas, and the channel upstream from this point would be a flood control channel to Fort Worth and would include the West Fork Floodway and the Dallas Floodway Extension for flood control and recreational purposes.

Notes: (1) Other alternatives may be developed in the remaining studies.

(2) All alternatives which include, or might include, navigation will not be studied further unless the existing constraints on navigation studies are removed by the Federal Congress.

The Trinity River Authority of Texas held an election on March 13, 1973, to seek voter approval of a tax and a bond issue to finance the non-Federal portion of certain TRA programs including the Trinity River Project. The tax and the bond issues were rejected by the voters. Subsequently, Congress directed the Corps of Engineers to cease further navigation preconstruction planning in fiscal years 1974 and 1975. This report addresses the authorized project as presently updated and includes navigation data collected before suspension of navigation planning funds. Section 4 of this report addresses the physical and environmental differences between the Authorized Project Plan as modified by subsequent preconstruction planning studies and the Authorized Project Plan Without Navigation as formulated and modified by preconstruction planning studies.

Authorization of construction and land acquisition for a project does not preclude subsequent planning and design changes. Future investigations on any project would include continuing studies and modifications to improve design, and reduce costs and adverse environmental effects. Further navigation studies cannot be accomplished on the Trinity River Project unless Congressional restraints are removed in the future. The Corps of Engineers will welcome comments concerning new alternatives and the technical accuracy of this report.

JOE H. SHEARD
Colonel, CE
District Engineer

TABLE OF CONTENTS

SECTION 1 - BASIN ENVIRONMENTAL SETTING

PARAGRAPH		PAGE

SECTION 2 - PLANNING OPTIONS

SECTION 3 - AUTHORIZED PROJECT PLAN

SECTION 4 - AUTHORIZED PROJECT PLAN WITHOUT NAVIGATION

SECTION 5 - COORDINATION WITH OTHERS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF ATTACHMENTS

APPENDIXES

A. PLATES AND PHOTOGRAPHS

B. BIOLOGICAL INVENTORY WITH EFFECT EVALUATION

SECTION I - BASIN ENVIRONMENTAL SETTING

1.01 Basin Physiography. The Trinity River Basin is situated in east central Texas and encompasses an area of 17,969 square miles including all or portions of 38 counties. Its location and configuration are shown on Plate 6, Appendix A. Altitudes range from sea level at the mouth of the Trinity River to over 1500 feet msl in the extreme upper reaches of the Basin (Plate 7, Appendix A). The gradient of the river is about three feet per mile in the vicinity of Fort Worth and becomes progressively smaller toward the mouth with an average through this reach of about 0.8 feet per mile. Topographic expression is controlled to a large extent by the resistance to erosion of the various exposed geologic formations. Consequently, physiographic classification in Texas is based primarily in terms of underlying rocks, although these physiographic designations also carry important distinctions as to soils and vegetation. The Basin is situated in two physiographic provinces (Feeneman, 1938): the Central Lowland province (Osage Plains section) in the extreme northwestern headwaters on rock outcrops of Pennsylvanian and Permian age, and the Coastal Plain province (West Gulf Coastal Plain section) which includes outcrop areas of Cretaceous, Tertiary, and Quaternary formations.

1.02 Central Lowland Province (Osage Plains Section). The Osage Plains Section of the Basin is restricted in size, encompassing most of Jack County and small portions of five adjacent counties. The topography is in sharp contrast to that in the rest of the Basin (Plate 6). Northwestward dipping limestone and sandstone strata of Paleozoic age have produced rugged eastward-facing escarpments with partially dissected dip slopes. Stream valleys are relatively narrow and steep with poorly developed flood plains. The area is moderately rugged in appearance, indicative of a somewhat youthful stage in the erosional cycle.

1.03 Coastal Plain Province (West Gulf Coastal Plain Section). To the east, Cretaceous, Tertiary and Quaternary rocks onlap the truncated Paleozoic rocks and dip gently gulfward. These younger strata form the West Gulf Coastal Plain section and outcrop in northeastward trending belts of essentially treeless plains alternating with gently rolling, timbered hills.

1.03.01 Cross Timbers. Adjoining the Osage Plains section on the east the Western Cross Timbers forms a belt of slightly rolling forested land on rocks of the Lower Cretaceous Trinity Group. In the vicinity of Arlington, Texas, a similar belt called the Eastern Cross Timbers is formed on the Woodbine sand. The belts are similar except that the oak forests in the eastern area are continuing to disappear rapidly because of encroaching urbanization. The sands of the Woodbine contain many cemented zones which produce minor resistant hillocks, while the western belt is more intricately dissected.

1.03.02 Grand Prairie. Separating the two forested belts is the Grand Prairie, on which most of the city of Fort Worth is situated. In this area, a series of interbedded shales and resistant limestones of the Lower Cretaceous Series crop out, producing relatively flat, stratum plains with minor escarpments.

1.03.03 Eagle Ford Black Prairie. East of the Woodbine outcrop, the erodible Eagle Ford shale, on which the cities of Grand Prairie and Irving are founded, forms a narrow, flat to gently rolling prairie zone, maturely dissected by Mountain Creek and Elm Fork, tributaries to the Trinity River. The prairie zone is almost devoid of trees, except for scattered mesquites, with wooded areas restricted mainly to the stream courses.

1.03.04 White Rock Escarpment. This Escarpment is formed at the contact of the erodible Eagle Ford shale and the relatively resistant Austin chalk. The Austin chalk forms the cuesta on which most of the city of Dallas is founded and is over 100 feet higher than the Eagle Ford Prairie to the west. The drainage on the cuesta is often structurally controlled by minor joints and faults in the chalk formation producing a modified trellis pattern. The soil cover near the escarpment is thin, supporting an assemblage of small, shallow-rooted trees. A short distance down the dip slope, the Austin chalk forms deep, black, prairie soils, similar to those formed on the adjacent Taylor marl.

1.03.05 Black Prairie. The dark to black waxy soils formed on the Austin, Taylor. Navarro and Midway groups and the flat to gently rolling land surface characterize a broad area called the Black Prairie. The soils formed on the Taylor marl are considered the most typical of the Black Prairie soils. The Midway-Wilcox contact generally defines the boundary between the Black Prairie and the East Texas Timber Belt.

1.03.06 East Texas Timber Belt. The East Texas Timber Belt is a region characterized by gently rolling, hilly topography controlled by alternating sands and shales of Eocene and Miocene age. The region is crossed by two prominent landward facing escarpments: (1) the Nacogdoches, formed on the ironstone beds of the Claiborne group, and (2) the Kisatchie Escarpment to the south, supported by the Catahoula sandstone. At present, the region includes generally more forested than cleared land. The seaward facing Hockley Scarp divides the gently rolling East Texas Timber Belt from the almost featureless Pine Flats.

1.03.07 Pine Flats. This narrow zone, as the name implies, is transitional between the more elevated forested land to the north and the flat, relatively treeless coastal areas.

1.03.08 Coastal Prairie and Marsh. This area is very flat and slightly lower than the Pine Flats belt. The uplands are almost treeless, while the flood plain areas still include bottomland hardwood forests with pine on the upland slopes.

1.04 Basin Geology. All strata that outcrop in the Trinity River Basin are of sedimentary origin. They include principally limestones, shales, marls, sandstones, chalks, sands, silts, clays, and gravels. Limestones and shales predominate northwest of Fort Worth. Unconsolidated sands, silts, clays, and gravels make up most of the materials in the coastal area. For a general description of these formations, see Table 1-1. Areal geology of the flood plain and adjacent areas is shown on Plates 8.1 through 8.5.

1.04.01 Structure. Rocks in the northwestern part of the Basin consist principally of Upper Pennsylvanian and Permian sandstones, limestones and shales which have been tilted to the northwest and beveled by erosion. Subsequently, Cretaceous, Tertiary and Quaternary sediments of marine and continental origin have been deposited unconformably on the older strata and dip gently to the southeast, but at a steeper rate than the land surface, producing a banded outcrop pattern with progressively younger formations outcropping in a downstream direction. The rate of dip and thickness of these individual formations increase in a gulfward direction. The features described in the following paragraphs have been superimposed on this monocline or gentle southeastward dip.

1.04.01.01 Mexia-Talco Fault System. This fault system, consisting of en echelon faults downthrown predominantly to the south, crosses the Basin in a northeast-southwest direction (see Plates 8.2 and 9). Northeast of Corsicana, where this zone crosses the flood plain, rocks of the Midway group are faulted down against Cretaceous rocks. The faults of this system appear to be inactive and are for the most part concealed. They have no significant surface expression in the Basin area.

1.04.01.02 Mount Enterprise-Jarvis-Elkhart Fault System. This system is also en echelon and is comprised of faults predominately downthrown to the south with numerous grabens (downthrown blocks). The largest of these structures is the Elkhart graben, adjacent to the flood plain near river mile 296. This system is aligned roughly parallel to the present coastline and crosses the Basin through Anderson, Houston, and Leon Counties (see Plate 8.3). The faults appear to be inactive with no significant surface expression.

TABLE 1-1

GENERAL DESCRIPTION OF STRATIGRAPHIC UNITS

System	Series	Group	Stratigraphic Units	Approx. Thickness (feet)	Physical Characteristics of Rock Units
	Recent		Alluvium		Unconsolidated clay, silt, sand and gravel deposits.
	Recent or late Pleistocene		Deweyville Formation	0-50+	Unconsolidated clay, silt, sand and gravel deposited at a level slightly above present floodplain.
Quaternary			Fluviatile Terrace Deposits	0-80	Unconsolidated clay, silt, sand and gravel terrace deposits in river valley. Three distinct terraces are recognized and may be in part correlative to Beaumont Formation.
	Pleistocene		Beaumont Formation	100±	Unconsolidated clay, silt and sand.
			Montgomery Formation (Upper Lissie)	100±	Clay, silt, sand and some siliceous gravel; locally calcareous.
			Bentley Formation (Lower Lissie)	100±	Clay, silt, sand, and minor amounts of gravel.
- - - - - -	- - - - - -		Willis Formation	100±	Clay, silt, sand, and some siliceous gravel.
	Pliocene		Goliad Sand	0-500	Sand, gravel, calcareous sandstone; interbedded clay.
Tertiary			Fleming Formation	1,300-1,450	Clay, silt, and sand; clays commonly calcareous.
	Miocene		Catahoula Formation	250-300	Mudstone and sand, tuffaceous. Lower portion of formation quartz sand. Fossil wood abundant.

(Continued)

Tertiary	Eocene or Oligocene		Whitsett	30-70	Quartz sand, fine to medium grained, tuffaceous, lignitic.
	Eocene	Jackson	Manning Formation	250±	Quartz sand and clay, lignitic. Fossil wood abundant.
			Wellborn Formation	50-150	Quartz sand, fine to very fine grained, glauconitic and lignitic, with interbeds of lignitic clay. Locally marine megafossils.
			Caddell Formation	50-150	Quartz sand and clay; clay, sandy and lignitic; sand, glauconitic.
		Claiborne	Yegua Formation	600-1000	Clay, quartz sand and lignite. Upper portion of formation mostly clay, lower portion mostly sand. Marine megafossils.
			Cook Mt. Formation Stone City Formation	450-470	Clay, marl and sand; lignitic, glauconitic with some limestone lentils.
			Sparta Sand	200±	Quartz sand, fine to very fine grained with lignitic clay and silt partings.
			Weches Formation	50-90	Glauconite, glauconitic marl and quartz sand. Marine megafossils.
			Queen City Sand	325±	Quartz sand, fine grained, with interbeds of clay, clay ironstone beds, and concretions common.
			Reklaw Formation	30-130	Marquez member: clay and silts; carbonaceous, glauconitic, clay ironstone with imprints of marine megafossils. Newby member: glauconite, quartz sand, clay; marine megafossils.
			Carrizo Sand	60-150	Quartz sand; upper portion fine grained with some clay and silt interbeds; lower portion fine to medium grained.
		Wilcox	Undivided	2000±	Quartz sand, silt, clay, carbonaceous clays and lignite; fossil wood.

(Continued)

Tertiary	Eocene	Midway	Wills Point Formation	500±	Clay and silt; silt increases upward, local occurrences of lignite and calcareous concretions. Formation becomes glauconitic near base.
			Kincaid Formation	180±	Clay; glauconitic, calcareous, silty or sandy. Phosphatic near base, and some thin limestones occurring near top of formation.
Upper Cretaceous	Gulf	Navarro	Kemp Clay and Corsicana Marl	Undivided 550±	Clay and marl; silty, sandy, calcareous, glauconitic, locally gypsiferous.
			Nacatoch Sand	200±	Sand and sandy shale; locally cemented to form calcareous sandstone; glauconitic marine megafossils.
			Neylandville Formation	140±	Clay; calcareous, locally sandy, glauconitic and fossiliferous. Some concretionary beds.
		Taylor	Marlbrook Marl (Upper Taylor marl)	400±	Marl and clay; chalky.
			Wolf City Formation	250±	Alternating sandy, calcareous clay; marly sand and thin beds of calcareous sandstone
			Ozan Formation (Lower Taylor marl)	550±	Marl and clay; sandy, calcareous.
		Austin	Austin Chalk	700±	Limestone; basal 150 feet of formation consists of massive chalk layers separated by thin shaly layers. Middle portion 250 feet, characterized by thick shaly limestone layers. The uppermost portion contains more shale and less chalk.
		Eagle Ford	Arcadia Park Shale	100±	Clay, shale and limestone. Basal portion clay, separated from upper shaly portion by thin limestone flags. Numerous calcareous concretions in upper portion.

(Continued)

Upper Cretaceous	Gulf	Eagle Ford	Britton Shale	320±	Clay, marl and shale with some limestone seams, calcareous concretions, and bentonite seams. Lower 20 feet (Tarrant Member) consists of sandy clay, limestone and calcareous concretions.
		Woodbine	Lewisville Formation	250±	Sandstone, sandy clay and clay.
			Dexter	100±	Sandstone, sand and clay; fossil plant remains.
Lower Cretaceous	Comanche	Washita	Grayson Marl	75±	Shale and marl with thin limestone layers in upper portion of formation. Marine megafossils.
			Main Street Formation	30±	Limestone, chalky, massive to medium beds separated by thin shale layers. Marine megafossils.
			Pawpaw Formation	20±	Shale, calcareous, sandy near base. Thin, sandy limestone layers present in the basal beds.
			Weno Limestone	55±	Limestone predominant in upper half of formation, shale in lower half. Locally poor to abundant marine megafossils.
			Denton Clay	35±	Clay, calcareous, locally sandy or silty. Marine megafossils.
			Fort Worth Limestone	30±	Limestone; chalky, limestone beds separated by thin layers of calcareous snale. Marine megafossils.
			Duck Creek Limestone	50±	Upper 2/3 of formation consists of marl & calcareous shale interbedded with limestone. Lower 1/3 massive limestone.
		Fredericksburg	Kiamichi Clay	30-50	Clay, silty, calcareous, minor amounts of thin limestone lentils. Marine megafossils.
			Goodland Limestone	120±	Limestone with alternating marl & clay beds. Marine megafossils.
		Trinity	Paluxy Formation	95-105	Sandstone & mudstone. Sandstone commonly crossbedded. Mudstone, sandy, massive. Sandy, fossiliferous limestone beds locally in upper 50 feet.
			Glen Rose Formation	40-200	Limestone, distinctly bedded with alternating units of clay, marl and sand.
			Twin Mountain Formation	150±	Upper part, claystone; middle part sandstone above claystone; lower part, mostly sandstone with some claystone & conglomerate. Locally crossbedded.
Permian	Wolfcamp				Mudstone & sandstone. Massive to thick-bedded. Sandstone in part conglomeratic.
Pennsylvanian	Cisco				Red sandy shale with some sandstone & thin limestone beds.
	Canyon				Massive limestones with thick-bedded sandy shales & some sandstone.

Data Source: Bureau of Economic Geology, University of Texas at Austin

1.04.01.03 Salt Domes. There are 15 major salt dome structures within the Basin. The Butler, Keechi, and Palestine domes are related structurally to the Mount Enterprise fault system. These three domes have pushed Upper Cretaceous rocks to the surface and are highly faulted (see Plate 8.3). Oil and gas are not produced from these domes at present but most of the other domal structures in the Basin have supported active oilfield operations.

1.04.01.04 Coastal Faults. Most of the Gulf Coastal Zone is crossed by parallel faults. Twelve faults, shown on Plate 8.5, have been detected between the town of Hardin, Texas, and the mouth of the Trinity River. The faults are typically displaced downward toward the Gulf and are mostly the result of loading, on the gulfward side, of river deposited sediments during Pleistocene times. Such sediment loading is no longer common along the Gulf Coast except in the Mississippi Delta area. The apparent lack of surface expression indicates that most of the faults between Hardin and Trinity Bay have been inactive for a considerable length of time. Reactivation of some linear coastal faults has probably occurred in the Houston area and as far east as Baytown where withdrawal of ground water over several decades has resulted in gradual land subsidence (Fisher et al, 1972).

1.04.01.05 East Texas Embayment. The East Texas embayment has a major influence on the structural attitude of the Trinity River Basin strata. The embayment is a depositional basin and the deepest part is east of the Trinity River Basin. Its axis is a gradually curving eastward arc from the vicinity of Tyler, Texas, to Houston County. Formations in the upper part of the Trinity River Basin dip toward the embayment in a direction slightly south of east, but the younger formations which occur in a downstream direction dip progressively more to the south so that the dip near the Gulf Coast is to the southeast. The basinal structure of the embayment has left resistant ironstone beds of the Claiborne group as surface outliers. The Ironstone Hills occur over a broad area in eastern Texas and in Anderson and Henderson Counties.

1.04.02 Flood Plain. The Trinity River flood plain varies from about one-half mile wide at Dallas, where the river dissects the relatively resistant Austin chalk, to about ten miles at various points in the lower reaches of the river. The flood plain becomes generally wider in a downstream direction and the average width is slightly over three miles. The land area of the entire 100-year flood plain between Riverside Drive in Fort Worth and Trinity Bay is approximately 585,000 acres. The flood plain alluvium is composed of sands, silts, clays, and gravels. Typically, the alluvial sequence consists of silt or clay underlain by sand with a basal gravel layer. The maximum alluvial thickness encountered is about 70 feet, and the average is 30 to 35 feet, while the thickness of terrace materials is usually slightly less. Most of the gravel occurs in the upper reaches of the river, especially near Dallas, while clays predominate in the coastal areas. Gravel sizes decrease in a downstream direction and very little gravel larger than pea-size occurs below Tennessee Colony. Meander scars, indicative of maturity in the erosional cycle of the river, are much more evident in the lower reaches, as are point bar and back swamp deposits. Natural levee deposits which occur intermittently throughout the river length are most in evidence from Trinidad to Wallisville Lake. Ground water in the terrace and flood plain alluvium of the Trinity River is in hydraulic connection with the river, its major tributaries, and larger lakes. The source of water in the alluvial aquifer is chiefly the infiltration of rainfall on the surface of the alluvium. Most measured water levels in flood plain wells range from 5 to 25 feet with an average depth of about 12 feet. Near the mouth of the river the water table is close to the surface and marshy conditions prevail over large areas of the flood plain. Under natural conditions, most of the alluvial ground water is discharged into surface water bodies, evaporated or transpired. Pumpage from wells, mainly for domestic and stock purposes, is small (Table 1-2). During periods of high river stage, ground water that normally seeps into the river is backed up in the alluvium, and a large part goes into riverbank storage along with some of the floodwater. Water levels in the alluvium rise during these periods, particularly near the river. Water levels in wells near the river may rise 10 to 20 feet depending on the height and duration of the river stage while, at the same time, water levels in wells near the outer edges of the flood plain may rise only a foot or less. When the river stage declines, ground water again discharges into the river, and water levels decline.

1.04.03 Terraces. River terraces are remnants of ancient river flood plains and are generally classified on the basis of their height above the present river level (see Plate 9). The highest terraces at the outer edges of the flood plain are remnants of the oldest flood plain. Cycles of downcutting produce successively lower and younger flood plain levels. The Trinity River terraces represent flood plains in existence during Pleistocene times. This period in the relatively recent history of the earth saw the periodic advance and retreat of continental glaciation. Although the glaciers never advanced south of northern Kansas, the glacial cycles had a definite effect on Trinity River flood plain deposition. Glacial stages were periods of heavy rainfall and low sea level. During these times, enough water was locked in the continental glaciers to cause a general lowering of sea level of as much as 450 feet. The unusual rainfall occurred when cold air masses from the north contacted the warm, moist air from the Gulf. These conditions produced cycles of downcutting and the establishment of progressively lower and

TABLE 1-2

CHARACTERISTICS OF OTHER AQUIFERS IN THE TRINITY RIVER BASIN

Aquifer	Thickness	Avg transmissibility in gals/day/ft	Water Quality	Avg pumping rate of individual wells in gals/min	Areal Concentration of pumping	Total pumped in 1960 in Acre-feet	Remarks
ROCKS OF PENNSYLVANIAN AGE		Low	Good to Brines	Up to 60 gpm	Northwestern part of basin	117	
NACATOCH	200'	Low	Variable	Less than 10 gpm	Southern Navarro, Henderson Cos	31	
ALLUVIUM		-	Fair	Up to 200 gpm	Along River & Tributaries mostly in upper reaches	336	Susceptible to contamination by industrial or municipal wastes
YEGUA	Up to 1500'	-	Variable	25 to 250 gpm	Madison, Houston & Grimes Cos.	151	
COOK MOUNTAIN	Up to 500'	Low	Variable	Up to 30 gpm	Southern Leon & Central Houston Cos.		
JACKSON GROUP	Up to 1200'		Variable	200 gpm	Grimes, Trinity & Walker Cos.	341	

SOURCE: TWDB Bull. 6309

younger flood plains. These conditions were interrupted by interglacial periods during which the glaciers retreated, the sea level rose, and a warm climate prevailed -- sometimes warmer than the present climate. Three separate terrace levels are generally recognized in the vicinity of Dallas, with remnants of two older terraces at somewhat undefined ages and elevations. The present flood plain, about 20 feet above river level, is designated the T-0 terrace and the successively older terraces, T-1, T-2, and T-3, lie about 50, 70, and 90+ feet above river level, respectively. The T-5 terrace is considered to be pre-Trinity, i.e., existing before the Trinity River (Slaughter, 1974). There is general agreement on the origin of the terraces and approximate ages although the sources of the alluvial materials are still poorly understood. The interglacial ages are correlative with deposition of the terraces: T-3 with the Yarmouth interglacial age, (at least 250,000 years old) and T-2 with the Sangamon interglacial age (at least 70,000 years ago). The age of the T-1 terrace has been relatively well established by radiocarbon dating at 23,000 to 20,000 years, while the present Trinity River flood plain level is related to the ultimate post-glacial attainment of present sea level, which occurred about 4500 years ago. Terraces in the middle Trinity River flood plain are delineated by Bureau of Economic Geology Atlases as Qt_1, Qt_2, and Qt_3, and correspond closely in elevation above river level to the T-1, T-2, and T-3 terraces of the Dallas area. They also correspond as to age and, in general, as to fossil content. The T-2 terrace has for many years been a prolific source of Pleistocene faunal remains in the Dallas area. Paleontological surveys and studies in the midbasin area appear to add to the evidence of upper and middle Trinity River terrace correlation. Terraces south of Highway 21 include the Deweyville formation and the Beaumont formation. The Deweyville probably represents a minor still-stand or temporary readvance of glaciation. The age is estimated at between 13,250 and 30,000 years by most geologists, but Aten (1966) states that the Deweyville may have formed as late as 5000 to 7000 years ago and delineates four separate Deweyville levels, ranging from 0 to 30 feet above the present flood plain level. The Beaumont formation which forms the upper terrace level along the lower Trinity River also occupies the broad interdistributary areas along the coast. The Beaumont is at least 30,000 or 40,000 years old as determined by radiocarbon dating.

1.04.04 Trinity Bay. The configuration of the Trinity-Galveston Bay complex is a result of processes which have been going on for the last 4500 years and are still occurring. Fisher et al (1972) outline these processes which began to occur as the sea level rose to its present elevation:

(1) Deeper parts of the Trinity and San Jacinto estuaries began to fill with sediment eroded from the walls of drowned valleys.

(2) The Trinity and San Jacinto bay-head deltas began their slow filling of the uppermost parts of the estuaries.

(3) Headward erosion by short streams continued within Pleistocene interdistributary areas where significant compaction of mud is occurring.

(4) Marshes encroached upon subsiding Pleistocene delta deposits and bay areas that were filled by storm-washover fans and bay-margin deposits.

The building of the Trinity delta has been slow as a result of low river discharge and sediment load, but it is estimated that since 4500 B.P. (before present) the mouth of the Trinity River has been extended eight to ten miles. The area that is now Lake Anahuac was originally the upper end of Trinity Bay but was bypassed by the southward encroachment of the delta. At present the delta is being eroded on the western side while progradation or lateral growth is occurring at discharge points near Anahuac. Bay bottom muds have drifted as much as five miles to the south from the Trinity River mouth. Relative changes in sea level of less than 15 feet have occurred over this time period. More recently, an average deepening of the bay by 1.15 feet from 1854 to 1933 was reported in a study by Shepard (1953). He concluded that the amount of sediment carried during those years, prior to extensive agricultural clearing in the flood plain, was insufficient to keep up with scour of the bay bottom by wind, waves, and tide. It seems likely that compaction and settlement of bay-bottom Pleistocene muds have also been contributing factors. This imbalance (sedimentation vs scour) is also evidenced by the failure of the Trinity and San Jacinto Rivers to fill their estuaries, as have most other Texas rivers during the last 4500 years. The difference is probably because of the nature of the drainage basin and the sediment supply to the river. At present, only about two percent of the sediment entering Lake Livingston passes through the spillway, and most sediment contributions from tributaries below Livingston Dam will be inhibited by Wallisville Dam. It seems likely that, in the future, aggradation and progradation of the delta will occur only during high flows and that the primary agents in the shaping of the delta will be wind-generated wave erosion and deposition.

1.04.05 Paleontology. Much of the stratigraphic classification in Texas is done by fossil content. Geologic formations are often identified, especially in the subsurface, by the presence and relative abundance of certain key fossils, or more commonly, by suites or assemblages of fossils. The Trinity River Basin is underlain by sedimentary rocks, most of which were deposited in near-shore, shoreline, or lowland terrestrial environments. These environments are the types most likely to accumulate organisms in abundance, and almost every formation exposed in the Basin is fossiliferous. Gillette and Thurmond (1971) have noted the following sequences considered especially important to paleontologists and stratigraphers:

> The Permian "red-beds" region in the northwestern section of the basin for their terrestrian Paleozoic amphibians and reptiles (only a couple localities elsewhere in the world have proven as productive and as important to vertebrate evolution); the Lower Cretaceous formations in the northern and western part of the Basin for their occasional ancestral mammal content; the Upper Cretaceous formations which were deposited in a shallow sea, for their invertebrate content, and for their large marine reptiles; the Paleocene-Cretaceous formational contact for purposes of correlation with other regions of the world; the Eocene and Middle Tertiary sediments for their invertebrate and vertebrate fossils; and the Quaternary formations, especially of Dallas and surrounding counties for their abundant vertebrate faunas of Pleistocene age.

Terrace deposits in the Dallas area have been a subject of much interest and study for many years because of their Pleistocene mammal content, consisting of bones of extinct giant elephants, mastodons, bisons, ground sloths, camels, saber-toothed tigers, antelopes, and horses. Finds have been numerous in the T-2 Terrace in the Dallas area, and younger forms occur in the T-1 terrace.

1.05 Ground Water Aquifers. A primary aquifer is defined by the Texas Water Development Board (TWDB) as a geologic formation which yields large quantities of water over a relatively large area (Peckham et al, 1963). There are four primary aquifers in the Trinity River Basin, the Trinity Group in the upper Basin, the Carrizo-Wilcox and the Sparta in the middle Basin, and the Gulf Coast aquifer in the lower Basin. Secondary aquifers include the Woodbine in the Dallas-Fort Worth area and the Queen City in the midreach. Their hydrologic characteristics are described in Table 1-3, and the locations of Basin aquifers are shown on Plate 10.

1.05.01 Trinity Group Aquifer. The sands of the Trinity group of Lower Cretaceous age occur as two formations: a basal member (Travis Peak formation) which is usually called the Trinity sand in north and west Texas and an upper member referred to as the Paluxy sand. The Trinity sand consists of alternating beds of sand, shale and thin limestone and generally increases in thickness with distance from the outcrop. In the Fort Worth-Dallas Area the Paluxy sand is about 500 to 800 feet higher than the top of the

TABLE 1-3

CHARACTERISTICS OF PRIMARY AND SECONDARY AQUIFERS IN THE TRINITY RIVER BASIN

Aquifer	Thickness	Area of Outcrop in Trinity Basin	Avg yearly rainfall on outcrop area	Avg specific capacity in gals/min/ft of drawdown	Avg transmissibility in gals/day/ft	Water Quality	Avg pumping rate of individual wells in gals/min	Areal Concentration of pumping	Water level declines thru 1960	Available perennial yield in Acre-feet	Total pumped in 1960 in Acre-feet	Remarks
* TRAVIS PEAK	500-1200'	1200 square miles	32"	4	4,000 to 25,000	Soft, high in dissolved solids	550 gpm	87% in Dallas & Tarrant Cos.	Up to 300' in Fort Worth	50,000 to 55,000	34,222	
PALUXY				Less than 2	4,400	Soft, good	150 gpm	90% in Dallas & Tarrant Cos.				
# WOODBINE	200 to 500'	900 square miles	34"	Less than 3	300 to 3,200	Poor, high in dissolved solids, sulfate, fluoride and locally chloride and iron	130 gpm	Most in Dallas Co.	8' per year 1940-1960	12,000	5,739	
* CARRIZO-WILCOX	200-2600'	1100 square miles	40"	9	27,500	Good	420 gpm		Slight in vicinity of Palestine	70,000 to 80,000	4,506	Low transmissibilities and poor water quality in vicinity of salt domes
* SPARTA	300'	250 square miles	44"	10.5	19,000	Good	560 gpm	Most near Crockett and Madisonville	Very little	50,000 to 60,000	1,255	Transmissibilities could be possibly doubled if entire thickness were screened.
# QUEEN CITY	100 to 400'	925 square miles	40"	2	8,000	Good		Only major pumpage at Centerville	None	20,000 to 30,000	107	
* GULF COAST	1,200'		50"	High	Up to 200,000	Good to excellent	High	Over 80% for irrigation	Slight declines in heavily pumped areas	66,000	19,343	Salt water encroachment near coastal areas

*Primary Aquifer: Provides large volume of water over large geographic area

#Secondary Aquifer: Provides more restricted usage; either in volume of water or in geographic area

Data Source: TWDB Bull. 6309

Trinity sand. Most water wells in the upper Trinity River Basin draw from the Trinity sand, but a few draw from the Paluxy or from both. Many municipalities, including Fort Worth and Dallas, have in the past pumped from the Trinity and Paluxy sands. Wells in the Trinity sands, except those on the outcrop, formerly had a natural flow, but the artesian pressures have declined and water levels in these wells, even in areas remote from heavy pumping, now range from 300 to 1000 feet below the surface. Near the outcrops, water from these sands is usually hard but comparatively low in dissolved solids. Wells further downdip encounter water which is softer but higher in mineralization.

1.05.02 Carrizo-Wilcox Aquifer. The Wilcox formation is composed of sand, silt, and clay and is connected hydraulically to the Carrizo formation in many places. The Carrizo-Wilcox is the primary aquifer in the midbasin area and contains large amounts of both fresh and brackish water. Some tonguing or interfingering of the fresh and brackish water is encountered; however, the fresh water-brackish water contact is usually encountered at considerable depth. The Carrizo-Wilcox water is low in dissolved solids, generally less than 200 mg/l. South of the Mount Enterprise fault zone, mineralization of the Carrizo water is somewhat higher, typically between 300 and 700 mg/l. Generally, wells in the outcrop areas encounter a highly mineralized water. This is believed to be caused by either a lack of flushing or a concentration of minerals by evapotranspiration. Wells near the outcrop areas of the Carrizo and Wilcox formations generally contain water with a high iron content.

1.05.03 Gulf Coast Aquifer. This aquifer is made up of a series of water-bearing sands within the Pleistocene, Pliocene, and Miocene sequences. Wesselman (1971) lists the three aquifers that make up the Gulf Coast aquifer, with their formational names, as the Upper Chicot aquifer (alluvium, Deweyville deposits, and Beaumont Clay), the Lower Chicot aquifer (Montgomery formation, Bentley formation and Willis sand), and the Evangeline aquifer (Goliad sand and upper sands of Fleming formation). North of Chambers County the Gulf Coast aquifer also includes the Jasper aquifer, which consists of lower Fleming sands and the underlying Catahoula sandstone.

1.05.04 Sparta Aquifer. The Sparta aquifer is more than 300 feet thick downdip from the outcrop and reaches a maximum thickness of about 380 feet in Walker and Grimes Counties. The formation is massive, unconsolidated, and contains about 60 to 70 percent fine to medium-grained sand with lateral and vertical gradations to clay or shale. The development of the aquifer has been somewhat restricted, and most of the pumpage occurs in Madison and Houston Counties. Many wells tapping the Sparta aquifer have screened only the upper producing sand lenses of the aquifer because of restricted needs of the users. The Sparta aquifer has great potential for further development through increased transmissibility if the entire thickness is screened.

1.05.05 Woodbine Aquifer. The Woodbine aquifer is composed of lenticular, crossbedded, loose to slightly consolidated, fine-grained, ferruginous sand and sandstone, interbedded with laminated clay. Sand composes about 50 percent of the formation and sandbeds are more massive and numerous in the lower part of the aquifer. Pumping tests on Woodbine wells in the Trinity River Basin have indicated a relatively low coefficient of transmissibility. Water quality in this aquifer is the poorest of all the primary and secondary aquifers in the Basin. The quality becomes poorer in a downdip direction and, in many areas, various mineral concentrations exceed the U.S. Public Health Service standards.

1.05.06 Queen City Aquifer. This aquifer is composed of 60 to 70 percent gray, micaceous, medium to fine-grained quartz sands and grades laterally and vertically to shale and sandy shale lenses. It also contains minor amounts of lignite and several glauconitic sand layers. Transmissibilities are relatively low. The water is generally soft, and the quality is good, although high iron concentrations have been a problem, especially in wells near the Weches formation contact, and hydrogen sulfide has been encountered in some areas.

1.05.07 Other Aquifers. Aquifers listed in Table 1-2 have provided low to moderate volumes of water in localized areas. Transmissibilities are generally low, and water quality is highly variable.

1.06 Ground Water Declines. Changes in ground water levels are principally caused by changes in either recharge or discharge. When a well is pumped, a cone of depression is produced in the water table. This dewatered area is in the shape of an inverted cone with the essential flow down the surface of the cone from all sides into the center. The shape of the cone is a function of the pumping rate and the transmissibility of the aquifer that is being dewatered. In general, a rapid pumping rate produces a deep, steep-sided cone while an aquifer with a high transmissibility (such as a gravel lens) may have a shallow cone with gently sloping sides. The depth of the cone or amount of drawdown is important in the design and proper development of a water well. Theoretically, equilibrium is reached when the supply from the outer fringes of the cone is equal to the volume of water being pumped. Problems of historical declines associated with excessive drawdown occur when pumping rates (discharge) repeatedly exceed ground water supply (recharge). In drought years, the greater need for ground water when recharge is minimal compounds the problem. When pumped wells are closely spaced, as in large cities, cones of depression eventually overlap, and the water table is lowered over broad areas. In 1970, there were approximately 117,000 acre-feet of ground water used in the Trinity River Basin. Although ground water levels fluctuate, both seasonally and yearly, depending on rainfall and other factors, ground water levels have steadily declined in heavily pumped areas over the period of record. Because of increasing demands, it is anticipated that ground water levels will continue to decline at the present rate. Problems associated with overpumping have forced many municipalities to turn to surface water sources.

1.06.01 Upper Basin. The city of Fort Worth obtained about a million gallons per day from the Trinity sand until 1914, when Lake Worth was built. Lake Worth water was the principal source after that date, but with increased industrial development, many commercial wells were drilled in the 1920's and 1930's. In 1932, Eagle Mountain Lake began operations, and these two lakes, along with Cedar Creek and Bridgeport Lakes, now supply the city's municipal needs. By 1942, ground water was being withdrawn at a rate of 7 to 7.5 million gallons per day, principally from the Travis Peak formation. Drawdowns were experienced on the order of 10 to 20 feet per year, with a maximum cumulative drawdown of about 770 feet in north Fort Worth. Dallas County has had a similar history of persistent declines, and municipal water is now obtained from water supply lakes. Because of problems of overproduction of ground water, municipal water is supplied primarily from surface water sources in the Dallas-Fort Worth metroplex. Many wells are being held in reserve as civil defense and emergency supplies.

1.06.02 Midbasin. No serious problems associated with excessive drawdown now occur in the midbasin area. Until 1969, the city of Palestine had pumped as much as 2.2 million gallons per day, and the city of Athens as much as 1 million gallons per day, from the Carrizo-Wilcox aquifer, with consequent declines in the water table. These two cities now obtain their water supplies from Lake Palestine and Lake Athens, and the cones of depression in these two areas have largely disappeared.

1.06.03 Lower Basin. Steady water level declines in the Gulf Coast Aquifer have been experienced in heavily pumped areas during the period of record. This period includes the early 1940's to late 1960's for most wells in the Lower Basin. The greatest declines of Gulf Coast aquifer wells in the Trinity River Basin have occurred at Liberty (80 feet) and immediately west of Dayton (100 feet) during the period from 1908 to 1966. The Dayton area water levels are probably influenced additionally by large withdrawals in Harris County. Heavy pumping from the Jasper aquifer at Livingston has produced declines up to 48 feet from 1960 to 1966. No appreciable declines have occurred in San Jacinto County, except in a Jasper aquifer well north of Camilla, where the total decline from 1947 to 1965 was 15 feet. In addition, flowing wells have lowered water levels in the Jasper and Evangeline aquifers. Water levels in Chambers County are influenced by Harris County pumping, but from 1941 to 1965, declined only about 5 feet and 25 feet in the upper and lower Chicot aquifers, respectively (Anders et al, 1968).

1.07 Soils and Basin Land Use. Soils are produced at the surface of the earth from the interaction of five soil forming factors. These are the parent rock material, climate, organisms (plants and animals), time, and relief. Change in any factor of the interaction results in a modification of the soil that is produced, and these changes are infinite in a natural ecological unit as large as the Trinity River Basin.

1.07.01 Soil Classifications. To cope with the vast array of soils that exist, a standard classification system has been devised to combine similar soils into a workable number of categories based on observable and measurable properties of the soil. From the most general to most specific, these categories are the Order, Suborder, Great Group, Subgroup, Family, and Series. The soil Order is the most general level of soil classification and reflects in broad terms the geographic distribution of soils similar in degree and kind of horizon development. Plate 11 indicates the classification and distribution of soil Orders in the Trinity River Basin.

1.07.02 Land Use Potential. Soil is a vital natural resource, but soil properties alone do not determine the possible or optimum utilization of land. Other factors, including topography, climate, drainage and vegetation, define the area's suitability to produce food and fiber or to provide space for industry, homes, transportation, or recreation facilities. These factors were considered in dividing the Trinity River Basin into 8 Land Use Potential Resource areas shown on Plate 12.

1.07.03 Actual Land Use. The land use potential and actual land use differ because of social and economic needs. Plate 13 shows the actual land use in the Trinity River Basin in 1970. Detailed descriptions of Basin agricultural activities are given later in this section.

1.08 Trinity River Basin Climatology. Plate 14 displays Basin temperatures, annual rainfall, annual wind roses, annual streamflow, annual net lake evaporation, and notes on climatological extremes.

1.08.01 Climate. The climate of the Basin, although generally mild, has distinctive features, including wide variations in annual and daily temperatures and periodic floods and droughts. In summer, the days are generally hot, and the nights are moderately warm.

Subfreezing temperatures are rare in the lower section of the Basin near the Gulf of Mexico but are experienced occasionally during the winter in the northerly parts of the Basin. Generally, the winter temperatures are mild, with occasional cold periods of short duration resulting from the rapid movement of cold, high-pressure air masses from the polar region via the continental highlands. There are no important topographic features affecting climate in this area. There are increases in mean annual temperature, precipitation, length of growing season, and relative humidity from the headwaters to the Gulf.

1.08.02 Humidity. The relative humidity over the Basin is generally moderate, decreasing from humid in the lower portion near the Gulf to subhumid in the northwestern extremity of the Basin. Relative humidity observations at Fort Worth, Palestine, and Houston are indicated in Table 1-4.

TABLE 1-4

AVERAGE ANNUAL PERCENT RELATIVE HUMIDITY

	6 a.m.	Noon	6 p.m.	Midnight
Fort Worth	84	57	55	75
Palestine	84	57	60	-
Houston	92	61	68	89

1.08.03 Annual Rainfall. Mean annual precipitation over the Basin ranges from about 27 inches in the northwestern extremity to 51 inches at the lower end. The average annual precipitation over the Basin is about 38 inches. Average annual precipitation at Dallas and Fort Worth is 34.4 and 33.9 inches, respectively. Periods of excessive precipitation have been experienced in all parts of the Basin. Generally, the highest 24-hour and monthly periods have occurred during major storms. However, there are some instances of heavy precipitation resulting from local thunderstorms. Examples of the latter type of observed precipitation are the 14.21 inches at Kaufman on August 22-23, 1908, and the 9.18 inches at Dallas on August 26-27, 1947. Table 1-5 shows precipitation at selected stations in the Basin for four major storm periods, both short and long, in which the storm covered a large portion of the Basin and caused major flooding.

TABLE 1-5

PRECIPITATION FROM MAJOR BASIN STORMS AT SELECTED STATIONS

Location of Station	Storm of May 22-26 1908 (inches)	Storm of Apr 21-Jun 1 1942 (inches)	Storm of Mar 28-Apr 2 1945 (inches)	Storm period of Apr-Jun 1957 (inches)
Gainesville	8.3	16.4	7.4	26.3
McKinney	4.0	17.1	1.0	29.2
Weatherford	6.4	13.5	3.2	31.1
Roanoke	6.0	18.8	-	33.2
Fort Worth	7.3	17.0	3.5	31.0
Mansfield	7.0	15.5	9.8	31.2
Dallas	4.0	12.4	1.4	30.6
Kaufman	2.5	13.0	10.0	24.2
Rosser	3.5	13.7	8.7	22.6
Corsicana	3.0	11.4	7.3	28.4
Trinidad	2.5	8.3	8.2	23.8
Long Lake	-	8.0	5.4	20.1
Liberty	3.0	11.4	7.3	28.4

1.08.04 Snowfall. Snowfall is generally light over the Basin. It is occasional in the northern part of the Basin and rare in the southern area near the coast. It occurs at infrequent intervals and melts rapidly, without forming a seasonal accumulation.

1.08.05 Temperature. The mean annual temperature varies from 69.0 degrees at Liberty, in the lower part of the Basin, to 63.5 degrees at Bridgeport, in the upper part of the Basin. The mean annual temperature over the Basin is about 66 degrees. There is a range in mean monthly temperatures of about 35 degrees between the warmest month, July, and the coldest month, January. Subzero temperatures have been recorded over the northern section of the Basin extending as far south as Huntsville. Temperature ranges are rather narrow, or oceanic, near the coast but are wide, or continental in character, in the interior of the Basin.

1.08.06 Winds. The prevailing winds are from the south or southeast during the greater part of the year. Dry southwesterly winds are experienced occasionally. During the winter months, December, January, and February, the high-pressure air masses approaching from the northwest increase the frequency of northerly winds. Wind velocities are highest during the months of March and April, and the lowest wind velocities generally occur during July, August, and September. The maximum published wind velocity of 91 miles per hour occurred at Galveston in August, 1915, during a hurricane. In general winds over the Basin are relatively light. The average annual wind velocities are: 10.9 miles per hour at Galveston, 7.4 miles per hour at Palestine, and 10.8 and 12.3 miles per hour at Dallas and Fort Worth, respectively.

1.08.07 Evaporation. Evaporation is greatest in the higher and less humid upper portions of the Trinity River Basin and least in the humid area near the coast. Approximately two-thirds of the annual evaporation normally occurs during the six warm months, April through September, and practically the entire net evaporation loss occurs during the months of June, July, August, and September.

1.08.08 Hurricanes. A total of 33 hurricanes crossed the Texas coast during the period between 1900 and 1967, resulting in losses of thousands of lives and severe property damages. A hurricane with a probability of occurrence of about once in 100 years will produce high water of about 15 feet in the vicinity of Trinity Bay and the mouth of the Trinity River. The frequency of recurrence of a major storm of hurricane intensity at any point on the Texas coast is about once in 8 years. Tropical storms and hurricanes which hit the Texas coast in the vicinity of Galveston Bay may come inland and cross the drainage basin of the Trinity River. These storms often produce rainfall and flooding of major proportions far inland. Four hurricanes have come inland and crossed the Trinity River Basin, or dissipated within the Basin since 1900 (Texas Water Development Board, 1968).

1.08.09 Tornadoes. No data are available on the number of tornadoes occurring annually in the Trinity River Basin; however, data are kept on a statewide basis by the National Oceanic and Atmospheric Administration (NOAA). An average of 96 tornadoes per year are reported to touch down in Texas. Tornadoes occur with greatest frequency in north central and west Texas. Sixty percent of all Texas tornadoes occur within the three months of April, May, and June. Although tornadoes do not normally produce a significant amount of rainfall over large geographical areas, the violent thunderstorms that frequently spawn tornadoes may produce intense local rainfall and damaging hail. A hurricane moving inland may produce many tornadoes. Hurricane Beulah produced 115 tornadoes in Texas during the five-day period of 19-23 September 1967.

1.08.10 Growing Season. The growing season normally extends from the latter part of March to the early part of November in the upper Basin and from the early part of March to the latter part of November near the coast. The growing season averages 232 days in the northern part of the Basin and 277 days in the southern part.

1.08.11 Sunshine. On an annual basis, sunshine averages about 64 percent of the time possible for the Basin.

1.09 Watershed Area. The watershed boundary, the river, the major streams and tributaries, the large lakes (all manmade), and other water-related facilities are shown on Plate 1.

1.09.01 Streams. The main stem of the Trinity River is formed at Dallas by the confluence of the West Fork and the Elm Fork at river mile 505.5. Throughout its length, the Trinity River follows a tortuous course, meandering from one side of the valley to the other for a distance of about twice the length of the general axis of the valley. Data pertinent to the Trinity River and its pprincipal tributaries are shown in Table 1-6.

1.09.02 Lakes. Lakes in the Trinity River Basin, existing or under construction, include seven Corps of Engineers multiple-purpose lakes, 22 non-Federal conservation lakes, and 822 Soil Conservation Service small detention single purpose and multi-purpose lakes. A listing of these lakes, with pertinent data, is given in Table 3-2. Also included are lakes from which water is imported into the Trinity River Basin. The large, non-Federal lakes were built for the purpose of supplying municipal and industrial water to nearby cities. Many smaller, non-Federal lakes, not included in Table 3-2, have been built for recreation, irrigation, and industrial purposes. The lakes built by the Corps of Engineers were, as indicated above, multipurpose. These purposes included: flood control, water supply, navigation, recreation, and fish and wildlife conservation. The Soil Conservation Service detention lakes were built for the purposes of floodwater retardation, sediment storage, and conservation.

1.09.03 Other Developments. Other water resource development projects in the Trinity River Basin are shown in Table 3-3, including floodway and channel enlargement projects, agricultural levee projects constructed by local interests, and navigation projects.

1.10 Basin Water Agencies. Within the Trinity River Basin drainage area, there are several levels of jurisdiction ranging from state to city with overlapping controls in some areas.

1.10.01 Trinity River Authority of Texas. The Trinity River Authority of Texas (TRA) in 1958 formulated a Master Plan for water resources development in the Trinity River Basin. The Authorized Project was

TABLE 1-6

STREAMS OF TRINITY RIVER BASIN

Stream	Confluence with parent stream (mi above mouth)	Length (river miles)	Approximate total fall (feet)	Drainage area (sq mi)
Trinity River (incl West Fork)	-	715	1,250	17,969
West Fork	505.5	209	864	3,502
Clear Fork	558.7	70	775	518
Big Fossil Creek	542.7	21	296	75
Village Creek	533.8	33	458	188
Mountain Creek	507.8	37	463	304
Elm Fork	505.5	119	864	2,577
Denton Creek	18.4	102	685	719
Little Elm Creek	39.4	41	348	262
Clear Creek	50.5	55	650	354
White Rock Creek	493.1	42	386	136
East Fork	459.8	112	566	1,314
Duck Creek	31.0	22	270	45
Cedar Creek	385.5	92	374	1,090
Richland Creek	372.4	97	630	1,990
Chambers Creek	14.2	107	603	1,070
Tehuacana Creek	347.2	42	297	432
Catfish Creek	339.6	37	303	305
Upper Keechi Creek	272.8	40	352	511
Lower Keechi Creek	240.5	29	341	192
Bedias Creek	207.9	35	282	565
White Rock Creek	169.9	35	318	518
Long King Creek	117.5	31	258	225

incorporated as a part of the TRA Master Plan for the Trinity River Basin which is currently undergoing review, including plans for a series of public hearings. The TRA also manages Lake Livingston, sells water to municipalities, including the city of Houston, is the sponsor of some local flood protection projects, and operates facilities for the collection and treatment of sewage from several municipalities in the Dallas-Fort Worth Metropolitan Area.

1.10.02 Water Districts. There are five water districts in the upper Trinity River Basin that have been organized for the supply of surface water to municipalities.

1.10.03 Cities. About 25 cities have permits for the diversion of surface water from lakes for municipal use. Dallas withdraws water from several lakes in the Trinity River Basin and has planned for the importation of water from the Sabine, Sulphur, and the Neches River Basins.

1.10.04 Levee Districts. There are 38 water districts, levee districts, or floodway districts in the Trinity River Basin which have been involved in levee construction and improvements. Twenty-two of these are situated at least partially in the flood plain of the Trinity River. These levee and floodway districts provide varying degrees of protection for more than 134,000 acres of land along the Trinity River. Between Dallas and the proposed Tennessee Colony Lake site, about 80 percent of the river has a levee on at least one side, and about 63 percent has a levee on both sides. Between the proposed Tennessee Colony Damsite and Lake Livingston, about 25 percent of the river has a levee on at least one side. These levee districts are shown in yellow on Plate 1.

1.10.05 Metropolitan Leveed Areas. The leveed floodway system in Fort Worth was built in several increments, the earlier improvements being first constructed by the Tarrant County Water Control and Improvement District No. 1 (WCID No. 1) and later strengthened by the Corps of Engineers. Later increments were constructed by the Corps and were locally sponsored by the Tarrant County WCID No. 1. These floodways include portions of the West Fork and the Clear Fork of the Trinity River. The Big Fossil Creek floodway, which was built by the Corps, was initiated and sponsored by the city of Richland Hills. The Dallas levee system was originally developed by local interests and the levees were later strengthened by the Corps of Engineers. The agricultural levees in the Basin on both the main stem of the Trinity River and its tributaries were built many years ago by individual levee districts and have been periodically repaired by the Corps of Engineers under emergency disaster relief operations following breaks caused by flooding.

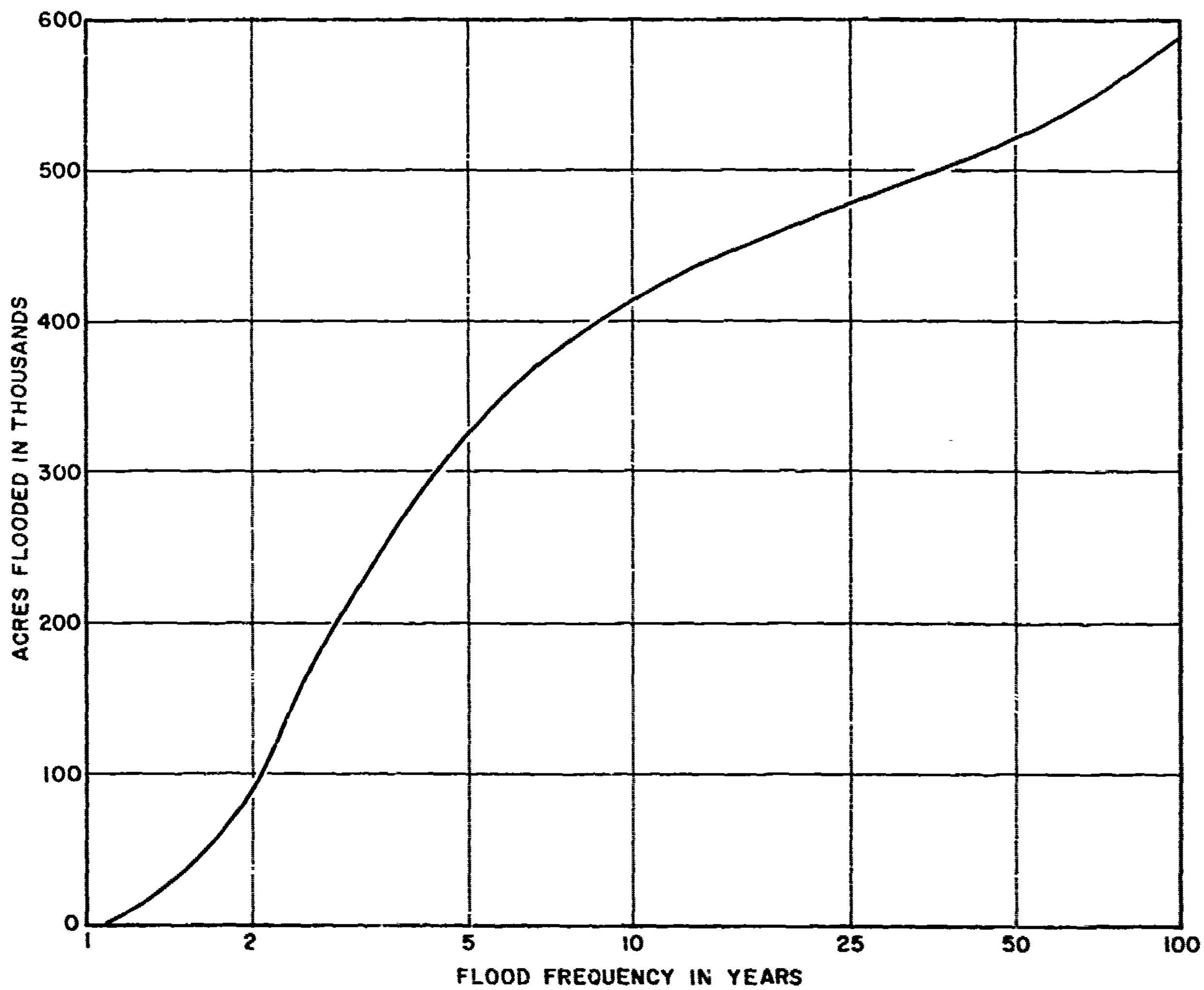
1.11 River Hydrology. The Trinity River is a mature stream, having a wide flood plain and a well developed meander pattern. Natural stream velocities vary from less than 1 foot per second to about 20 feet per second, depending on location and volume of water. During low flows, total flow time from Fort Worth to Trinity Bay is on the order of 50 days (U.S.G.S., 1972). Floods on the Trinity River may occur at any time of the year; however, they are more likely to occur in the spring. Major floods on the Trinity River do not follow any specific wet-dry cycle on an annual basis. Each flood deposits a silt load on the flood plain, but the time of occurrence and amount is so irregular that it precludes any useful application by man. Since floods often occur in the spring, or early summer, the resultant deposition of silt frequently occurs on crops or grass that have recently sprouted and causes damage. During the passage of any given flood, only a portion of the flood plain is inundated by the floodwaters. A statistical probability relationship has been established to predict the acres of flood plain land flooded between Fort Worth and Trinity Bay for a given frequency of flood, as indicated by Figure 1-1.

The lateral shifting of the Trinity River occurs over a long period of time. Most of the actual change in location of the river channel occurs during flood periods when the high velocity flows occur, but the alignment does not usually move a significant distance laterally during the passage of a single flood. The meandering of the river causes a problem from the standpoint of the local landowner, since the cutting away of the bank causes a loss of property. As the river erodes the bank on one side, it usually deposits sand and silt on the other side, so, in effect it tends to build up one place as it cuts away another. Following many major flooding periods, the Corps of Engineers has been called upon to construct bank stabilization works under emergency procedures to protect major structures such as highway and railroad bridges or agricultural levees. During its lateral shifting across the flood plain, the river occasionally cuts off a loop and forms an oxbow lake. Over very long periods of time, siltation from floods and the natural eutrophication process transform these oxbow lakes into lowlands. In the lower Basin where rainfall is high, these areas form wetlands that are valuable waterfowl habitats. These wetlands are able to retain runoff water because they become a trap for the clay materials carried by the river during flood stages, and these materials settle out to form a sealing layer over the bottom of the oxbow lake.

Natural channel depths in the river vary from 40 to 50 feet in the lower and midbasin area and are about 30 feet in the reach from Trinidad to Fort Worth. During low flow periods, flows may vary from less than 100 cubic feet per second (cfs) between Fort Worth and Dallas to around 400 cfs in the lower reaches of the river. Flows downstream from Lake Livingston are influenced by the releases from the lake. Low flows produce depths of less than five feet in most reaches of the river.

FIGURE I-I

ACRES FLOODED vs FREQUENCY



TRINITY RIVER FLOODPLAIN

(EAST FORT WORTH TO MOUTH OF RIVER)

About one-half of the average annual runoff from the Trinity River Basin comes from the lower one-third of the drainage area, with the upper two-thirds producing the other one-half. This estimate is based on historical flow records from USGS gages. As more of the upper drainage basin becomes controlled by water supply lakes, less rainfall from this area will appear as runoff in the river. Main stem lakes control virtually all of the low flows, but floodflows are for the most part passed through the lakes. An exception to this occurs following a long dry period when lake levels are low because of pumpage, evaporation, and low inflows, so that a portion of the flood volume will be retained as lake storage.

1.12 Surface Water Usage. Surface water sources supply most of the water presently used in the Trinity River Basin, although wells accounted for an estimated 117,000 acre-feet annually as of 1970. Surface water usage can be divided into three major categories: municipal, industrial, and irrigation. Plate 16, shows water use by counties in the Trinity River Basin. Cooling water for electric generating purposes is included in the same category as water for industrial purposes on Plate 16. Consumptive use of water for thermal electric purposes in 1970 in the Trinity River Basin required about 20,000 acre-feet annually. Irrigation as a major use of water from the Trinity River is limited to the lower Basin, and the three counties of Jefferson, Liberty, and Chambers account for most of it, as indicated on Plate 16. However, several other counties use as much as 1000 acre-feet annually, and these are also shown. All other individual irrigation permits less than 1000 acre-feet per year are indicated collectively on the plate. Permits for irrigation water in the Trinity River Basin authorize the use of about 295,000 acre-feet per year for that purpose. The enlarged map of the Houston area indicates the Coastal Industrial Water Authority (CIWA) canal system used for delivery of raw water to the Houston ship channel area, the Cedar Point heavy industry area, and Galveston County. It also indicates some of the primary irrigation canals in that area. In 1970, rates of usage for municipal purposes were found to be about 160 gallons per capita day (gpcd) for the upper Basin counties and about 115 gpcd for the lower Basin counties. Industrial water usage in 1970 was about 15 percent of the total municipal and industrial water used and totaled about 478,000 acre-feet annually. Food processing industries and chemical industries each accounted for about 27 percent of the total industrial consumption. Surface water usage for municipal and industrial purposes in the lower Basin (within the Basin limits) is minor compared to the upper Basin usage at the present time. Current plans by the city of Houston and the CIWA call for the annual diversion of about 1,000,000 acre-feet of water from the lower Trinity River to the San Jacinto River basin for use in the Houston area. The Texas Water Quality Board (1973) has deemed that the water in the Trinity River between Beach Street in Fort Worth and the headwaters of Lake Livingston is presently unsuitable for contact recreation or domestic raw water supply, but is suitable for noncontact recreation and fish and wildlife propagation. Ground water has traditionally supplied most of the needed water for both municipal and industrial purposes in the Houston area, but subsidence of the land surface caused by continued pumpage and drawdown on the water table in the Gulf Coast aquifer has caused Houston to look elsewhere for more water. The construction of Lake Livingston was a result of this quest. Houston and the heavy industries around Cedar Point and the Houston ship channel (steel and petro-chemical industries) require large volumes of water. The Coastal Industrial Water Authority was formed and has constructed delivery systems to transport Trinity River water to these industries.

1.13 Water Quality. Water quality has been a continuing problem in the Trinity River for many years. During public meetings held in December 1972, by the Corps of Engineers on the Trinity River Project, several references were made by residents of long standing to periods of very bad water quality in the river, with one particular resident referring specifically to poor water quality 48 years ago at a point downstream from Liberty. A phenomenon known in the Basin as "black rise" was discussed by local residents at the Fairfield, Texas, Environmental Planning Meeting of 14 December 1972. Apparently, this occurs on the river when a river rise follows a long, dry period, and the bottom sediments of the river which have accumulated during the low flow period are stirred up by the rise. These sediments, which have been deposited in the river by the effluents of the upstream sewage treatment and industrial plants, have a black color and a high oxygen demand and may cause fish kills because of the removal of the oxygen from the river water. Poor water quality results for the most part from an over-abundance of impurities introduced from inadequately treated sewage effluent, rainfall runoff from municipal areas, runoff from agricultural areas, and point source introduction of industrial effluents. Because of the large population of the Dallas-Fort Worth metroplex, most of the pollutants affecting the river are introduced near the upper end of the river and influence the river over most of its length. Sewage is sometimes discharged into the Trinity River in the Dallas-Fort Worth area with only primary treatment or with no treatment at all (North Central Texas Council of Governments, 1970). At the Dallas White Rock Creek Sewage Treatment Plant, for instance, a streamflow of about 5000 cfs (at river stage of about 24 feet) causes the secondary treatment to be ineffective. During these periods, primary treated sewage must be released directly into the river when the river stages are greater than 8 feet above normal. Raw sewage must be released when the river stage exceeds 32 feet above the normal. Similar problems occur at other sewage treatment plants in the area.

1.13.01 Urban Runoff. About 20 percent of the average annual volume of water carried by the Trinity River at Trinidad is urban runoff from the Dallas-Fort Worth Metropolitan Area. This runoff contains a broad spectrum of pollutants of various types from sources throughout the Metropolitan Area. These pollutants include: animal droppings; oil and fuel drip from streets, highways, and airfields; garbage and trash; industrial spillage and washings; pesticides, herbicides, and fertilizers from lawns, gardens, etc.; and silt and clay materials. The urban runoff from a moderate sized city has been reported by Vitale and Sprey (1974) to contribute from 40 to 80 percent of the total annual BOD and COD (biochemical and chemical oxygen demands) to the receiving waters. They further found that toxic materials, particularly heavy metals, are a significant problem and estimated that a typical moderate-sized city will yield up to 125 tons of lead and up to 15 tons of mercury per year in its urban runoff.

During October and November 1972, Stephen F. Austin State University, under contract with the Corps of Engineers and TRA conducted a cooperative water quality study during a river rise following rather heavy rainfall in the Dallas-Fort Worth Metropolitan Area. The purpose of this study was to obtain additional quantitative data on some constituents of urban runoff. Data from this study indicated that the first part of the river rise following heavy urban runoff contained excessive quantities of nutrients and other dissolved and suspended materials. As could be expected, the greater loading occurred at the sampling station furthest downstream. Table 1-7 lists the estimated loadings of selected constituents during the period 23 October 1972 through 31 October 1972, at the U.S. Highway 79 crossing of the Trinity River in Anderson and Freestone Counties. The average daily loading of orthophosphate at a site upstream from this location was reported by the North Central Texas Council of Governments (1970) to average 45 tons per day. As may be seen from Table 1-7, this amount was often exceeded during the six day period in October 1972.

TABLE 1-7

ESTIMATES OF TOTAL DAILY LOADINGS OF SELECTED CONSTITUENTS DURING A RISE IN THE TRINITY RIVER AT U.S. HIGHWAY 79, 23 - 31 OCTOBER 1972

Date	Total P (Tons)	NO_2-N (Tons)	NO_3-N (Tons)	NH_3-N (Tons)	Flow (cfs)
23 Oct 72	98.2	0.9	6.0	22.0	744
24 Oct 72	108.6	2.2	10.5	45.8	1,260
25 Oct 72	193.9	1.3	39.8	47.3	1,800
26 Oct 72	282.0	1.3	5.0	112.0	3,080
27 Oct 72	102.8	1.7	6.9	57.8	3,180
31 Oct 72	139.4	2.6	26.3	81.9	6,470
Totals	924.8	10.0	94.5	366.8	

Data Source: McCullough and Champ (1973)

1.13.02 Agricultural Runoff. Upper Basin agricultural activity also contributes pollutants to the Trinity River. A discussion of pesticide-herbicide pollution appears elsewhere in this section. Bacteriological analysis conducted by McCullough and Champ (1973) indicate that livestock may be a significant contributor to the water quality degradation in the Trinity River. The potential significance of animal wastes as a pollutant is often viewed in terms of human waste equivalents, which is the approximate number of humans necessary to produce the fecal waste generated by one animal (Wadleigh, 1968). The population equivalent is about 16.4 for cattle, 11.3 for horses, 1.9 for swine, and 0.14 for poultry. The extent to which animal wastes are attenuated before reaching water courses has not been defined by measurement in the Trinity River Basin. The latest date for which information has been published regarding the numbers of domestic animals in Texas counties is January 1972. The following domestic animal numbers are reported by the Texas Department of Agriculture and the U.S. Department of Agriculture (1973) for Tarrant, Dallas, Rockwall, Kaufman, Ellis, Navarro, Henderson, Anderson, and Freestone Counties:

Cattle	666,000	Poultry	396,200
Swine	37,200	Horses	185,000

When these numbers are converted to human waste equivalents, the total human population equivalent in the above listed counties is calculated to be 13,139,000, or more than the 1974 population of the entire State. Little or none of this waste is subjected to conventional sewage treatment.

1.14 Water Quality Parameters. A survey of the available literature on organic chemical pollution of freshwater showed that 496 organic chemicals have been reported or are suspected to be found in freshwater. Of these, 66 have been identified (Little, 1970). A similar survey (Little, 1971) disclosed that 266 inorganic chemicals can potentially pollute freshwater. Of these, 87 have been identified as being present in freshwater.

1.14.01 Biological Water Quality. A close relationship exists between the aquatic biota and the quality of the water making up their habitat. Generally speaking, polluted waters are capable of supporting a much less diverse biota than are non-polluted waters, although biological productivity in polluted waters is often quite high. Some changes come about in water as the result of natural processes that render water unfit for some uses, so in order to separate "man-caused" from "natural" water pollution, the former is defined as "... any impairment of the suitability of water for any of its beneficial uses, actual or potential, by man-caused changes in the quality of the water." (Warren, 1971).

Toxic materials are one form of water pollution which can be measured by quantitative analyses. They range from obvious poisons such as cyanide compounds to the more subtle poisons such as sublethal quantities of pesticides, herbicides, etc. The number of possible pollutants in water is increasing daily. New chemical products and by-products entering waterways make the direct measurement of all pollutants virtually impossible. Because of this, the numbers, kinds, and ratios of organisms present in a given lake, stream, or river are useful as indicators of varying degrees of pollution. The absence of certain organisms is also a useful indicator of some adverse conditions. These indicators may greatly simplify the obviously monumental task that would be required to directly measure the concentration of each possible pollutant.

Fish kills are indicative of sudden deterioration of water quality, such as a spill of toxic material or the sudden drop of dissolved oxygen. This type of indicator is a rather drastic notification of undesirable conditions. According to the latest published report on fish kills (U.S. EPA, 1972), one major kill occurred during 1971 in the Trinity River. This occurred in the vicinity of Anahuac, and a reported 3 million fish were killed. This kill was attributed to municipal sewage. Of the 21 identified sources of pollution in the United States which led to reported fish kills in 1971, inadequately treated municipal sewage was the leading killer of fish. In 1971, 25 million fish were reported killed by a summation of causes with 21.4 million of this total attributed to municipal sewage.

Water quality in the Trinity River is consistently much worse in the Dallas-Fort Worth reach than in the lower reaches of the river. Certainly some fish were killed in these municipal areas, but the fact that the water in the Dallas-Fort Worth portion of the Trinity River is so consistently polluted means that only a very few fish can survive there. Virtually no game fish are found in the 140 miles of the Trinity River between Fort Worth and Texas State Highway 31 (Fisher and Hall, 1973). Occasionally, rough fish are taken by anglers, sighted in the river, or found after fish kills in this area. Fish kills have occurred in recent years from Fort Worth to Trinity Bay, usually as a result of oxygen depletion in the water following the flushing downstream of oxygen demanding substances. In April 1971, dissolved oxygen was depleted to the 0 to 1 mg/l range as far downstream as Lake Livingston, resulting in a fish kill conservatively estimated at 200 tons of fish just above Lake Livingston headwaters (TRA, 1974).

The more subtle, long term changes in water quality have a different set of indicators. These include phytoplankton, zooplankton, and benthic invertebrate species diversity as well as the presence or absence of certain species or groups of these organisms.

1.15 Water Quality Analysis. The results of the water quality analysis of some of the more significant parameters are presented in Plates 15.1 through 15.19, Appendix A, which coincide with the following subparagraph titles. These plates indicate average concentrations for the various parameters from samples taken over a period of time ranging from eight months to two years under varying flow conditions, from the upstream Metropolitan Area to Trinity Bay. The upstream point shown on each plate, although not completely upstream from the effects of metropolitan pollution, is upstream from the larger sewage discharge points.

1.15.01 Dissolved Oxygen (DO). Perhaps the single most important parameter measured, as far as the aquatic environment is concerned, is dissolved oxygen. The minimum requirements for dissolved oxygen in the Trinity River, as listed by the Texas Water Quality Board (1973), are 4.0 mg/l in the tidal zone and 5.0 mg/l in the other portions, except when the river is effluent-dominated, at which time the standard is 2.0 mg/l. Samples were taken throughout the year, and the average of all points at each station is indicated on Plate 15.1 by the heavy line. The lowest values recorded were essentially zero in the vicinity of Dallas. Although the average value for all measurements taken in this section of the river dipped to about 3.7 mg/l, July and August concentrations often dip to less than 1.0 mg/l for long periods of time. A minimum requirement for the survival of sport fish such as bass is about 5.0 mg/l, and even though average conditions may indicate adequate oxygen for fish survival, a short period of time with low oxygen is sufficient for a fish kill. Downstream from Dallas, average concentrations of dissolved oxygen in the water gradually increase, but minimum readings under 4.0 mg/l persist to the sampling station just upstream from Lake Livingston.

1.15.02 Biochemical Oxygen Demand (BOD). BOD is a parameter inversely related to dissolved oxygen in water. In the Trinity River, one source of BOD is the organic enrichment introduced into the water from sewage and industrial plants in the upper Metropolitan Area. This organic enrichment provides food for the growth of bacteria and fungi, and these organisms grow at an exponential rate where all conditions for their growth are present. This very rapid growth continues until some limiting factor inhibits it. During the growth period of these organisms, they require oxygen both for respiration and for the completion of their feeding cycle. Plate 15.2 indicates that the average BOD concentration declines as measurement proceeds downstream, but values indicating acceptable water quality are not reached upstream from Lake Livingston.

Other sources of BOD in the Trinity River Basin include urban storm runoff, agricultural storm runoff, and natural detritus. Urban storm runoff picks up organic sediments, oils, tars, and other chemical by-products that have settled to the ground and transports them to the river. Agricultural areas also contribute organics from cattle feed lot operations and pasture areas. Natural detritus includes organic matter such as living and dead plants and animals and their waste products. Table 1-8 lists the discharges of BOD from the Dallas-Fort Worth Area sewage treatment plants reported during August 1972. Table 1-9 lists the Texas Water Quality Board's reported BOD for the Dallas-Fort Worth Area (TRA, 1974).

1.15.03 Ammonia. Ammonia nitrogen is the end product of the first stage of oxidative degradation of animal and plant proteins and is therefore the first nitrogen compound released by sewage digestion. Generally, in unpolluted waters where sufficient oxygen is available, ammonia nitrogen and ammonium compounds occur in relatively small quantities, usually on the order of 1 mg/l or less. In waters where dissolved oxygen has been depleted by pollutants, ammonia nitrogen concentrations may increase to extremes of 12 mg/l or more (Reid, 1961). As indicated on Plate 15.3, the average ammonia nitrogen level reaches a high of about 9 mg/l at Rosser. Individual high readings exceed 19 mg/l at both the Grand Prairie and Rosser sampling stations. The amount of ammonia in the water declines fairly rapidly downstream from Rosser, probably as a result of oxidation to nitrite nitrogen. As pointed out by Reid (1961), ". . . free ammonia in concentrations over 2.5 mg/l . . . is apt to be harmful to many fresh water species." An average concentration of 2.5 mg/l is reached upstream from the sampling station at river mile 265 near Crockett, although individual readings as high as 6 mg/l were recorded. The permissable limit for ammonia in public water supplies is 0.5 mg/l (EPA, 1971b). Records upstream from Fort Worth indicate maximum readings of less than 0.5 mg/l, which is an indicator of stream ammonia nitrogen before heavy organic loadings are introduced from the Metropolitan Area.

1.15.04 Nitrite. Nitrogen as nitrite occurs in very minute quantities in unpolluted waters and is often formed by reduction from nitrate by certain algae and bacteria. In polluted waters where ammonia nitrogen is present, nitrite nitrogen is formed by oxidation of ammonia nitrogen and this appears to be one of the processes occurring in the Trinity River. Heavy organic loads are dumped into the Trinity River along the West Fork, the main stem, and the East Fork. A large portion of the nitrogen load is in the form of ammonia. It oxidizes to nitrite as it continues downstream, but the process is probably slowed by the lack of dissolved oxygen in the water, so that the peak occurs at the sampling station at river mile 390 near Trinidad, with continued high readings as far downstream as river mile 265 near Crockett. Industrial activity may be contributing to the very high readings in this area, but some of the rise is also from the high organic loadings introduced into the river just upstream from Rosser by the East Fork. Average concentrations are less than 0.1 mg/l upstream from Fort Worth. Surface water criteria for public water supplies establish the permissible concentration of nitrates plus nitrites as nitrogen to be 10 mg/l (EPA, 1971b).

TABLE 1-8

MONTHLY AVERAGE DISCHARGES TO TRINITY RIVER, AUGUST 1972[1]

Discharger	Mile	Flow (cfs)	$CBOD_5$ (mg/l)	$CBOD_5$ (#/day)	Ultimate BOD	NH3-N (mg/l)	NBOD (#/day)	UOD (#/day)
Fort Worth								
Riverside	520.	28.	35.6	5,383	8,075	10.0(3)	6,910	14,985
Village Creek	506.	27.	37.6	5,482	8,223	11.3	7,529	15,752
Arlington	490.	15.	40.4	3,272	4,908	30.8(3)	11,401	16,309
TRA Central	483.	34.	30.0(2)	5,508	8,262	13.1	10,992	19,254
Dallas								
Dallas	470.	52.	28.7	8,059	12,089	7.7	9,881	21,970
White Rock	470.	123.	53.5	25,535	53,303	18.7	56,762	110,065
South Side	455.	3.	55.3	896	1,344	2.1	155	1,499

(1) Data from monthly reports of listed treatment plants unless otherwise noted.
(2) Approximate, unfiltered.
(3) Grab Sample

TABLE CALCULATIONS:

$CBOD_5$ = Five - day Carbonaceous Biochemical Oxygen Demand
Ultimate CBOD = 1.5 x $CBOD_5$
NBOD = Nitrogenous Biochemical Oxygen Demand = 4.57 x NH_3-N
UOD = Ultimate Oxygen Demand = Ultimate CBOD + NBOD

Data Source: Trinity River Authority, 1975.

TABLE 1-9

MAJOR WASTE DISCHARGES TO THE TRINITY RIVER[1]

Discharger	Mile	Flow (cfs)	$CBOD_5$ (mg/1)	$CBOD_5$ (#/day)	Ultimate CBOD (#/day)	NH_3-N (mg/1)	NBOD (#/day)	UOD (#/day)
Fort Worth								
Riverside North	520.	29.9	35.4	5,716	8,574	9.2	6,788	15,362
Riverside South[(2)]	520.	10.7	44.3	2,560	3,840	16.1	4,251	8,091
Village Creek	506.	45.5	26.4	6,486	9,729	8.0	8,983	18,711
Arlington	490.	13.6	43.8	3,217	4,826	20.2	6,780	11,606
TRA Central	483.	36.5	17.0[(3)]	3,351	5,027	15.1	13,601	18,628
Dallas								
Dallas/White Rock	470.	177.9	49.6	47,649	71,474	15.5	68,048	139,522
South Side	455.	4.3	47.2	1,096	1,644	5.0	531	2,175

(1) Texas Water Quality Board Data for Flow, $CBOD_5$, and NH_3-N
(2) Intermittent Use
(3) Filtered

TABLE CALCULATIONS:
$CBOD_5$ = Five-day Carbonaceous Biochemical Oxygen Demand
Ultimate CBOD = 1.5 x $CBOD_5$
NBOD = Nitrogenous Biochemical Oxygen Demand = 4.57 x NH_3-N
UOD = Ultimate Oxygen Demand = Ultimate CBOD + NBOD

Data Source: Trinity River Authority, 1975.

1.15.05 Nitrate. Nitrogen as nitrate may be considered as the final phase in the oxidation of nitrogen compounds. This oxidation is accomplished by bacteria which release energy for their own utilization in the process. Nitrogen in water in the form of nitrate rather than ammonia indicates that no additional oxygen is required for further biochemical processes as far as the nitrogen cycle is concerned. Nitrate nitrogen is most easily taken up by green plants rooted in the bottom or floating in the water, and this is basic to the problem caused by the release of nitrogen into any water body. Nitrate nitrogen usually occurs in relatively small concentrations in unpolluted fresh waters, with the world average being about 0.3 mg/l (Reid, 1961). At the upstream sampling station on the Trinity River the average concentration was about 0.4 mg/l. At the Grand Prairie sampling station (river mile 515), the average concentration was in excess of 4 mg/l, with a maximum of 15.6 mg/l. These very high nitrate concentrations are indicative of an effluent dominated stream. Since there are several treatment plants upstream from this sampling station, these high nitrate concentrations are not unexpected. The concentration of nitrate nitrogen declines progressively downstream to Rosser (river mile 450), where it begins a gradual increase to the headwaters of Lake Livingston. This secondary peak indicates oxidation of nitrate is continuing to occur. The gradual rise in nitrate concentrations could originate in runoff from adjacent commercially fertilized agricultural lands or discharges from industrial activities in this area. The nitrate nitrogen concentrations drop off fairly rapidly downstream from Lake Livingston, with an average concentration of about 0.6 mg/l at the Romayor Station (river mile 94).

1.15.06 Phosphorus. Phosphorus commonly occurs in natural waters and in waste waters in the form of phosphate. It may occur in ionic form, with particles of detritus, or in the bodies of aquatic organisms. Phosphates enter water from a variety of sources. Small amounts are sometimes added to municipal water supplies during treatment. Large quantities are added when water is used for laundering or other cleaning, since phosphates are a major ingredient of most detergents. Phosphates applied to land as fertilizers are carried into rivers and streams during storm runoff periods. Organic phosphates, whether formed in biological processes or by organic synthesis, are deposited in water bodies with sewage effluents. They may also be formed from orthophosphates in sewage treatment processes or by living organisms in the receiving waters (APHA, 1971). From an ecological point of view, phosphorus is often considered the most critical single factor in the maintenance of biogeochemical cycles (Reid, 1961). This importance stems from the fact that phosphorus is vitally necessary in the operation of energy transfer systems in living cells and that it normally occurs in very small amounts in natural waters. Most plants require phosphorus in the form of orthophosphates. A deficiency of this nutrient can lead to inhibition of phytoplankton growth, resulting in decreased productivity in aquatic systems (Reid, 1961). Most limnologists agree that, in order for phosphorus to be the limiting element as far as productivity is concerned, concentrations of total phosphorus no greater than 0.01 mg/l should be present (Vollenweider, 1968).

As noted on Plate 15.6, Trinity River orthophosphate concentrations upstream from Fort Worth averaged about 0.2 mg/l, with the maximum reaching about 1.2 mg/l. Since orthophosphates are always a quantity less than the total phosphorus, it is obvious that phosphorus is not a limiting factor in the Trinity River. While unaffected by major metropolitan sewage treatment plants, the river in this area does receive effluent from several small municipal treatment plants and runoff from a fairly large upstream area. These concentrations are therefore not considered indicative of natural concentrations of phosphorus in the Trinity River. At the U.S.G.S. gage at Grand Prairie (river mile 515), the maximum orthophosphate concentration rose to 22.0 mg/l, with an average concentration of 4.5 mg/l. After a slight decline below Dallas (river mile 490), a sharp increase occurred at the Rosser Station, with an average of about 6 mg/l and a maximum concentration of 39.4 mg/l. This increase is more than likely a response to additional phosphates introduced from the East Fork. At the Trinidad Station (river mile 390), the average concentration declined to about 4 mg/l, but the maximum reading remained extremely high, 34 mg/l. At the Midway Station (river mile 230) the average concentration rose to about 5 mg/l. The maximum concentration here was still very high at 27.2 mg/l. According to McCullough (1972a, 1973b), orthophosphate and BOD are closely related parameters with a significant correlation factor. This close correlation suggests that phosphate is being introduced into the river with domestic sewage as well as from agricultural and industrial sources. The average concentration dropped to about 0.3 mg/l at the Romayor Station downstream from Lake Livingston. This drop from the Midway Station indicates a significant trapping of phosphorus by the lake. The mean concentration at Romayor is still considerably in excess of concentrations necessary to sustain eutrophication.

1.15.07 pH. Plate 16.7, indicates the range of average pH values in the Trinity River varied between 7.3 and 7.9. However, the wide variation in extremes from a low of 6.2 to a high of 9.3 is indicative of the pH fluctuation associated with pollution from a wide variety of sources.

1.15.08 Specific Conductance. Examination of Plate 16.8, indicates that the specific conductance ranged between 38 and 2290 micromhos. The average of samples taken varied between 420 and 370 micromhos. The highest values of averages, standard deviations, and extremes, all occurred at the Grand Prairie Station, with a gradual reduction downstream from Dallas to about river mile 400, where the slope of the curve leveled off to an average of about 600 micromhos. Downstream from Lake Livingston, the average values ranged from 400 to 450 micromhos. The sharp rise at Grand Prairie may have been because of industrial plant discharges which were either highly acidic or had a high metallic salts content.

1.15.09 Chlorides. The Texas Water Quality Board (1973) has established standards for chloride concentrations in the Trinity River system which vary between 40 mg/l and 175 mg/l, depending on the particular reach. Plate 15.9 illustrates standards and measured concentrations for the mainstem of the river from Trinity Bay to about river mile 600. Excessive chlorides render water unfit for irrigation purposes, accelerate corrosion of most metals and make drinking water unpalatable. The higher chloride concentrations in the Dallas-Fort Worth Area are primarily because of industrial sources, although there are a few natural sources of chlorides. Other natural sources include runoff from the Palestine and Butler salt domes. Oilfield brines have been responsible for contributing chlorides to Richland and Tehuacana Creeks, with less important sources from some other tributaries. During a field reconnaissance of 36 oil fields in the Trinity River flood plain and tributary areas, Jones, H. L. (1973) noted that the practice in more than half of the fields was to allow brine and oil to overflow from disposal ponds, to seep into the ground water, or to be discharged directly into tributaries or the Trinity River. Jones, H. L. (1973) cited a study of the effects of oil field brine on water quality in the lower watershed of Chambers and Richland Creeks, Freestone County, by Osborne (1960). They reported a total brine yield of 95,300 barrels per day was disposed of on the surface. Their conclusion was that about 61,500 barrels drained directly into the tributaries of Chambers and Richland Creeks. Leifeste and Hughes (1967) reported that chloride concentrations in Richland Creek often exceeded 1000 mg/l. Sulfur mining in the lower Basin has been reported as a source of additional chlorides in concentrated brine form (McCullough, 1972b).

1.15.10 Sulfates. The Texas Water Quality Board (1973) has established standards for sulphate concentrations in the Trinity River system which vary between 40 mg/l and 175 mg/l, depending on the particular reach. Plate 15.10 shows the standards and measured concentrations from Trinity Bay to about river mile 600. Sulphates in drinking water can cause a laxative effect on new users in concentrations of 200 mg/l or more, and concentrations in the range of 200-900 mg/l of various sulphates can cause taste problems. About 10 percent of the samples at the Grand Prairie Station exceeded 150 mg/l indicating that some point source sulphate pollution was occurring from industrial sources in the Dallas-Fort Worth Area (Forest and Cotton, 1970).

1.15.11 Total Organic Carbon. Total organic carbon concentrations and ranges measured in the Trinity River by McCullough and Champ (1973) are shown on Plate 15.11. The highest concentrations of total organic carbon from the Trinity River waters were found at about river mile 492, south of Dallas. In systems without heavy municipal and industrial sewage pollution, the total organic carbon levels can be expected to increase in concentrations as one moves downstream (Champ, personal communication). Table 1-10 presents the estimates of daily average total organic carbon quantities being carried by the Trinity River at nine locations. The highest average daily loads were at about river mile 454 downstream from the confluence of the Trinity River and the East Fork of the Trinity River. The results of the carbon analysis showed that about half of the river mileage downstream from Fort Worth (about 250 miles) was affected by municipal and industrial wastes from Dallas-Fort Worth Metroplex. The Trinity River carried an estimated 35,000 metric tons of total organic carbon per year into Trinity Bay (McCullough and Champ, 1973), where together with the many tons of local marsh detritus, it was believed to play an important and beneficial role in the productivity of the Trinity Bay System (Parker et al, 1972). Table 1-11 presents the results of carbon analysis of sediment samples from the Trinity River (McCullough and Champ, 1973). It was found that the highest concentration of carbon, in mg/gram of dry sediment, occurred at about river mile 492, on the south side of Dallas.

1.15.12 Phytoplankton and Periphyton. McCullough and Champ (1973) found that phytoplankton density increased progressively downstream from about river mile 530, reaching a peak average biomass at about river mile 390. The population declined downstream from river mile 390 to river mile 115 and then began to increase again downstream from river mile 115 to the mouth.

The relatively low phytoplankton populations in the river from river mile 530 downstream to river mile 485 (just south of Dallas), as shown on Plate 15.12, are most probably caused by excessive organic pollution from the Dallas-Fort Worth Area (McCullough, 1972b, McCullough and Champ, 1973). Toxic industrial effluents released upstream may also have an impact on the phytoplankton density in the area at about river mile 530. Murphy et al (1971) have identified toxic effluents and their sources in the Fort Worth Area. Effluents from a metal etching plant upstream from river mile 530 were found to be consistently very acid and bioassay studies showed the effluent to be quite toxic. Murphy et al (1971) state, "Direct discharge of the effluent into the Trinity River would have a serious effect on all living organisms." Results of the investigation of McCullough and Champ (1973) occasionally showed an absence of coliform organisms despite the proximity to sewage treatment plant outfalls in the area. This was interpreted as additional evidence of the presence of toxic materials in the river water.

The phytoplankton community structure from river mile 530 downstream to river mile 265 (near Crockett) was that generally associated

TABLE 1-10

INDEX OF AVERAGE METRIC TONS/DAY/RIVER MILE OF TOTAL (TOC) DISSOLVED (DOC) AND PARTICULATE (POC) ORGANIC CARBON TO EACH STATION OF THE TRINITY RIVER, TEXAS

RM Above Station	Avg. TOC MT/Day	Index MT/Day/RM	Avg. DOC MT/Day	Index MT/Day/RM	Avg. POC MT/Day	Index MT/Day/RM
60	11.89	0.20	6.75	0.11	5.14	0.09
90	43.07	0.48	20.89	0.23	22.18	0.25
125	97.27	0.78	44.14	0.35	53.13	0.42
180	70.51	0.39	28.70	0.16	41.81	0.23
210	69.03	0.33	41.51	0.20	27.51	0.13
270	80.15	0.30	31.00	0.12	49.19	0.18
315	90.94	0.29	38.52	0.12	52.42	0.17
465	66.96	0.14	41.40	0.09	25.56	0.06
500	96.31	0.19	62.92	0.13	33.54	0.07
Means	69.57	0.34	35.09	0.17	34.50	0.18

Data Source: McCullough and Champ, 1973.

TABLE 1-11

TOTAL ORGANIC CARBON FOR BOTTOM SAMPLES FROM THE TRINITY RIVER
(MG CARBON/GRAM DRY WEIGHT SOIL)

River Mile 10	
10-17-72	61.8
12-15-72	55.2
1-11-73	31.9
2-23-73	29.0
AVERAGE	44.5

River Mile 308	
10-23-72	21.8
1-11-73	33.6
2- 7-73	45.7
3- 6-73	30.4
AVERAGE	32.9

River Mile 454	
10- 9-72	130.0
11-28-72	117.9
1-10-73	87.4
2-10-73	40.2
3- 3-73	41.6
AVERAGE	83.4

River Mile 71	
10-17-72	57.7
11-21-72	87.1
12-15-72	16.4
1-11-73	20.1
2-23-73	14.4
AVERAGE	39.1

River Mile 370	
10- 4-72	42.7
1- 4-73	55.5
2- 7-73	76.2
3- 6-73	5.4
AVERAGE	45.0

River Mile 492	
10- 9-72	150.0
11-28-72	150.0
1-10-73	61.5
2-10-73	136.1
3- 3-73	98.1
AVERAGE	119.1

River Mile 117	
10-17-72	41.6
11-22-72	28.7
2-10-73	5.5
AVERAGE	25.3

River Mile 395	
10- 4-72	27.7
11- 9-72	37.4
11-30-72	19.3
1- 4-73	44.8
2-10-73	19.3
3- 3-73	42.4
AVERAGE	31.8

River Mile 522	
10- 9-72	29.4
11-28-72	11.4
1-10-73	58.1
2-10-73	87.9
3- 3-73	67.1
AVERAGE	50.8

River Mile 266	
10-18-72	52.1
11-22-72	23.1
12- 2-72	65.4
1-11-73	13.6
2- 7-73	4.9
3- 6-73	36.1
AVERAGE	32.5

Data Source: McCullough and Champ, 1973.

with waters polluted with sewage. Dominant genera of the Division Chlorophyta included Chlorella, Scenedesmus, Chlamydomonas, and Micractinium. The genera Euglena and Phacus were also common in the 300 river miles downstream from Fort Worth, along with the diatom species (Division Chrysophyta) Nitzschia palea, Navicula cryptocephala, Gomphonema angustatum, and Gomphonema parvulum. Many of these species were listed by Palmer (1969) as being tolerant to organic enrichment and sewage and are commonly found in sewage oxidation ponds. Chlorella, which was dominant at many of the stations sampled above Lake Livingston, have been shown to readily take up ammonia. Plate 15.3 shows that ammonia levels have been generally very high in the Trinity River in the Dallas area.

McCullough and Champ (1973) interpreted the appearance of centric diatoms at the sampling stations downstream from Lake Livingston as reflecting a degree of recovery of water quality. While the Division Chlorophyta dominated the phytoplankton community from Lake Livingston upstream, the most common diatoms were pinnate diatoms (Nitzschia palea, Gomphonema parvulum). Downstream from Lake Livingston, the diatoms dominated the phytoplankton community with the centric diatoms more common than the pinnate forms. The most common centric diatoms in this lower reach of the Trinity River were Melosira distans, Melosira granulata, and Cyclotella glomerata.

McCullough and Champ (1973) prepared checklists and determined relative abundances of the periphyton diatoms in the Trinity River. Generally, the dominant species of diatoms collected in periphyton samples upstream from Lake Livingston were Gomphonema parvulum and Nitzschia palea, which have been cited by several authors, including Weber and Raschke (1970), Butcher (1947), Fjerdinstad (1964), and Hynes (1972) as being characteristic of waters with high organic pollution.

Downstream from Lake Livingston, the dominant periphyton species were generally Cyclotella meneghiniana, Melosira granulata, and Navicula rhynchocephala. Palmer (1969) has reported Melosira and Cyclotella species as being indicators of low organic enrichment. The fact that the lower portion of the Trinity River has high chloride concentrations is born out by the presence of Navicula rhynchocephala which, according to Patrick and Reimer (1966), appears to prefer or is tolerant of high concentrations of chlorides. Another periphyton diatom species found in the lower portion of the Trinity River, Diploneis smithii, is also indicative of high chloride concentrations in fresh water, according to Williams (1964).

A periphyton species diversity analysis was carried out by McCullough and Champ (1973), the results of which are shown in Table 1-12. Their interpretation of diversity index values was based on the work of Wilhm and Dorris (1968), who suggested that values of less than 1.0 indicate heavy pollution, values of 1.0 to 3.0 indicate moderate pollution, and values greater than 3.0 indicate relatively unpolluted water. The direct applicability of the diversity index of Wilhm and Dorris in this particular instance is open to question, but would at least be indicative of degrees of pollution.

TABLE 1-12

DIVERSITY INDEX VALUES FOR PERIPHYTON SAMPLES, 1972-1973

River Miles Above Mouth	Oct 72	Jan 73	Mar 73
522	0.85	1.5	-
492	0.5	0.8	-
454	0.9	1.3	1.7
395	1.9	2.2	-
370	2.3	2.5	-
308	2.1	2.0	-
266	2.8	2.4	-
117	2.6	2.3	2.1
71	1.9	2.2	2.6
10	3.2	2.9	2.8
8	2.7	-	-

Data Source: McCullough and Champ (1973), based on index of Wilhm and Dorris (1968).

Diversity index values ranged from a low of 0.5 at about river mile 492 (just downstream from Dallas) to a high of 3.2 at about river mile 10. Index values in the Dallas-Fort Worth area were indicative of heavy pollution, with values consistently below 1.0. The diversity index for the periphyton gradually increased downstream. The reach between Dallas and Lake Livingston showed an increase from about 0.8 to 2.0, the range characteristic of moderately polluted water. Below Lake Livingston, diversity values were variable, ranging from 1.9 (moderate pollution) to 3.2 (relatively unpolluted water).

1.15.13 Benthic Analysis. Benthic organisms, being basically immobile and often having complex food webs, are considerably more sensitive to changes in the aquatic environment than are chemical tests. Chemical tests often give an average value, or an instantaneous value. However, benthic analysis is indicative of the aquatic condition over a long period of time. For example, periodic releases of toxic materials may go undetected in period chemical sampling but may have an impact on the benthic community long after the released materials have been carried downstream.

McCullough and Champ (1973) analyzed benthic samples taken from the Trinity River between Fort Worth and Trinity Bay. A list of organisms collected, with numbers and percentage composition, may be found in that report. Interpretation of the diversity index followed that of Goodnight (1973) by which index values of less than 1.0 were indicative of heavy pollution, values from 1.0 to 3.0 were indicative of moderate pollution, and values above 3.0 were representative of relatively unpolluted water. The averages and extremes of the values found during the 1972-1973 investigation are shown on Plate 15.13.

McCullough noted that the diversity index values for that section of the Trinity River between river mile 530 and 390 indicated heavy pollution, and the remainder of the sampling downstream resulted in index values which typified moderately polluted waters. Proceeding downstream the general trend is an increase in diversity. The rather high index value seen on Plate 15.13 at about river mile 485 was explained by McCullough and Champ (1973) as consisting of a number of different gastropods, some of which appeared to be land snails which had been washed into the river by high runoff. He considered the area between river mile 350 and 400 to be "zones of recovery," as can be noted by fluctuations in diversity -- most probably caused by pollutants carried downstream, fl w rate, flood conditions and other physical and chemical factors. The low value observed at the last downstream sampling area could have been caused by any or all factors such as salt water intrusion, toxic industrial effluents, high water flow in the river, or others.

McCullough and Champ (1973) noted the benthic community structure, with particular attention to the presence or absence of well-known species recognized to be indicators of certain levels of water quality. In the Dallas-Fort Worth Area and downstream to about river mile 450, bottom samples consisted of a layer of decaying detritus (in some cases evidence of raw sewage covering a thick, black, sludge-like material). In this reach, primarily pollution-tolerant organisms were the only species present (Tubificidae, Chironomidae, and pulmonate gastropods). Diversity index values there were consistently low. A comparison of the relative percentage of oligochaetes to total biota (Goodnight, 1973) revealed above 80 percent tubificid oligochaetes in this reach of the river which is an indication of a high degree of organic or industrial pollution.

In the reach between river mile 350 and 400, the samples contained bottom materials made up of clay and rocks or small pebbles. In addition to organisms found in the upstream samples listed above, leeches and caddis fly larvae were found. While leeches are considered to be pollution-tolerant organisms, caddis fly larvae, which are gill-breathers, are indicative of water with a rather high quality.

A still higher degree of water quality recovery was illustrated by the diversity index values from about river mile 310 downstream to the headwaters of Lake Livingston. The bottom material was principally clay and/or fine sand. Clean water indicator organisms such as gill-breathing molluscs, gill-breathing insects (mayflies and dragonflies) and decapod crustacea were prevalent in this reach. Tubificid worms (sludge worms) and chironomid larva (midges), indicators of pollution, were found in some of their lowest numbers. Members of Unionidae (fresh water clams) were found in this reach. Their presence is a sign of relatively clean water (Goodnight, 1973).

All the sampling carried on by McCullough and Champ (1973) downstream from Lake Livingston reflected "moderate pollution" conditions with diversity index values between 1.0 and 3.0. The research, however, indicated that the index values were lower than should be expected with the relatively high quality of water found there. This was attributed to the unstable substrate and rather high flows which caused considerable shifting of sands. Higher values occurred during early winter after long period of moderate flows. The lowest values were found during or just after major water releases from Lake Livingston. High releases have been shown by other investigators (Blanz et al, 1969, and Neel, 1963) to adversely affect benthic community development where the substrate is relatively unstable.

Sampling in the Trinity River at about river mile 70 also revealed adverse effects on the benthic community caused by shifting bottom sands. Most of the organisms in this reach were "clean-water" organisms. One exception occurred in October when there was a surprising combination of the largest number of individuals of the genus Hexagenia, an indicator of good water, together with the largest number of tubificids, indicators of polluted water.

Sampling in the Trinity River at about river mile 10 revealed the lowest average benthic community diversity of the stations below Lake Livingston. Both effluents from a nearby industrial operation and a salt water wedge from Trinity Bay are likely to have had adverse effects on these benthic communities.

1.15.14 Zooplankton. Zooplankton sampling and analysis was conducted in the Trinity River between Fort Worth and Trinity Bay by McCullough (1972b) and McCullough and Champ (1973). Although some controversy exists over whether or not rivers support true plankton communities, there is still considerable valuable information to be gained from zooplankton sampling and analysis in rivers. Hynes (1971) states that, while crustacea normally dominate the zooplankton in lakes, river zooplankton are dominated by planktonic rotifers, and the crustacea are not numerous and are relatively unimportant. The relative abundance of the rotifiers and crustacea found in the Trinity River during 1972-1973 is illustrated in Figure 1-2. It shows that in the Trinity River, crustacean populations rose to importance only at about river mile 265, upstream from Lake Livingston, and at about river mile 115, downstream from Lake Livingston. McCullough and Champ (1973) consider the direct flow of water from the lake environment to be the reason for the abundance of crustacea there. Dominant rotifiers found were several members of the family Branchionidae and Keratella spp. and occasional individuals of the general Kellicottia and Notholca. Also found were the rotifers Filinia, Lecane, Monostyla, Philodina, and Rotaria.

The planktonic crustacea were primarily Copepoda and Cladocera. The Cladocera were dominated by the genus Bosmina. Other commonly found genera included: Moina, Simocephalis, Pleuroxis, Chydorus, and Alona. The cyclopoid copepods included Tropocyclops prasinus Fischer 1860, Cyclops spp., Mesocyclops edax Forbes 1891. Calanoid copepods and two species of harpactacoid copepods were also found.

Average diversity index values for zooplankton (Plate 15.14) appear to be rather erratic. However, unusually high rotifer counts in September and October probably accounted for the low index value at about river mile 310. Without that low value, an upward trend in diversity index values would be seen downstream to Lake Livingston. The effects of releases from Lake Livingston, coupled with the stress involved in changing from a still water to a flowing water environment, probably accounted for the lower diversity values at about river mile 115, downstream from Lake Livingston. Diversity rose at about river mile 70 but fell off again at about river mile 10, even though the total number of zooplankton was rather high there. Once again, the special conditions in this downstream area (salt water wedge, industrial effluents, etc.) were judged to be responsible for these results (McCullough and Champ, 1973).

Sampling and analysis in the 75 miles of river downstream from Fort Worth showed that a large percentage of the zooplankton

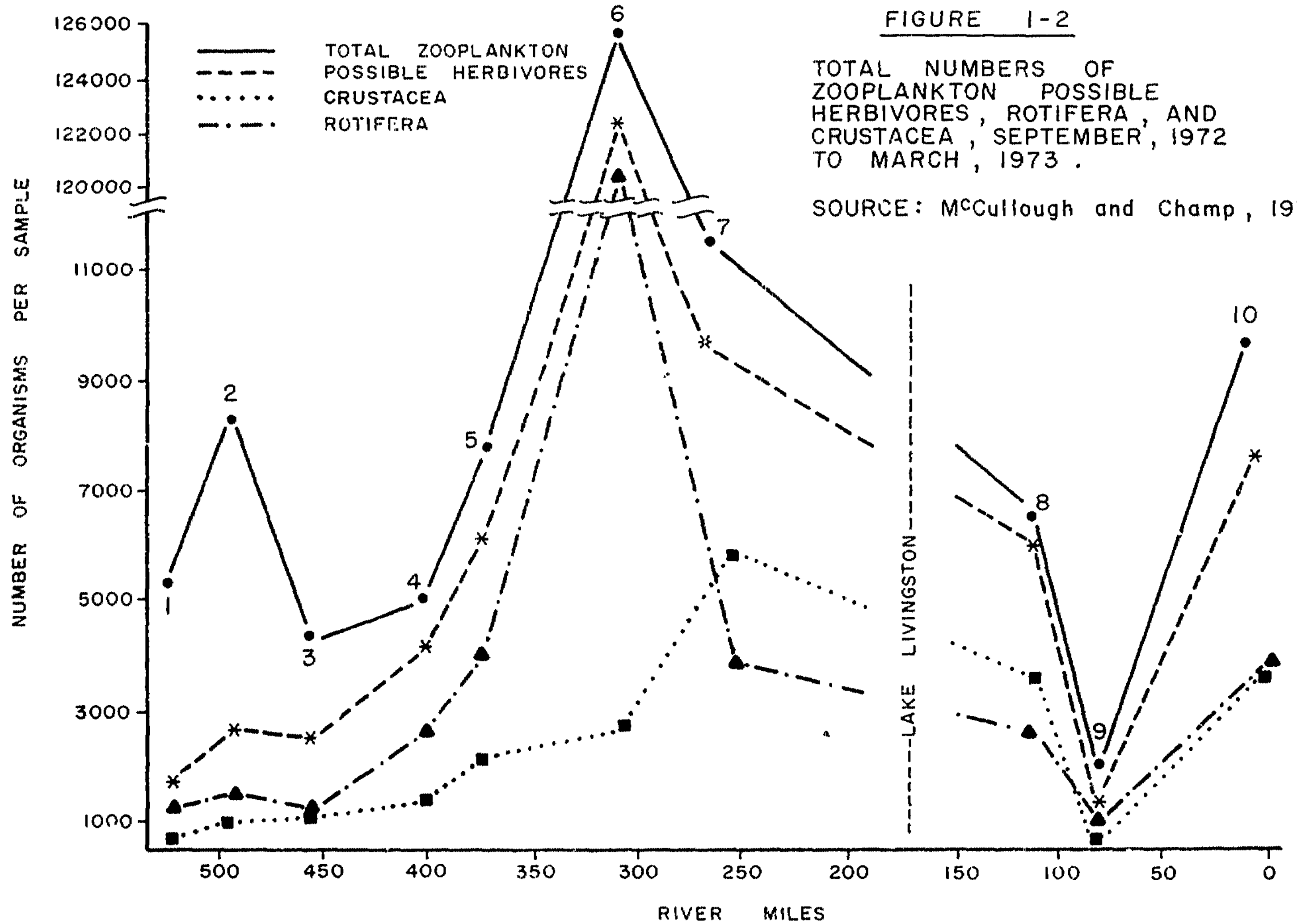


FIGURE 1-2

TOTAL NUMBERS OF ZOOPLANKTON POSSIBLE HERBIVORES, ROTIFERA, AND CRUSTACEA, SEPTEMBER, 1972 TO MARCH, 1973.

SOURCE: McCullough and Champ, 1973

population consisted of non-herbivorous species of protozoa which included many ciliates. Hynes (1971) associated these bacteria-eating populations with severe organic pollution, and the inclusion of these resulted in a paradoxical rise in species diversity values, even though heavy pollution existed. The area between river mile 375 and 395 (considered by McCullough and Champ (1973) to be areas of "recovery") showed that total zooplankton populations and herbivore populations rose simultaneously (Figure 1-2). The rise in herbivores primarily consisted of increased numbers of rotifiers. Between river mile 375 and the headwaters of Lake Livingston, zooplankton populations rose rapidly, reaching their highest level at about river mile 365.

1.15.15 Coliform and Streptococci Bacterial Analyses. Another useful biological indcator is the measurement of coliform bacteria. Extensive investigations have been conducted to establish the significance of the coliform group densities as a measure of the degree of pollution. Generally speaking, these densities indicate the degree of contamination of the water with wastes from human or animal sources. The Texas Water Quality Board (1973) has established acceptable limits for fecal coliform for various reaches of the Trinity River. That agency sets the goal that all surface waters used for domestic water supply conform to the U.S. Public Health Service Drinking Water Standards, latest revision. It is recognized that not all surface waters being used can meet these standards, but if particular waters are the only source of supply, the standards may be relaxed. In water for domestic raw water supplies: (1) it is desirable that the total coliform content should not exceed 100/100 ml and the fecal coliform content not exceed 20/100 ml, and (2) surface waters are deemed unsatisfactory where the monthly arithmetic average total coliform content exceeds 10,000/100 ml and the fecal coliform exceeds 2,000/100 ml.

In bacteriological studies conducted in the Trinity River during 1972 and 1973 (McCullough and Champ, 1973) both the multiple tube fermentation tests and the membrane filter analysis were employed. These methods are both accepted as standard methods. The results of total coliform, fecal coliform, and fecal streptococcus counts are given in Plates 15.15 through 15.19. Ratios of fecal streptococci to fecal coliform which are 4.0 and above indicate possible human contamination (Geldreich and Kenner, 1969). All sampling upstream from Lake Livingston resulted in average ratios above 4.0 while all sampling downstream had average ratios below 4.0, for the period of the investigation.

Most strains of coliforms are symbiotically related to the intestinal tract of warm-blooded animals, although the majority of organisms identified in the study were varieties of Escherichia coli. The fecal coliform tests were conducted so as to verify the authenticity of data (fecal coliform counts should always be less than total coliform counts), although the tests are also a useful way to determine whether or not the organisms involved are of fecal origin.

In the sampling upstream from Lake Livingston, mainly Escherichia coli were found. Smaller numbers of Enterobacter aerogenes and Citrobacter freundii were found. Fecal coliform studies downstream from Lake Livingston revealed only Escherichia coli.

The fecal streptococci classification included Streptococcus faecalis, S. bovis and S. equinis. S. faecalis was the principal organism found at all sampling stations. The other two streptococci were found occasionally in sampling upstream from Lake Livingston. S. bovis was found in the Trinity River at about river mile 70. This particular organism does not multiply in water and has a rapid die-off in water (Geldreich and Kenner, 1969). Fecal streptococci are native to the intestinal tracts of warm-blooded animals. Eighty percent or more of human fecal streptoccus bacteria is included in the S. faecalis group (Millipore Corporation, 1972). Cows and horses are probable sources for S. bovis and S. equinis.

It is important to note that actual numbers and organisms may have been higher than that determined by McCullough and Champ (1973), since several factors are known to interfere with bacterial growth during culture techniques; i.e., turbidity, growth of other bacteria in the culture, and possible acid and gas production in the multiple-tube fermentation test.

1.15.16 Sediment Oxygen Demand and the "Black Rise." The phenomenon known locally as the "black rise," which was discussed briefly at the introduction of the section on water quality, was investigated by McCullough and Champ (1973) during the passage of a river rise between October 23 and 31, 1972. Samples were collected at the Cayuga (U.S. Highway 287), Fairfield (U.S. Highway 79), and Crockett (State Highway 7) stations during this period. The flow of the river varied from 300 cfs prior to the investigation to a peak of 7000 cfs during the river rise. The rise was gradual, extending over about six days. An abrupt rise would tend to cause more adverse conditions of sediment mixing than a gradual rise. There had been a period of about four months of low flows prior to the rise that was investigated. A long period between flushing times would tend to build up the organic sediments in the river so that the conditions caused by the "black rise" would be more severe. As a result of the study of this river rise, some general observations can be made. Most of the stations showed a drop in dissolved oxygen as the river began to rise, followed later by an increase in dissolved oxygen. The turbidity, color, and conductivity in most case increased during the rise. At the U.S. Highway 287 station, the initial wave continued relatively high chloride and sulfate levels, perhaps resulting from the flushing of tributaries which drain petroleum production areas. Ammonia concentration doubled in the initial flood wave, but dropped to very low levels three days later as the rise continued. Both BOD and total organic carbon showed correspondingly high concentrations during the initial rise. Although these data reflect only one river rise, and a short segment of the river, they can be used to draw some conclusions when combined with other data.

During the sampling of the bottom sediments from the Dallas-Fort Worth Area and the sediments below the confluence of the Trinity and the East Fork of the Trinity River, a high amount of total organic carbon was found. A thick layer of black sludge was very evident at stations in these areas during most collecting periods, but appeared to be greatly reduced during periods of high flow. The origin of the sludge is primarily sewage effluent, evidenced by the fact that the organic content of the bottom sediments progressively declined at the stations farther downstream. The total carbon data and the sediment oxygen demand data strongly suggested that the sediments taken from stations in the Metropolitan Area would account for the depressed oxygen values observed during the river rise sampling period. These bottom sediments did not appear to be densely packed, but rather were loosely packed and easily disturbed by strong currents. As the sediments became resuspended and mixed with river water, a large increase in oxygen demand would occur (McCullough and Champ, 1973). These "black rises" have caused fish kills far down the river from the Metropolitan Area, and have an adverse influence on water quality as far downstream as Lake Livingston.

1.15.17 Herbicides and Pesticides. An assessment of the insecticides and herbicides that are used within the counties in the watershed is probably a good indication of the relative amounts of these pesticides polluting various regions of the river. McCullough and Champ (1973) cite the study of Bailey and Hannum (1965) who presented data showing a high correlation between insecticide application and insecticide concentrations in river waters and sediments.

With the exception of Chambers County near Trinity Bay, the largest users of insecticides and herbicides appear to be the counties bordering the river for about 200 miles downstream from Dallas (Tables 1-14, 1-15, and 1-16). Information regarding usage of pesticides in the Dallas-Fort Worth Metropolitan Area is not available. The quantities listed should be considered conservative inasmuch as individual users volunteered the information to county agents. Ellis, Kaufman, and Navarro Counties, just downstream from the Dallas area, plant large acreages of cotton,

TABLE 1-13

CUMULATIVE ACREAGE TREATED WITH INSECTICIDES IN 1970-71

Sampling Station	River Mile	Adjacent Counties	Cumulative Acreage* Treated
Rosser	454	Ellis	414,000
		Kaufman	119,000
Highway 85	430	Henderson	14,900
		Navarro	49,100
Cayuga	370	Anderson	43,427
		Freestone	9,000
Fairfield	308	Anderson Freestone	(both counties included above)
Highway 7	266	Leon	10,000
		Houston	48,000
Highway 21	231	Leon Houston	(both counties included above)

*The term "cumulative" refers to total acres treated per year, although the same acreages may have been treated more than once, or with more than one insecticide.

Data Source: Texas A. & M. Extension Service, Texas A. & M., College Station, Texas.

TABLE 1-14

ESTIMATED INSECTICIDE USAGE IN SELECTED COUNTIES, DALLAS TO TRINITY BAY, TEXAS, 1968-1971

	Pounds of Insecticide Used per Year			
	1968	1969	1970	1971
Anderson County				
Carbaryl	4,730	6,581	23,111	-
DDT	2,250	2,700	1,840	-
Diazinon	580	160	1,280	-
Guthion	37	-	1,260	-
Malathion	1,110	730	4,313	-
Methyl parathion	328	393	643	-
Parathion	464	780	3,990	-
Toxaphene	1,875	2,533	1,533	-
Chambers County				
Carbofuran	-	-	-	15,500
Dallas County - no entries				
Ellis County				
Carbaryl	-	-	-	1,200
DDT	-	-	-	600,000
Malathion	-	-	-	450
Parathion	-	-	-	1,425
Toxaphene	-	-	-	400,000
Freestone County				
Carbaryl	8,430	13,256	14,231	-
DDT	-	900	2,700	-
Guthion	2,100	3,412	2,940	-
Malathion	1,305	2,048	1,974	-
Methyl parathion	-	131	418	-
Parathion	1,708	2,633	2,583	-
Toxaphene	11	750	2,383	-

(continued)

	Pounds of Insecticide Used per Year			
	1968	1969	1970	1971
Henderson County				
Carbaryl	6,271	49,352	10,202	-
DDT	150	450	450	-
Diazinon	750	500	700	-
Guthion	105	105	105	-
Malathion	1,494	4,776	1,751	-
Methyl parathion	59	65	65	-
Parathion	756	6,119	1,168	-
Toxaphene	125	2,875	625	-
Houston County				
Carbaryl	-	-	-	32,850
DDT	-	-	-	45,000
Malathion	-	-	-	7,327
Parathion	-	-	-	16,548
Toxaphene	-	-	-	30,000
Kaufman County				
Carbaryl	-	-	-	29,700
DDT	-	-	-	150,000
Malathion	-	-	-	5,200
Parathion	-	-	-	8,550
Toxaphene	-	-	-	100,000
Leon County				
Carbaryl	-	-	-	1,500
DDT	-	-	-	12,000
Diazinon	-	-	-	200
Malathion	-	-	-	375
Parathion	-	-	-	150
Toxaphene	-	-	-	8,000
Liberty County				
Carbofuran	-	-	-	25,000
DDT	-	-	-	6,000
Toxaphene	-	-	-	94,000

(continued)

	Pounds of Insecticide Used per Year			
	1968	1969	1970	1971
Navarro County				
Carbaryl	10,525	13,975	28,009	-
DDT	60,000	60,000	22,650	-
Diazinon	50	50	100	-
Guthion	840	1,050	-	-
Malathion	1,088	706	2,838	-
Methyl parathion	8,750	8,750	3,303	-
Parathion	2,696	2,048	4,800	-
Toxaphene	50,030	50,083	20,041	-
Polk County				
Carbaryl	-	-	-	37
Malathion	-	-	-	100
Methyl parathion	-	-	-	6
Parathion	-	-	-	450
San Jacinto County - no entries				
Trinity County				
Malathion	-	-	-	57
Parathion	-	-	-	258
Walker County				
Malathion	-	-	-	50
Parathion	-	-	-	225

Data Source: Individual County Agents.

(-) indicates information not available.

TABLE 1-15

HERBICIDE USAGE IN SELECTED COUNTIES, DALLAS TO TRINITY BAY, TEXAS, 1970-1971

	Total Gallons Used per Year		
	2,4-D		2,4,5-T
Counties	1970	1971	1971
Anderson	1,622	-	-
Chambers	-	-	-
Dallas	-	288	0
Ellis	-	-	-
Freestone	782	-	-
Henderson	5,100	-	-
Houston	-	6,99[illegible]	205
Kaufman	-	3,104	0
Leon	-	6,097	227
Liberty	-	-	-
Navarro	6,529	-	-
Polk	-	1,001	133
San Jacinto	-	0	0
Trinity	-	115	11
Walker	-	7,831	1,550

- No entries provided.

Data Source: Texas Department of Agriculture

TABLE 1-16

MAXIMUM PESTICIDE-HERBICIDE CONCENTRATIONS*

	1967-1968	1969-1970	1970-1971	1971-1972
Heptachlor	0.00	0.00	0.00	0.00
Heptachlor epoxide	0.00	0.00	0.00	0.00
Lindane	0.01	0.05	0.04	0.03
2,4-D	0.17	1.6	0.23	0.29
2,4,5-T	0.05	0.10	0.06	0.06
Silvex	0.00	0.01	0.00	0.00
Aldrin	-	0.00	0.00	0.00
DDT	-	0.14	0.10	0.02
DDE	-	0.00	0.00	0.03
DDD	-	0.04	0.02	0.00
Dieldrin	-	0.25	0.05	.04
Endrin	-	0.00	0.00	0.00
Chlordane	-	0.41	0.3	0.3
Diazinon	-	0.00	0.44	0.37
Methyl Parathion	-	0.00	0.46	0.00
Parathion	-	0.00	0.00	0.00
Malathion	-	-	1.0	0.05
Toxaphene	-	-	0.0	-

*micrograms per liter detected in the Trinity River at the USGS Rosser water quality sampling station while Chambers County, near the Gulf Coast, is a major rice-producing county. In the northern region of the biological study area, the major contaminants are the insecticides DDT, Toxaphene, and Carbaryl, while in the southern regions of the river, Carbofuran and Toxaphene are probably the most significant. Carbofuran (Furadan) is now being recommended by the Texas A&M University Agricultural Extension Service as the proper insecticide to control the rice water weevil, which is usually the most important insect pest on rice; however, some extension agents have recommended Heptachlor for treatment (Heptachlor is more persistent in the environment).

According to U.S. Geological Survey data, the concentrations of pesticides and herbicides in the Trinity River waters are suitably low. However, the concentrations in the river sediments were found in later tests to be considerably higher.

McCullough and Champ (1973) cited the report of Bailey and Hannum (1965) that pesticide concentrations in river waters decreased at a rate of about 0.0016 micrograms per liter (μg/l) per mile downstream from the points of application. The removal may in part be due to organism uptake, degradation of the molecule, or accumulation in the sediments. The study also reported pesticide concentrations in the river sediments exceeded those in water 20 to 100 times, with the concentrations being proportionately higher in fine sediments. McCullough and Champ (1973) also cited Wharton (1970) who reported that many pesticides such as DDT have a high affinity for silt and would be trapped by sediments as silt is deposited.

Because many of the pesticide compounds degrade very slowly in nature and because these compounds tend to become concentrated at progressively higher levels in the aquatic food chain, there is a general concern from a public health standpoint.

McCullough and Champ (1973) collected and analyzed Trinity River sediments during 1972-1973. A total of 49 samples were collected. Table 1-17 gives the averages for pesticide concentrations in micrograms per kilogram (μg/kg) of sediments. Samples having a pesticide content of less than 0.2 μg/kg of sediment were averaged in as zero, except for Chlordane which has a lower detectable limit of 1.0 μg/kg.

Chlordane varied between 402.47 μg/kg at the Rosser Station on October 12, 1972, to an undetectable quantity at the Cayuga Station on January 12, 1973. DDE showed a smaller range, varying between 10.99 μg/kg sediment at the Rosser Station on January 12, 1973, to an undetectable amount on several occasions. Analysis of variance (ANOVA) indicates that both DDE and Heptachlor

TABLE 1-17

PESTICIDE CONCENTRATIONS IN BOTTOM SEDIMENTS
1972 AVERAGE CONCENTRATIONS AT GAGING STATIONS
(μg/kg)

Pesticide	*	Rosser RM 454	Hwy 85 RM 430	Cayuga RM 370	Fair-field RM 308	Hwy 7 RM 266	Hwy 21 RM 231
LINDANE	25	1.60	.44	.64	.40	.28	.05
ALDRIN	12	.62	0.00	1.31	.02	0.00	.02
CHLORDANE	92	127.02	49.69	22.41	12.09	9.75	25.16
HEPTACHLOR	41	5.07	.80	.56	.11	.05	.12
o p' DDE	78	3.85	2.36	1.10	.50	.65	.91
o p' DDT	16	0.00	0.00	.88	.12	.67	.52
MIREX	4	0.00	0.00	.17	0.00	.18	0.00
ENDRIN	10	1.89	0.00	.45	0.00	0.00	0.69
DIELDRIN	8	.40	.42	.61	0.00	0.00	0.00
METHOXYCHLOR	-	0.00	0.00	0.00	0.00	0.00	0.00

*Percent of Samples Containing Measurable Quantities

Data Source: McCullough and Champ (1973)

are statistically related to chlordane concentration (significant at probability = 0.01). Heptachlor was detected more often in samples from the upper three sampling stations than from the lower three. It occurred in 75.3 percent of the samples collected at the lower three. Concentrations of Lindane were relatively low at the State Highway 7 and State Highway 21 stations with a high of just over one µg/kg of sediment. Lindane concentrations were detected in 5 out of 19 samples at the Fairfield and Cayuga Stations and ranged between 0.93 and 3.92 µg/kg of sediment. Sediments from the sampling stations at State Highway 85 and Rosser contained the highest concentrations of Lindane. It occurred in 5 out of the 13 samples and ranged between 1.05 and 6.52 µg/kg.

Aldrin was found to be concentrated around the Cayuga Station. It was found in 3 of the 9 samples taken from that station and ranged in concentration between 0.62 and 9.58 µg/kg of sediments. Only traces of aldrin residues were found at sampling stations downstream from the Cayuga station.

Endrin residues were detected in one sample from the Rosser Station, one from the State Highway 85 Station, and one from the Cayuga Station. No detectable quantities were found at the Fairfield or State Highway 7 Stations.

No DDT was found at the two uppermost stations, Rosser and State Highway 85, but it was detected in two samples from the Cayuga Station. It appeared more often (5 of 14 samples) in samples from the two lowermost stations, State Highway 7 and State Highway 21. Only one sample from the Fairfield Station contained measureable DDT concentrations. Measured DDT concentrations ranged between 0.22 and 7.34 µg/kg of sediment.

No Dieldrin was detected at the three lowermost sampling stations. The three uppermost stations had four samples with detectable quantities of Dieldrin residues. Mirex was found in one sample from the Cayuga Station and one from the State Highway 7 Station. No Methoxychlor was detected in any of the samples.

Statistical treatment of the data by McCullough and Champ (1973) indicated no significant difference in the average concentrations of any two adjacent stations for Chlordane, DDE, and Heptachor, in organics, clays, silt, or sand. Multiple regression analyses indicated a high correlation between Chlordane and percent organics, and between DDE and percent organics (significant at the 0.01 probability level).

Pesticide concentrations in the bottom sediments downstream from Lake Livingston appear to be quite low. Samples taken near the Interstate 10 bridge near Wallisville, Texas, contained only two insecticides, Lindane (0.2 µg/kg of sediment) and Chlordane (less than 1.0 µg/kg of sediment). McCullough and Champ (1973) did not feel that rice production was resulting in significant pesticide contamination of bottom sediments in the lower Trinity River.

Pesticide analysis of well water samples taken by McCullough and Champ (1973) near Rosser revealed no detectable quantities of pesticides.

McCullough and Champ (1973) cite the early studies of Surber (1948), Sun (1950), and Young and Nicholson (1951), and the more recent studies of Brown and Nishioka (1967), Breidenbach et al (1967), and Barthel et al. (1969), which relate to the adverse effects due to accumulation of pesticides in the environment. The effects of pesticides on nontarget organisms and the potential for increasing concentrations in food chains have emphasized the need for monitoring the levels of pesticides in aquatic systems.

Pesticides can enter water by many routes, including drift from aerial applications to agricultural crops, accidental spills into streams, and direct application for aquatic pest controls. McCullough and Champ (1973) cited evidence from the study of Nicholson (1967) which indicates that industrial waste discharge from pesticide manufacturers and surface runoff from areas which have received pesticide applications are responsible for the largest percentage of pesticide contamination of waters.

The pesticide concentrations in river sediments are directly dependent on watershed characterisics such as land use patterns, surface erodability, rainfall patterns, and soil composition of the treated acreage (McCullough and Champ, 1973). High organic matter in soils has been reported to decrease pesticide concentrations in runoff (Bailey and White, 1964; cited in McCullough and Champ, 1973).

The fate of pesticides carried into a river depend upon the type of sediment with which they become associated. Finer textured sediments have a proportionately greater concentration of pesticides and thus more easily transport pesticides downstream (Bailey and White, 1964; cited in McCullough and Champ, 1973). As the river currents slow, its decreased load capacity permits the pesticide-containing sediments to settle out. It is not unuusual to find that the pesticide contents in silt and clay deposits of a slow-moving river exceed that of the water by several hundred-fold (Edwards, 1970; cited in McCullough and Champ, 1973).

In the Trinity River investigation conducted by McCullough and Champ (1973), the percent organics, sand, silt, and clay were determined in order to assess the relationship existing in the Trinity River between soil composition and pesticide contents. According to statistical treatment of the collected data, a significant relationship existed between

Chlordane and DDE residues and that of the organic and clay content of the sediments. These pesticides not not appear to be well correlated with silts. Sand showed negative correlation with pesticide content. The occurrence of the other pesticides were so scant that statistical treatment was difficult. The averages of percent organics, clays, and silts generally decreased downstream, as did pesticide concentrations. Pesticide concentrations increased slightly at the State Highway 7 and State Highway 21 Stations, yet percent organics, silts, and clays did not. Rainfall, river flow, season, and agricultural land use appear to be factors which also influence pesticide transport.

Table 1-18 lists the correlation coefficients for second-order regression analysis carried out by McCullough and Champ (1973). The results indicated that percent organics and percent clays are good predictors of Chlordane and DDE levels in sediments.

TABLE 1-18

CORRELATION COEFFICIENTS FOR DDE AND CHLORDANE VERSUS VARIOUS PARTICULATES

			r-value
Chlordane	vs	Percent Organics	.951**
DDE	vs	Percent organics	.994**
Chordane	vs	Percent clays	.947**
DDE	vs	Percent clays	.987**
Chlordane	vs	Percent silt	.652 N.S.
DDE	vs	Percent silt	.686 N.S.
Chlordane	vs	Percent sand	.912*
DDE	vs	Percent sand	.895*

*Indicates significance at the 95% confidence level.

**Indicates significance at the 99% confidence level.

N.S. Indicates no significance.

Data Source: McCullough and Champ (1973)

The above data suggested a strong relationship between organics and DDE and between organics and Chlordane. Clays also showed positive correlation for those pesticides, but silts did not. The study of McCullough and Champ (1973) cited Bailey and White (1964) and Kunze (1966) whose results were in agreement with their own. It appears that pesticides have increasing affinities for sediment particles of smaller and lighter texture.

The source of pesticide contamination are not accurately known. Data from the Texas A&M University Agricultural Extension Service indicated that counties adjacent to the Rosser Station used more insecticides than the counties further downstream. McCullough and Champ (1973) found that the Trinity River apparently recovers somewhat from pesticide load as the water moves downstream. Le Grand (1966) states:

> When waste containing pesticides come in contact with water or the soil, contaminates in them start to move with the entraining water, and they also start a complex course of attentuation, or weakening in strength and consistency . . . by decaying or some inherent power to decrease in potency, by sorption on soil materials and by dilution through dispersion.

The heavy domestic sewage load from the Dallas-Fort Worth Area provides a heavy organic loading which could furnish the mechanism for transport of the pesticides, and domestic and industrial discharges from the Metropolitan Area may be one of the major sources of pesticides in the Trinity River sediments.

1.15.18 Heavy Metals. Many heavy metals are known to have toxic effects of living organisms depending on their chemical forms, concentrations, combinations, and other factors. In aquatic ecosystems, adverse effects include inhibition of algae growth and killing a variety of organisms from microscopic plankton through the fishes. Heavy metal measurements in water samples taken from the Trinity River near Rosser, downstream from Dallas, (Table 1-19) indicate that some potential problems may exist in this regard.

1.16 Galveston Bay. The Galveston Bay System, of which Trinity Bay is a part (Plate 1), has about 341,000 acres of water surface and is the largest inland bay system on the Texas Coast. Galveston Bay is the most important bay, economically and ecologically, on the Texas Coast. It has been reported that its large acreage and its wide range of depth, temperature, and salinity conditions make Galveston Bay an important nursery ground for fishery products taken in the Gulf of Mexico adjacent to the Texas Coast. Inflow of fresh

TABLE 1-19

HEAVY METAL CONCENTRATIONS *

	Oct 1971	Jan 1972	March 1972	June 1972	USPHS Drinking Water Permissible Limits
Dissolved Cadmium	1	0	0	0	10
Dissolved Chromium	0	0	0	0	50
Dissolved Cobalt	0	0	0	0	-
Dissolved Copper	5	8	8	9	1000
Dissolved Iron	100	30	130	150	300
Dissolved Lead	2	0	0	0	50
Dissolved Lithium	0	20	20	20	-
Dissolved Manganese	100	100	110	170	50
Dissolved Mercury	1.1	1.9	0.5	0.4	-
Dissolved Nickel	9	9	21	16	-
Dissolved Strontium	380	640	490	400	-
Dissolved Zinc	60	50	90	90	5000

*micrograms per liter detected in the Trinity River at the USGS Rosser water quality sampling station.

water to the Galveston Bay System during the period 1941 through 1957 averaged about 10.2 million acre-feet annually, although total yearly inflows varied from as little as 1.4 million to more than 20 million acre-feet. Approximately 2.1 million acre-feet of the average annual freshwater inflow consisted of runoff from adjacent coastal basins. An average of about 1.4 million acre-feet of precipitation falls directly on the bay annually. Therefore, in the past the total volume of freshwater available to the bay on an average annual basis has been about 11.6 million acre-feet (Texas Water Plan, 1968).

1.17 Trinity Bay. Trinity Bay has a surface area of 81,920 acres, representing about 24 percent of the total surface area of the Galveston Bay System. Trinity Bay is approximately 15 miles long and 10 miles wide, with an average depth of about 8 feet. The volume, calculated by Lankford et al (1969), is about 654,000 acre-feet. In addition to the drainage area of the Trinity River (17,969, square miles), Trinity Bay has a local drainage area of approximately 150 square miles. The bay is adjacent to about 7 square miles of marsh and an additional 27 square miles of river delta marsh.

1.17.01 Tides. The mean diurnal tidal range in the vicinity of Anahuac (located near the northeast corner of the bay) is 0.9 feet. The water surface elevation is also affected to a considerable extent by winds. The elevation may be depressed as much as 2.5 feet below mean sea level or raised as high as 16 feet above sea level by hurricanes. The frequency with which any point on the Texas Coast line may be subjected to destructive wind forces of hurricane intensity is estimated to be once in about eight years. A storm tide of 14.5 feet above mean sea level at Galveston (15 feet at Anahuac) can be expected to occur about once in 100 years, and a storm tide of 5 feet can be expected about once in 8 years. Under ordinary conditions, sustained southerly winds often create tides of 3 feet above mean sea level.

1.17.02 Bay Salinity. As with any estuarine area, the salinity varies and is affected by several outside forces. During a three year period in which Trinity Bay was studied, the salinity of the bay varied from less than one part to about 20 parts per thousand (Fisher et al, 1972). By comparison, the salinity of the Gulf of Mexico off the coast of Galveston ranges between 25 and 35 parts per thousand. Parker et al (1972) indicate that almost three times the daily volume of runoff from the Trinity River is transported into and out of the Galveston Bay System by tidal currents, and even more may be transferred by winds. The major portion of these tidal flows is transported into lower Galveston Bay, and most is dissipated before it enters Trinity Bay. During periods of low flow from the Trinity River, Parker feels that flushing of the bay is considerably reduced. Evaporation during low flow periods is likely to be a significant factor in increasing the salinity, although on an average annual basis the rainfall is about equal in volume to evaporation. Water is sloshed back and forth by tidal motion but moves downstream to the estuary mouth primarily by the addition of water from upstream. Without the river flows, flushing may be accomplished in several tidal cycles. Because of the thorough vertical mixing over the entire depth range of the bay by wind and tidal forces, it was found that there was little variance in salinities between bottom and surface waters at any particular location. While winds are not thought to be effective in creating permanent circulation patterns in the bay, they do sometimes contribute to salinity changes. During periods of sustained wind, the friction of the wind on the water surface tends to build up wind tides. These inflowing and outflowing tides can significantly influence the salinity of the bay, the lower reach of the Trinity River, and the marsh areas surround the bay. High southerly winds tend to force the saline waters of lower Galveston Bay into Trinity Bay and the waters from Trinity Bay up the river. Northerly winds tend to reduce salinities in the northern portions of the bays.

1.17.03 River Flows and Salinity. The most significant force controlling the salinity of Trinity Bay is the Trinity River. It is during periods of high inflow from the Trinity River that the lowest levels of salinity are experienced and during low flows that the highest salinity levels are found. The highest inflows usually occur during the months of April, May, and June.

Major floods overtop the banks of the river, flattening the peak discharge, and prolonging the flood period. The maximum flood of record on the Trinity River at Liberty occurred on May 8-11, 1942. This flood produced a peak stage of 29.38 feet at the Liberty gage and had a peak flow of 114,000 cfs. Flood stage at the Liberty gage is 24 feet and is reached when the flow is 20,000 cfs. The river has been at or above flood stage at the Liberty gage an average of 43 days a year. A maximum duration of 77 days above flood stage occurred from January 8 through March 24, 1932. Between April and September of 1957, more than 8 million acre-feet of water were discharged into Trinity Bay from the Trinity River; this is enough runoff to flush the bay 12 times. Too much freshwater can be lethal to the majority of truly marine animals, although where a consistent supply of fresh water exists, many marine organisms adapt to it and maintain high productivity.

During low flow periods, the salinity of Trinity Bay is greatly increased, reaching as high as 24 parts per thousand at the mouth of the bay (Fisher et al, 1972). Solomon and Smith (1973) reported salinity ranges from near 0 to 20 parts per thousand in the upper bay and 1 to 30 parts per thousand at the mouth. The higher ranges are usually found during periods of low flow, which frequently occur during the dry summer months. It is during these same periods that prevailing winds from the south tend to push the saline waters into the mouth of the Trinity River. As a result of these conditions, a higher density salt water wedge moves up the river underneath the freshwater flowing downriver. During years when low flows persist for a long period of time, the salt water will intrude to the pump intakes of the irrigation canal systems located downstream from Liberty. In the past, during periods of low flows, irrigation companies constructed temporary dams across the river channel below their irrigation pumps to prevent the salt water from entering their canal systems. There are about 140,000 acres of rice being irrigated by these companies. Irrigating begins about the 15th of March each year and continues intermittently until about October 15th, usually making two crops per year. This irrigation season spans both the normally wet spring and the dry summer periods.

1.18 Trinity River Flows Into Trinity Bay. Flow readings at the river mile 96 gage, adjusted for estimated areal flows below this gage for the 1925-1965 period of record, indicate that the average annual flow into Trinity Bay from the Trinity River has been about 5.4 million acre-feet. Beginning in the 1950's, considerable impoundment of water in manmade lakes occurred, and it is now estimated that the average annual flow into Trinity Bay from the Trinity River is about 3.5 million acre-feet. About 12 percent of this average annual flow is municipal and industrial return flow effluents. Various estimates have been made concerning the minimum water required by Trinity Bay to maintain species diversity and productivity. In 1962 the Fish and Wildlife Service of the Department of the Interior estimated that an average monthly freshwater discharge of about 120,000 acre-feet from March through October would be required to maintain salinity conditions in the bay within the range considered optimum for shrimp and oyster growth. Parker et al (1972) estimated that about 1.3 million acre-feet, or enough to flush the bay twice a year, may be the minimum necessary to maintain current levels of productivity in Trinity Bay.

1.19 Air Quality. Within the Trinity River Basin and the adjacent Houston area (Harris County), approximately 97 percent of the population reside and work in roughly 10 percent of the total area (U.S. Bureau of Census, 1973). With the exception of local burning and the waste emissions of a few rural industries, air pollution problems are concentrated around the population centers of Dallas-Fort Worth in the upper Basin, and Houston.

In response to the Federal Clean Air Act of 1965 and the amended Air Quality Act of 1967, Texas developed an implementation plan for the control of air pollution dated January 28, 1972.

The Texas Air Control Board, created in 1965, has the responsibility for administration of this plan. The implementation plan divided the State into 12 regions. The Trinity River Basin lies within parts of Regions 1, 3, 7, 8, 10, and 12 (Figure 1-3). Data from the 1972 Annual Surveillance Report, Texas Air Sampling Network, Texas State Department of Health are displayed in Table 1-20. It may be noted that the National Ambient Air Quality Standards are often exceeded in Regions 7 and 8. But review of this table indicates sizable emissions of sulfur dioxide, but due to the relatively low sulfur content of current fuels, these emissions are generally well below the maximum prescribed by national standards. Oxides of nitrogen are fairly high, sometimes exceeding national standards with about 95 percent of the emissions from the combustion fossil fuels (Texas Air Quality Board, 1974). The majority of particulate emissions appears to originate from industrial processes and sometimes exceeds national standards.

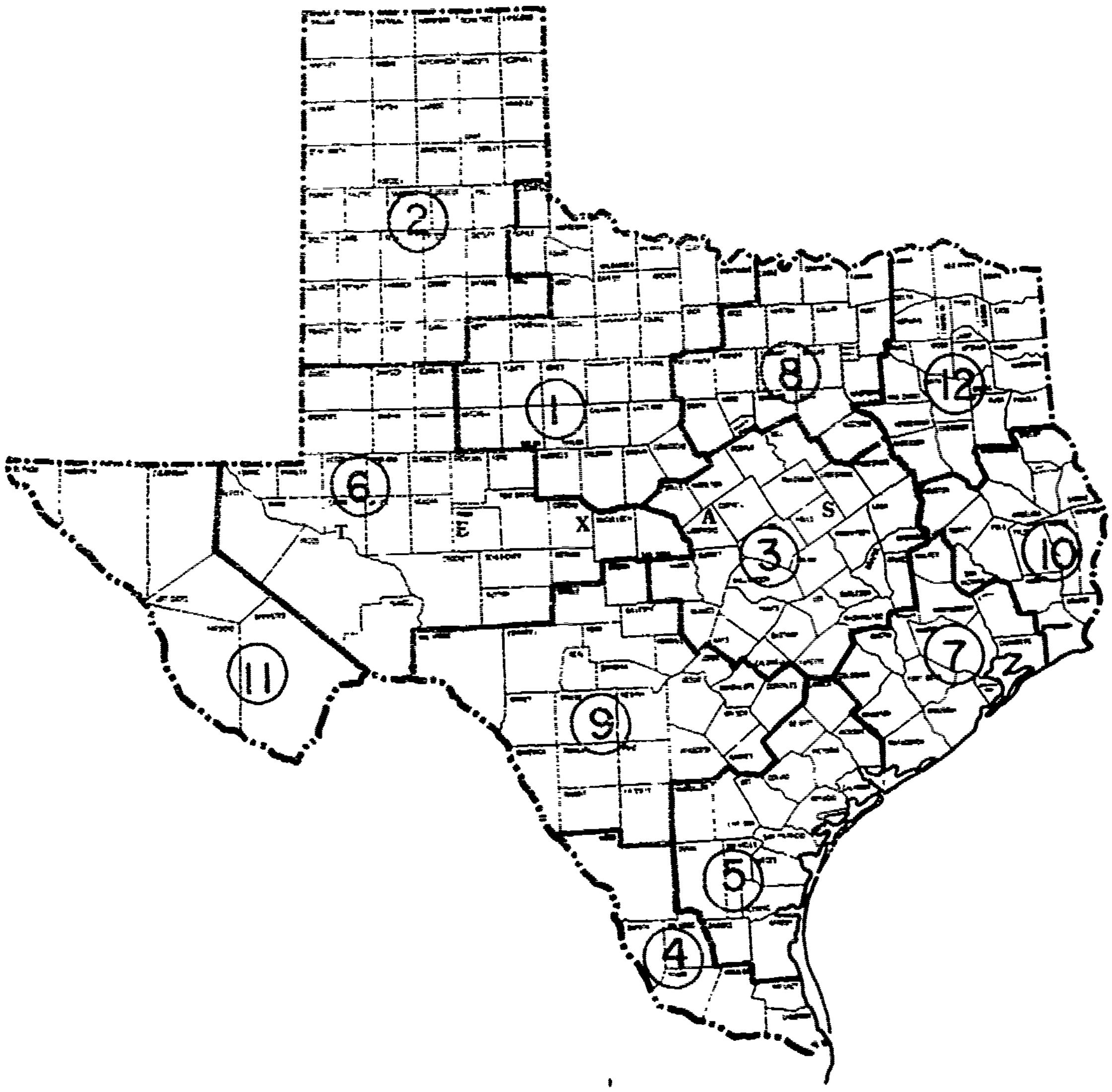
Photochemical oxidants result primarily from products produced by the burning of fossil fuels and their reaction with ultraviolet light. Because of the large number of internal combustion engines in the Dallas-Fort Worth and Houston Areas, it can be assumed that these pollutants exist in those and other metropolitan areas. Smog can be formed when sufficient water vapor is present during the photochemical oxidation reaction. Smog has received widespread attention for its adverse affects, primarily on the eyes and respiratory system. Smog may also have a toxic effect on some plants. Losses to American agriculture due to the sum total of air-pollutants have been estimated at more than $500 million annually (Hepting, 1971). Smog from the Los Angeles area was blamed for a 25 percent reduction in California citrus crops south of the city during the 15 years preceeding 1964 (Hepting, 1971).

Winds in the Dallas-Fort Worth region normally disperse air pollutants and thus prevent their concentration. For this reason, a large portion of the community is unaware of the air pollution problem. This problem becomes readily apparent and noxious only when wind velocities are low or a temperature inversion develops.

The first phase of the Dallas-Fort Worth Regional Airport was recently completed and is one of the largest airports in the world. The concentrated population in this area combined with the total vehicular emissions could become a serious problem in ambient air quality control.

All new industries are required by present State regulations (Art. 4477-5, Vernon's Texas Civil Statue) to be in compliance with air pollution regulations upon beginning operations. With a few exceptions, existing industries in Texas have complied, or are making progress towards compliance, with the requirements of the Texas Clean Air Act. There has been a noticeable reduction in

FIGURE I-3



TEXAS AIR QUALITY CONTROL REGIONS

TABLE 1-20

AREA AIR QUALITY MEASUREMENTS *

National Ambient Air Quality Standards			Range of Measured Concentrations			
			1972 1/		1974 2/	
Pollutant	Primary	Secondary	Dallas-Fort Worth	Houston-Galveston	Dallas-Fort Worth	Houston-Galveston
Particulate Matter						
Annual Geometric Mean	75	60	36-102	40-97	----	----
Maximum 24-hr Concentration[a]	260	150	115-676	108-283	7-80	53-125
Sulfur Oxides						
Annual Arithmetic Mean	80(.03 ppm)	60(.02 ppm)	4-6	3-28	----	----
Maximum 24-hr Concentration[a]	365(.14 ppm)	260(.1 ppm)	12-63	8-320	----	----
Maximum 3-hr Concentration[a]		1300(.5 ppm)	----	----	---- 13-52[b]	---- 3-210[b]
Carbon Monoxide						
Maximum 8-hr Concentration[a]	10(9 ppm)	Same as Primary	----	----	----	----
Maximum 1-hr Concentration[a]	40(35ppm)		----	----	0.3-5.1	0.2-3.9
Photochemical Oxidants						
Maximum 1-hr Concentration[a]	160(.08 ppm)	Same as Primary	----	205-501 3/	0-290	10-402
Hydrocarbons						
Maximum 3-hr (6-9 am) Concentration[a]	160(.24 ppm)	Same as Primary	----	----	66 2327	399-4721
Nitrogen Oxides						
Annual Arithmetic Mean	100(.05 ppm)	Same as Primary	19-160	48-110	----	9-113

a Not to be exceeded more than once a year

b One-hour values

* All measurements are expressed in micrograms per cubic meter (ug/m^3) except for those for carbon monoxide, which are expressed in milligrams per cubic meter (mg/m^3). Equivalent measurements in parts per million (ppm) are given for the gaseous pollutants.

1/ 1972 Annual Surveillance Report, Texas Air Sampling Network

2/ 1974 National Aerometric Data Bank, Quarterly Frequency Distribution, Texas

3/ 1973 Monitoring and Air Quality Trends Report, U. S. Environmental Protection Agency

----Indicates no data available

outdoor burning and smokestack emissions throughout Regions 7 and 8. Hearings and lawsuits have at times been necessary to bring about compliance. The State Air Quality Board and the Environmental Protection Agency have the responsibility of preserving and enhancing air quality in the State of Texas.

1.20 Noise Pollution. The great majority of significant noise pollution generally comes from the same sources that produce air pollution, burn fossil fuels (natural gas, oil, lignite, and coal) to power transportation vehicles, or produce mechanical or electrical energy.

Noise has been defined an an unwanted by-product of modern life (EPA, undated). Sounds of suffient intensity are known to produce temporary and occasionally permanent physiological changes in man, including construction of small arteries, increased pulse and respiration rate, involuntary muscular responses, and dilation of eye pupils. Humans repeatedly exposed to intense noise often experience permanent hearing loss (Jones, 1973). Several Federal agencies are becoming increasingly involved with the abatement of undesirable noise. The Department of Transportation is interested in highway, motor vehicle, tire, railroad, and subway noise. The development of quieter aircraft engines is the concern of the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration. The Department of Housing and Urban Development (HUD) is interested in the reduction of noise in multi-family dwellings, and the Department of Health, Education and Welfare is concerned with the health aspects of noise (Jones, 1973). The Environmental Protection Agency's noise control activities were authorized by the Noise Pollution and Abatement Act of 1970 and the Noise Control Act of 1972. Their broad mission is to identify and classify causes and sources of noise and to determine their effects on public health and welfare.

Within the Trinity River Basin, the majority of noise pollution is found in the Dallas-Fort Worth Metropolitan Area, although the relative quiet of the rural areas in the remainder of the Basin is being disturbed by ever-increasing numbers of automobiles, recreational motorcycles, and the multitude of other noise producers that accompany increasing population. There appears to be no comprehensive quantitative data on noise pollution in the Dallas-Fort Worth Area or elsewhere in the Trinity River Basin, although the agencies HUD, FAA, etc., in the two cities do monitor noise intensities in high noise areas such as freeways and the regional airport.

1.21 Solid Waste Disposal. An average of 5.5 pounds per capita per day of municipal solid waste (urban refuse and garbage) is collected in the United States (EPA Pamphlet AP-42). In the Dallas-Fort Worth

Standard Metropolitan Statistical Area (SMSA) the 1970 census population was 2,377,979 (Texas Almanac, 1973). The estimated population for this area at the end of 1972 was 2,536,900. This would mean that about 14 million pounds of municipal solid waste are collected per day in the Dallas-Fort Worth SMSA, or about 5 illion pounds per year. This does not include uncollected urban and industrial waste of about 4.5 pounds per capita per day that is disposed of by other means. Assuming an average landfill depth of 12 feet and a weight of compacted waste materials of 800 pounds per cubic yard, about 330 acres per year are needed to dispose of this solid waste by landfill methods. In the Dallas-Fort Worth urban area, the majority of solid waste is disposed of by the sanitary landfill method. This is also true of most of the other large cities and towns within the Basin. In rural areas, disposal of solid waste is accomplished by a mixture of burning and dumping, with burned and unburned solid waste being buried intermittently as it becomes a significant visual or odor problem. The areas that are normally used for disposal of solid waste are in the flood plain of the Trinity River and its tributary ravines. A serious problem can be the contamination of groundwater and runoff water by leachate from landfills (Glysson, et al, 1972). Current planning by local interests indicates a continuation of the practice of utilizing low areas for sanitary landfills.

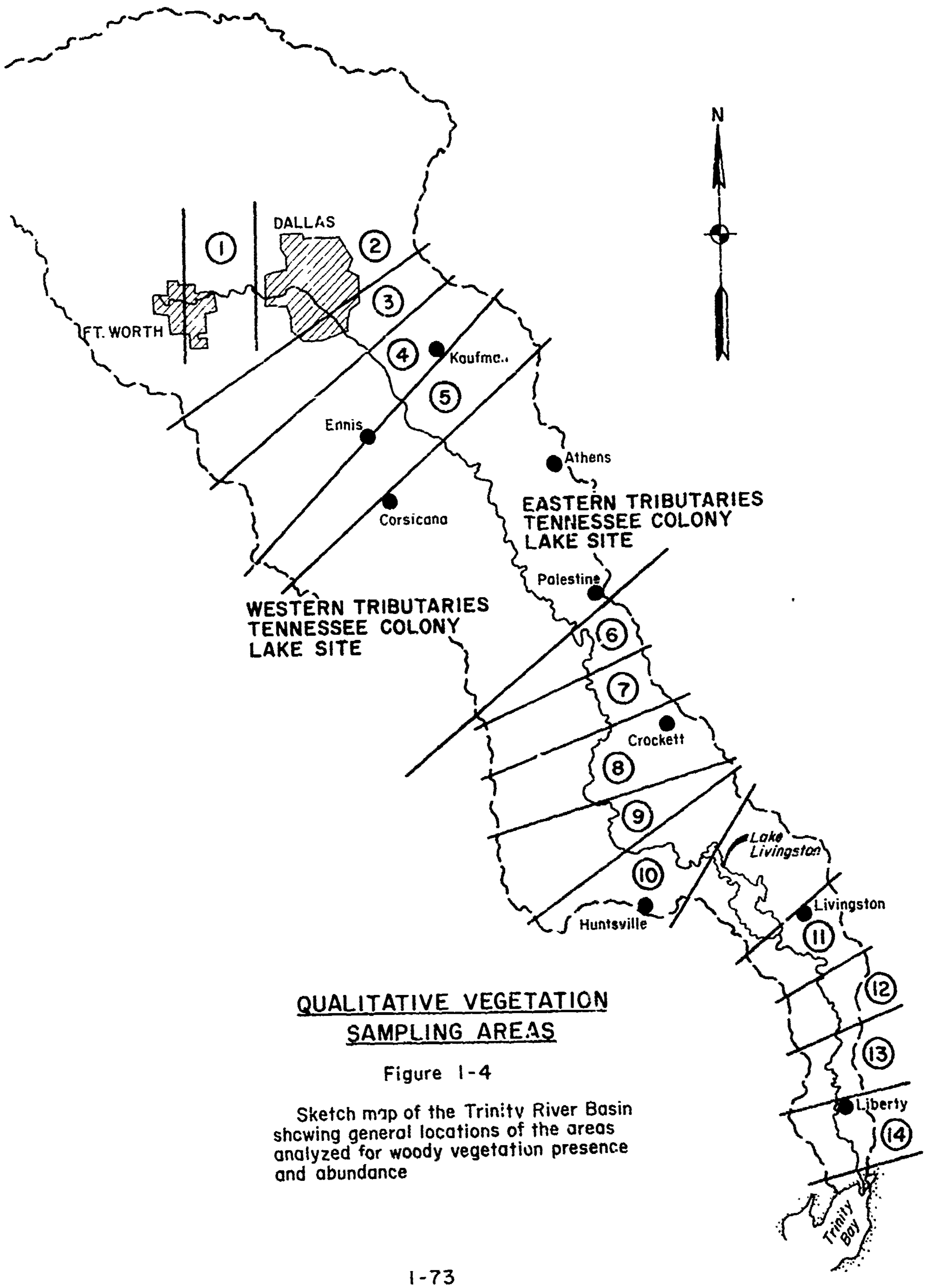
1.22 Basin Vegetation. The Trinity River Basin is larger than each of the following states: Connecticut, Delaware, Hawaii, Maryland, Massachusetts, New Hampshire, New Jersey, Rhode Island, and Vermont. The classification of vegetative characteristics in an area this size is a monumental task. Considerable background data have been assembled and extensive species lists of the vegetation found in the Trinity River Basin have been compiled by many investigators including: Gould (1969), Mahler (1972), Nixon (1972a), Nixon (1972b), Nixon (1973), and Nixon and Willett (1974). Taxonomic lists are included in Appendix B. This section is confined to a condensation of the information currently available. Plate 17 illustrates the relationship of the Trinity River Basin to the vegetational areas of Texas and presents a brief description of the natural climax vegetation and the current general vegetative character of each zone. The vegetation in any area is directly dependent upon the area's land use. Plate 13 depicts the general land use patterns of the Trinity River Basin. Farm levees in the area from Dallas to Lake Livingston (Plate 1 and photograph 15) usually occur in areas being used principally to cultivate row crops, although many farm levees can be found adjacent to "improved" grazing land.

Herbaceous vegetation of the Trinity River Basin has been studied by Nixon (1973) and a partial checklist of herbaceous species based on his study has been included in Appendix B. The vegetation of greatest concern to the environmental planning in the Trinity River Basin is the bottomland hardwood forests, which have been classified by Bray (1906) and Collier (1964) as distinct vegetational types. These bottomland forests associated with the Sabine, Neches, Trinity, and San Jacinto River systems occupy large areas and are considered by Bray (1906) and Braun (1950) to be westward extensions of hardwood forests typical of river bottom areas to the southeast.

Quantities of forested and open land in the flood plain, based on the lates USGS quadrangle topographic maps, updated by aerial photographic mosaics, have been measured in various reaches of the river from Fort Worth to Trinity Bay (Tables 1-45 and 1-46).

Nixon (1972a and 1972b) conducted a vegetational survey and qualitatively classified the vegetation in selected portions of the Trinity River Basin, with particular attention to the flood plain. He arbitrarily divided the Trinity River Basin from Fort Worth to Trinity Bay into 14 areas and described the vegetation found in each. Figure 1-4 shows the area locations, and Table 1-21 summarizes the results of Nixon's investigations.

1.22.01 Quantitative Studies. A baseline of the characteristic makeup of the woody vegetation of the bottomland hardwood forests of the Trinity River Basin has been established. Quantitative vegetational studies were made by Nixon (1973) in each of the five vegetational areas (after Gould, 1969) in the Trinity River Basin. Each sampling area was selected on the basis of its exemplary features, and all trees and shrubs with diameter breast height (dbh) of greater than one-half centimeter (cm) were quantified using the plot method. Additionally, a special study was made of the vegetation in a heron rookery area a few miles downstream from Lake Livingston and just east of the Trinity River. Each plot was 5 meters on a side and situated along a belt transect. Transects were generally 250 meters (m) in length and composed of 100 plots. Woody species were identified, measured, and counted, and from these data, frequency, density, dominance and importance value figures were obtained. Maps illustrating the locations of each of the six sampling areas and each site within a specified area are included in Appendix B. The resulting frequency, dominance, density, size, and importance data are given in Appendix B (importance is the sum of the percentage relative density, percentage relative frequency, and percentage relative dominance and does not imply ecological importance). The data from these quantitative studies have been summarized in Table 1-22. All the species sampled which had "importance values" ranging from 1 to 10, with 10 the least important are listed, along with a description of the area in which they were found and their average ranking in "importance" in each area.



QUALITATIVE VEGETATION SAMPLING AREAS

Figure 1-4

Sketch map of the Trinity River Basin showing general locations of the areas analyzed for woody vegetation presence and abundance

TABLE 1-21

WOODY VEGETATIONAL ABUNDANCE IN TRINITY RIVER FLOODPLAIN AND ADJACENT UPLAND SITES

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	Eastern Trib TC Lake	Western Trib TC Lake	AREA 6	AREA 7	AREA 8	YOUNG Creek	AREA 9	AREA 10	AREA 11	AREA 12	AREA 13	AREA 14
American basswood							U										
American beautyberry						U											
American elder																	D
American elm	D					GA	D										
American holly						D(up)											
Bald cypress						D(low)								LA	LA	D	
Black gum						D											
Black hickory						D											
Black walnut						D											
Black willow	LA	D	LA			D	D	LA	LA	LA	D	LA		D			D
Blue beech						D											
Box elder						D(low)	D								D		D
Bristly greenbrier							U										
Bar oak							LA										
Carolina basswood							D										
Cat brier							U										
Cedar elm	D	LA	D	D	D	GA	D	LA		LA	D		LA				
Chestnut oak															LA	D	
Common buttonbush			LA		D	U,D(low)								LA		U	U
Common green-brier	U					U	U										
Coral berry	U						U										
Deciduous holly						U	U										
Dwarf palmetto													LA				
Eardrop vine							U										
Eastern cottonwood	LA	D													D	D	
Eastern red cedar											LA						
Farkleberry						U											
Flowering dogwood						D(up)											
Forestiera							U&LA										
Green ash	D	LA	D	D	D	D	D		LA						LA	D	
Gum bumelia											D						
Hawthorn							LA							D		U	
Honey locust						GA			LA	LA		D		D	D	D	
Laurel oak																	
Loblolly pine						D(up)					LA		LA				D
Mustang grape						U	U				D			U		U	
Osage orange							LA										

D = dominant
D(up) = dominant in upland sites
D(low) = dominant in lowland sites
U = understory
LA = locally abundant
GA = generally abundant

See map for specific area locations. Areas are shown from upstream (Area 1) to downstream (Area 14) sequentially.

(continued)

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	Eastern Trib TC Lake	Western Trib TC Lake	AREA 6	AREA 7	AREA 8	Young Creek	AREA 9	AREA 10	AREA 11	AREA 12	AREA 13	AREA 14
Overcup oak						D											
Pecan					LA		D								D	D	
Peppervine						U			LA		LA					U	
Persimmon						D					LA				D	D	D
Poison ivy	U			D		U	U	LA	LA	LA	LA	D	LA	U	U	U	U
Possum-hawholly												LA	LA				
Post oak						D(up)						D					
Red cedar											LA						
Red mulberry		LA					D	LA									
Redbud						GA											
River birch						D											
Roughleaf dogwood						U	U&LA								D	D	D
St. Peter's wart						U											
Sandjack oak						D(up)											
Sea myrtle						D(low)											
Shining sumac											LA						
Shumard red oak							D										
Soapberry	D	LA					LA										
Southern red oak						D(up)					LA			D			
Supplejack						U	U										
Swamp privet	LA			D	D		LA	LA	LA			LA			LA	U	U
Sweetgum						D					D		LA		D	D	D
Sycamore							D								D	D	D
Texas sugarberry	D	LA	D	D		GA	D					D			D	D	D
Trumpet honeysuckle						U											
Tupelo														LA			
Virginia creeper															U		
Water elm						D	LA										
Water hickory						GA,D(low)							LA			D	D
Water locust														D			
Water oak						D	LA				D						D
Wax myrtle						U&D(low)											
White ash						D(up)											
Willow oak						D							LA	D			
Winged elm						GA					D						
Yaupon						U&D(up)	U				D						

D = dominant
D(up)= dominant in upland sites
D(low)= dominant in lowland sites
U = understory
LA = locally abundant
GA = generally abundant

See map for specific area locations. Areas are shown from upstream(Area 1) to downstream (Area 14) sequentially.

Data Source: Nixon and Willett (1972).

TABLE 1-22

SELECTIVE SUMMARY OF QUANTITATIVE VEGETATIONAL STUDIES

SPECIES	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
American Beautyberry	-	-	1 (1)	-	6.5(2)	1 (1)
American Hophornbeam	-	-	-	-	5 (1)	-
Bald Cypress	-	-	-	2 (2)	5.5(2)	-
Black Hickory	-	-	3 (1)	-	-	-
Black Oak	-	-	-	8.5(2)	7 (2)	-
Black Walnut	-	-	5 (1)	-	8 (1)	-
Black Willow	-	-	-	-	-	4.5(4)
Blue Beech	-	-	-	-	1 (1)	5 (2)
Bottomland Post Oak	-	-	-	-	6 (1)	-
Box Elder	-	-	-	-	9 (1)	6 (1)
Carolina Ash	-	-	-	3 (1)	-	-
Cedar Elm	3 (3)	2 (2)	1.5(2)	2 (3)	5.5(4)	3.4(7)
Chestnut Oak	-	-	-	-	10 (1)	6.5(2)
Common Buttonbush	-	-	-	4 (1)	8.5(2)	1.8(7)
Deciduous Holly	3 (2)	-	3.5(2)	4.7(3)	5.2(4)	7.4(5)
Dogwood	-	-	-	-	4.5(1)	-
Eastern Cottonwood	-	-	-	-	-	3.5(2)
Forestiera	-	3 (1)	5 (2)	-	-	-
Giant Cane	-	-	-	-	3 (1)	-
Green Ash	2.5(2)	3.5(2)	6 (1)	-	1.5(2)	2.9(10)
Gum Bumelia	-	4.5(2)	-	-	-	-
Hawthorn	-	-	5 (1)	1.7(3)	6 (3)	5.2(4)
Honey Locust	-	-	4 (1)	5.2(4)	9 (1)	3 (1)
Osage Orange	5 (1)	-	-	-	-	-
Overcup Oak	-	-	-	7 (2)	1.5(2)	6 (1)
Parsely Hawthorn	-	-	-	-	10 (1)	-
Pasture Haw	-	-	-	8 (1)	-	5.4(5)
Pecan	1 (1)	-	3 (1)	6 (1)	2.5(2)	7.5(2)
Persimmon	-	-	-	7 (1)	10(1)	8.5(2)
Post Oak	-	-	2 (1)	-	-	-
Rattlebush	-	-	-	-	-	6 (3)
Red Maple	-	-	-	1 (5)	-	-
Roughleaf Dogwood	4.5(2)	-	-	-	-	-
Shumard Oak	5 (1)	-	-	-	-	-
Snowdrop Tree	-	-	-	7 (1)	-	-
Southern Magnolia	-	-	-	-	4 (1)	-
Southern Red Oak	-	-	-	2.5(2)	8 (2)	6.4(5)
Swamp Privet	3 (1)	-	-	-	4 (1)	-
Sweetgum	-	-	4 (1)	2 (1)	3 (2)	3.5(4)
Tassel-white	-	-	-	4 (1)	-	-
Texas Sugarberry	2.5(2)	1 (2)	1 (1)	6 (4)	3.4(5)	3.7(6)
Tupelo	-	-	-	1 (2)	1.5(2)	4 (5)
Water Elm	-	-	-	3 (1)	4 (2)	4.2(5)
Water Hickory	-	-	-	8 (1)	5.5(2)	5 (2)
Water Locust	-	-	7 (3)	-	5 (1)	5.5(2)
Water Oak	-	-	-	2.5(2)	5.2(4)	3.9(7)
White Ash	-	-	-	-	-	3.7(3)
Willow Oak	-	-	3 (1)	3.5(2)	-	2.3(4)
Winged Elm	-	-	-	7.5(2)	4.5(2)	6.8(5)
Yaupon	-	-	-	-	2 (2)	-

Notes: 1. The number in parenthesis indicates the number of sites at each area at which that species was found.

2. Ranking in importance value from 1 to 10 (1 is highest value)

3. Underlined species listed as endangered by the Texas Organization for Endangered Species.

4. See Appendix B for details.

Data Source: Nixon and Willett (1974)

For example, in Area 3 American Beautyberry was found in only one site but had a high importance value of 1, while in Area 5 it was found at two sites but had a relatively low importance value of 6.5. It may be seen that only nine species within an "importance value" of 10 or greater were found in Area 1, five species in Area 2, fifteen species in Area 3, twenty-four species in Area 4, thirty-three in Area 5, and twenty-eight species in the heron rookery area (Area 6). The greater diversity of woody vegetation was found from Area 3 downstream as is evidenced by the data shown in Appendix B.

1.22.02 Dallas-Fort Worth Floodplain Succession. Large portions of forested bottomlands in the Dallas-Fort Worth area have been excavated for many years for their gravel content, leaving these areas unleveled and subject to vegetative invasion. Photo #16, Appendix A shows one of these typical areas. This condition is common enough to warrant special mention. Nixon (1973) made a comparative quantitative investigation near Dallas involving the vegetation of four adjacent areas. One of these was a relatively undisturbed, unexcavated forested area. The other three areas had been excavated approximately 3, 5, and 47 years before the investigation. Originally the topography was flat, while excavation resulted in alternating ridges and furrows. This condition was less pronounced in the older excavations, indicating long term erosional processes. Soil mixing, direction of furrows, water surface areas, and adjacent vegetation are some of the factors influencing vegetative succession.

The results of the herbaceous analyses in terms of importance values (importance value is the sum of relative frequency and relative density) for species from each of the four areas are shown in Table 1-23. Importance values of shrub and vine species are shown in Table 1-24 for each of the four areas. Table 1-25 illustrates the importance values (the sum of relative frequency, relative density and relative dominance divided by three) of the tree species from each of the four areas.

The important values in each of the above three tables display the successional pattern of vegetative invasion. While Western Cross Timber areas eventually enter a splitbeard bluestem or little bluestem successional stage, vegetational trends in the Trinity River bottom area seem to be directed towards a grass-to-sedge ground layer. Golden aster, wild lettuce, and pale-seeded plantain were dominant in the three-year-old area. Golden aster was still dominant in the five-year-old stage, but grasses (which included six-week fescue, panic grass, and paspalum grass) replaced other dominants. The 47-year-old area was dominated on south and west-facing slopes by such grasses as brome, panic grass, and little barley, with Indian blanket, woodsorrel,

TABLE 1-23

A COMPARISON OF THE IMPORTANCE VALUES*
OF THE DOMINANT HERBACEOUS SPECIES FROM FOUR AREAS

Species	Excavated 3-year-old area	Excavated 5-year-old area	Excavated 47-year-old area	Unexcavated area
Gold Aster	42	31	3	
Wild Lettuce	20	1	1	1
Cut-leaf Evening Primrose	11	6		
Yellow Wood-sorrel	10	4	17	
Paleseed Plantain	19	5	5	
Heartwing Sorrell	5	8		
Paspalum Grass	1	15	1	
Panic Grass No. 1	2	15		
Six-week Fescue	5	42	5	
Brome Grass	1	1	32	
Panic Grass No. 2			11	
Nut Grass			14	
White Avens			15	1
Panic Grass No. 3		2		33
Catchweed Bedstraw			1	20
Sedge No. 1			1	17
Black Snakeroot			2	17
Sedge No. 2				21

*Importance value is equal to the sum of relative frequency and relative density.

Data Source: Nixon (1973)

TABLE 1-24

A COMPARISON OF THE IMPORTANCE VALUES*
OF SHRUB AND VINE SPECIES FROM FOUR AREAS

Species	Excavated 3-yr-old area	Excavated 5-yr-old area	Excavated 47-yr-old area	Unexcavated area
Maypop	17	19		
Mustang Grape		8	25	
Bull-brier	169	119	39	33
Carolina Snailseed	9		9	8
Virginia Creeper	5	13	20	74
Coral-berry		14	18	19
American Beautyberry		23	1	23
Pinewoods Grape		4		5
Poison Ivy			60	4
Southern Dewberry			11	3
Peppervine			11	2
Alabama Supplejack			6	1
St. Andrews Cross				11
Fox Grape				17
Total	200	200	200	200

*Importance value is equal to the sum of relative density and relative frequency.

Data Source: Nixon (1973)

TABLE 1-25

A COMPARISON OF IMPORTANCE VALUES* OF TREE SPECIES FROM FOUR AREAS

Species	Excavated 3-yr-old area	Excavated 5-yr-old area	Excavated 47-yr-old area	Unexcavated area
Cottonwood	44	77	10	
Black Willow	56	17	P***	
Winged Elm	S**	3	10	24
American Elm	S	2	6	3
Pecan		S	3	3
Ash		S		7
Roughleaf Dogwood		S	8	
Flameleaf Sumac			5	
Bumelia			3	
Yaupon			5	
Hackberry			29	P
Eastern Red Cedar			23	7
Rusty Blackhaw			2	3
Hercules Club			2	3
Blackjack Oak			P	2
Shumard Oak			P	7
Post Oak			P	16
Possum-haw Holly			P	1
Eastern Redbud				5
Red Mulberry				4
Mexican Plum				14
Hickory				3
Chinese Elm				1

*Importance value is the sum of relative frequency, relative density and relative dominance divided by three.

** S = Seedlings present.

*** P= Trees and seedlings present but not in plots.

Data Source: Nixon (1973)

southwest bedstraw, and nut grass commonly found. The herbaceous vegetation of the unexcavated area was dominated by panic grass, the sedges, catchweed bedstraw, and black snakeroot, with dye bedstraw and poverty oatgrass commonly occurring. Nixon (1973) contends the species of the unexcavated area are generally representative of Texas river bottom areas.

The succession of shrub and vine species indicates a cat-brier (along with maypop, Virginia creeper, coral-berry, and American beautyberry)-to-poison ivy (with cat-brier, Virginia creeper, coral-berry, and mustang grape)-to-Virginia creeper (with cat-brier, coral-berry, American beautyberry, fox grape, and St. Andrews cross) pattern.

Black willow and eastern cottonwood were dominant tree species in the 3- and 5-year-old study areas. Cottonwoods, which grow tall, generally bring about the eventual disappearance of the willows. There is a general concurrence among botanists that an increase in Texas sugarberry, eastern red cedar, winged elm, roughleaf dogwood, and American elm occurs. Trinity River bottom successional trends indicate that Texas sugarberry and eastern red cedar (dominants in the 47-year-old area) may be succeeded by winged elm, post oak, and Mexican plum. Nixon (1973) feels that past disturbances in the flood plain make further successional determinations difficult to resolve.

1.22.03 Introduced Plant Species. The discussion here will be limited to those naturally expanding populations, accidentally or intentionally introduced, which pose a threat to existing ecosystems or the beneficial use of natural resources by man. No attempt will be made to discuss the some 200,000 species of plants which have been introduced for decorative or agricultural activities.

1.22.03.01 Alligator Weed. One of the aquatic weeds currently a problem in Texas is alligator weed (*Alternanthera philoxeroides*). This plant is believed to have been introduced to Texas waterways by the dumping of ship ballast in the late 1800's (Ehrenfeld, 1970). It causes problems by clogging waterways and reservoirs, making boat passage virtually impossible. Alligator weed iis found in various portions of the Trinity River Basin (Nixon, 1973).

1.22.03.02 Water Hyacinth. The water hyacinth (*Eichhornia crassipes*), a native of Central America, was sold in the United States in the late 1800's because of its beauty in its natural setting. It thrives in the fresh waters of the United States, since it has few natural enemies. The water hyacinth is found in most of the river basins in Texas, including the Trinity River Basin, and is regarded as a nuisance species.

1.22.03.03 Mesquite. The southwestern mesquite includes spiny trees and shrubs belonging to the species Prosopis juliflora. It is a native species, but due to grazing and browsing by domestic livestock and cessation of grassland fires (among other reasons), its once restricted habitat has virtually exploded. It now dominates large areas of Texas and is found as far east as the Trinity River Basin.

1.22.03.04 Tamarisk. The five-stamen tamarisk (Tamarix pentandra) is an alkali-tolerant species which has spread from its original introduction from Eurasia to the Southwest at a rapid rate and thus deserves special mention. The spread of tamarisk was aided by man's removal of woody riparian competition, and today it covers many major waterways in the Southwest, including Texas.

1.22.03.05 Hydrilla. Hydrilla verticellata is native to Eastern Asia and has been an aquatic nuisance in the waters of India, Central Africa, Russia, Germany, and Australia before becoming a problem in the United States (Guerra, 1974). Hydrilla became established in the United States in the late 1960's when it was imported as an aquarium plant. In 1974, some 50,000 acres of Florida waters contained hydrilla and the plant has rapidly spread westward to Texas, where it was first identified in Lake Livingston in August, 1974.

1.22.04 Rare and Endangered Plants Native to Texas. The literature review by Mahler (1972) reports the presence in the Trinity River Basin of 16 taxa which fall into the category of rare and endangered as classified by the Rare Plant Study Center in Austin, Texas (1971). Reference to the more recent publication of the Rare Plant Study Center (1972) was used to bring the information up to date. This resulted in several changes in the list given by Mahler (1972). Several species which had been listed as being rare and endangered are now listed as being "presumed extinct," with none recorded since 1930 from Texas. These are:

1) Dryopteris cristata (crested shield fern).

2) Ilex myrtifolia Walt (myrtle holly).

3) Hymenoxys texana (Texas bitterweed).

4) Machaeranthera aurea (Houston machaeranthera).

5) Oenothera sessilis (coastal evening primrose).

The following vascular plants are listed as being ". . . very rare; acutely endangered in Texas but . . . distributed broadly but regionally in North America and extending into Texas.":

1) Ophioglossum nudicaule (fragile adder's tongue). Reported from Hardin County.

2) Psilotum nudum (whisk fern). Only one plant reported - that from Hardin County.

3) Carex granularis (meadow sedge). Reported from Bowie County.

4) Carex tenax (wire sedge). Reported from Hardin County.

5) Danthonia sericea (downy danthonia). Reported from Bowie County.

6) Calopogon barbatus (bearded grass-pink). Reported from a bog in Henderson County.

7) Aster scabricaulus (rough-stem aster). Reported from Tyler and Van Zandt Counties.

8) Dioclea multiflora (Boykin clusterpea). Reported from Jasper and Tyler Counties.

9) Cuphea carthagensis (tropical waxweed). Reported from Hardin County.

10) Magnolia ashei (Ashe magnolia). No specific reports.

11) Magnolia pyramidata (pyramid magnolia). Reported from Jasper County.

12) Parnassia asarifolia (grass-of-parnassus). Reported from Nacogdoches County.

13) Stewartia malacodendron (silky camellia). No specific reports.

The following vascular plants are listed as being ". . . scarce, endangered in Texas," but ". . . distributed broadly but regionally in North America and extending into Texas.":

1) Diarrhena americana (American beakgrain). Found in northeast Texas.

2) Habenaria lacera (ragged fringed orchid). No specific reports.

3) Sabal minor (Louisiana palm). No specific reports.

4) Ilex ambigua (Carolina holly). No specific reports.

5) Solidago auricultata (earleaf goldenrod). Reported from Harrison County as well as Jasper and Newton Counties.

6) Solidago caesia (blue-stem goldenrod). No specific reports.

7) Carya myristicaeformis (nutmeg hickory). No specific reports.

8) Lindera benzoin (spice bush). No specific reports.

9) Amelanchier arborea (serviceberry). No specific reports.

10) Brazoria pulcherrima (brazosmint). Known only from Leon County near Centerville.

The Rare Plant Study Center (1972) does not have good information on abundance of plants outside North America, so no world-wide assessment is shown.

To date, none of the rare or endangered plant species listed also have been encountered during Trinity River bottomland investigations.

1.22.05 Localized and Endemic Woody Species. One hundred forty-eight species of woody plants were noted by Nixon (1973) in the Trinity River Basin. All but ten species are widely distributed in the United States. These ten species and their distributions are listed below:

1) Amorpha paniculata (amorpha). Eastern Texas, Louisiana, Arkansas, and Oklahoma.

2) Vitis mustangensis (mustang grape). Eastern Texas, Louisiana, Arkansas, and Oklahoma.

3) Sophora affinis (Eve's necklace). North and central Texas and the Edwards Plateau, Arkansas, Oklahoma, and Louisiana.

4) Solanum triquetrum (Texas nightshade). Central, South and West Texas and in adjacent portions of Mexico.

5) Rubus saepescandens (blackberry). East Texas and southern Louisiana.

6) Crataegus brazoria (Brazos hawthorne). Eastern Texas and the Blackland Praries.

7) Crataegus glabriuscula (hawthorne). Endemic to north-central and south Texas.

8) Quercus texana Buckl. (Texas red oak). Restricted to the rocky limestone slopes of central Texas.

9) Rubus aboriginum (blackberry). Eastern Texas.

10) Rubus apogaeus (blackberry). Eastern Texas.

1.22.06 Vascular Endemics Whose Primary Habitat Lies Within the Trinity River Basin. Fifteen vascular species, listed by Mahler (1972) as being endemic to Texas, are found primarily or entirely within the Trinity River Basin. Their names and approximate locations (when known) are given below.

1) Coreopsis intermedia (cordleaf coreopsis). Freestone County in the basin; Franklin, Wood, and Upshur Counties in northeast Texas.

2) Crataegus warneri (Warner hawthorne). Walker and Anderson Counties in the Basin, Cherokee County outside the Basin.

3) Helianthus debilis (sunflower). Chambers County in the Basin; Jefferson and Galveston Counties outside the Basin.

4) Hibiscus dasycalyx (hibiscus). Trinity County.

5) Liatris cymosa (branched grayfeather). Walker County in the Basin; Brazos and Washington Counties outside the Basin.

6) Mirabilis collina (four o'clock). Anderson County in the Basin; Cherokee and Smith Counties outside the Basin.

7) Palafoxia reverchonii (reverchon polypteris). Young, Freestone, Anderson, Leon, Houston, Trinity, and Polk Counties in the Basin; Upshur, Smith, and Montgomery Counties outside the Basin.

8) Physostegia pulchella (lionsheart). Kaufman and Navarro Counties in the Basin; Hunt County outside the Basin.

9) Polygonella parksii (jointweed). Leon County in the Basin; Atascosa and Wilson Counties outside the Basin.

10) Rosa ignota (rose). Johnson County.

11) Rubus duplaris (dewberry). Collin and Freestone Counties only.

12) Rubus velox (dewberry). Collin County in the Basin, Austin County outside the Basin.

13) Schoenolirion texanum (Texas sunnybell). Walker County in the Basin, Brazos and Austin Counties outside the Basin.

14) Wilkommia texana (Texas Wilkommia). Ellis County in the Basin; Kelburg, San Patricio, and Bee Counties outside the Basin.

15) Veronia vulturina (ironwood). Dallas County.

1.22.07 Champion and Famous Trees. The champion and famous trees of the Trinity River Basin are shown on Plate 18 and listed in Appendix B. Several candidates were found by Nixon (1973) which are expected to supersede smaller trees currently listed as champions.

1.23 Terrestrial Fauna. The upper half of the Trinity River lies mostly in the Texan Biotic Province, and the lower half of the Trinity River lies on the western edge of the Austroriparian Biotic Province (Blair, 1950). The avian and mammalian faunas are generally typical of those found in southeastern United States (Fisher, 1972). Its position, between the eastern forests and the Great Plains grasslands, results in a region of ecological transition where many eastern forest birds and mammals reach their western range limit and some prairie species reach the eastern extension of their habitats. This mixing of fauna is most evident in the upper Trinity River Basin where the plains species usually occupy upland habitats and eastern species the lowland habitats (Fisher, 1972).

The abundant bird and mammalian faunas of the Trinity River Basin are most diverse in the bottomland forests adjacent to the river. Clearing of these areas by landowners is steadily diminishing the quality and quantity of valuable habitat. Species lists of the terrestrial fauna of the Trinity River Basin have been assembled (Ubelaker, 1972; Fisher and Rainwater, 1972; Fisher, 1972; and Fisher and Hall, 1973), and the combined data from these are included in Appendix B. Ubelaker (1972) and Fisher and Rainwater (1972) conducted literature surveys, while Fisher (1972) and Fisher and Hall (1973) concentrated on field investigations.

1.23.01 Quantitative Studies. Quantitative data on lower form terrestrial fauna are difficult to obtain. No complete quantitative studies of the lower form fauna are known to exist for the Trinity River Basin, nor are such studies commonly conducted over large areas such as the Trinity River Basin. Appendix B lists the lower form fauna which have been reported from the Trinity River Basin (Ubelaker, 1972).

The first investigation of Fisher (1972) concentrated on the presence and relative distribution of birds and mammals in the Trinity River Basin. The study by Fisher and Hall (1973) dealt with obtaining quantitative data on birds and mammals from each of ten permanently established sampling sites. Populations at these sites were compared with each other and were correlated with a quantitative estimate of habitat diversity at each site. Comparisons were also made among the three arbitrarily designated river regions (upper, middle, and lower portions of the area shown on Figure 1-5), and seasonal changes in population size and composition were documented. Species diversity indices were computed for both bird and mammal populations at each of the ten study areas, for each of the three river sections, and for the study area as a whole.

The general locations of the ten study areas along the Trinity River are shown in Figure 1-5. A 1500 meter transect line was marked and sampling stations were established along this transect at approximately 15 meter intervals at each study area. Transects were selected to best represent the areas, consequently straight transect lines were rare. A summary outline of each transect area is given in Appendix B. Habitat diversity indices were calculated for each transect and river section, and for the river as a whole, using the Shannon-Wiener function.

1.23.02 Rare, Endemic and/or Endangered Species of Animals.

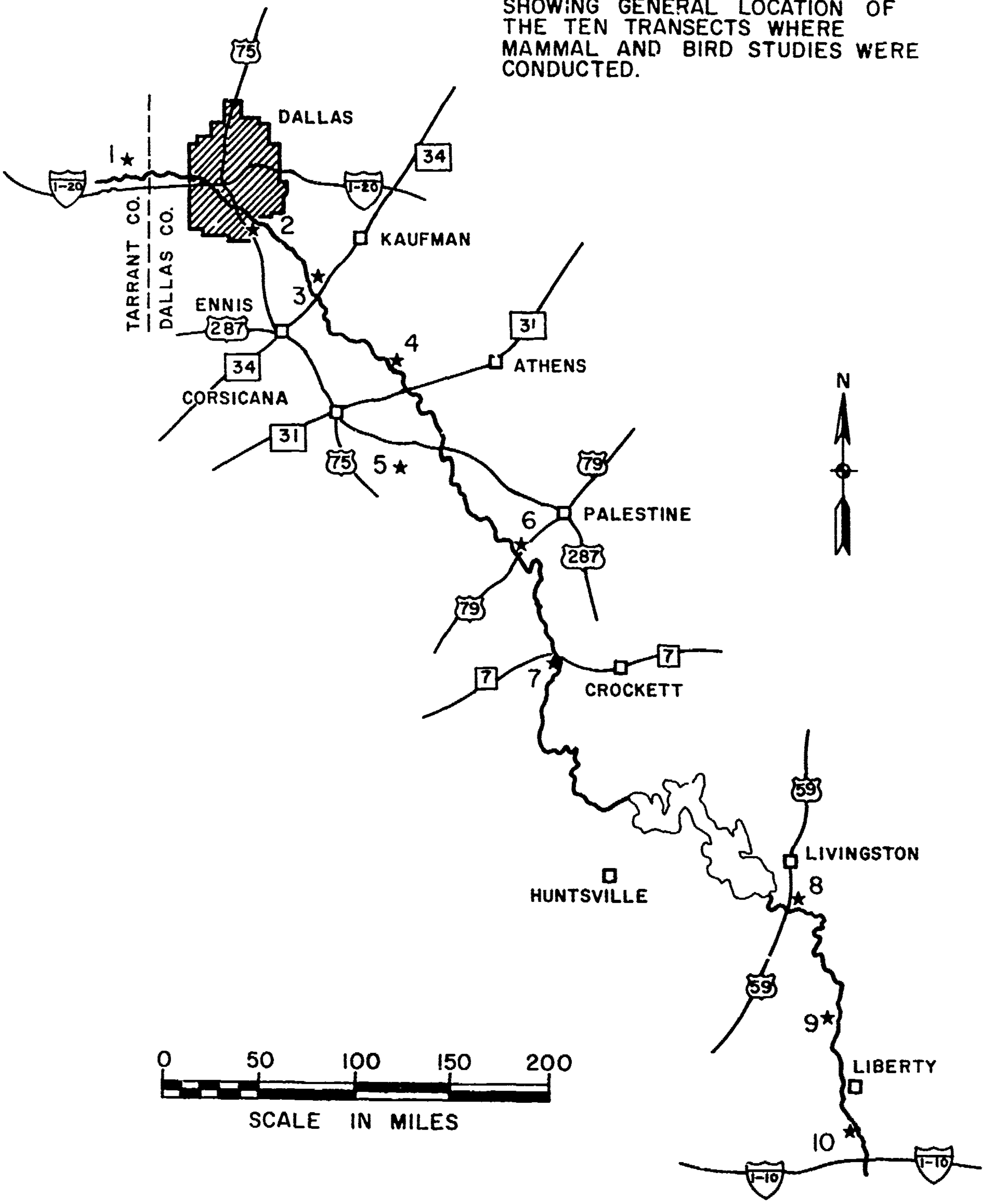
1.23.02.01 Red Wolf (*Canis niger*). The red wolf once ranged over east and central Texas north to the Red River (Davis, 1966). Recent specimens from Texas are all from the upper coastal region, in and around Chambers County. Much evidence of interbreeding with coyotes is available (McCarley, 1959 and Fisher, 1972). This interbreeding causes considerable confusion in identification. Fisher (1972) feels it is quite probable that red wolves could and probably do occasionally wander northward along the lower part of the Trinity River in Liberty County. Its preferred habitat is open areas with adequate cover, rather than extensive forests.

1.23.02.02 Cougar or Mountain Lion (*Felis concolor*). This species once ranged throughout the State, and while there are still frequent unconfirmed reports from many parts of east Texas, they are known to currently occur with certainty in Texas only in the more remote parts of south and west Texas. Even there, their numbers are dwindling. It is possible that the Tanner Bayou area is large enough to support a pair of these animals, and some residents of Liberty county have reported seeing either mountain lions or their tracks recently (Fisher, 1972). Mountain lions are not officially considered rare in the United States, but are considered rare in Texas.

1.23.02.03 River Otter (*Lutra canadensis*). This species has been positively identified from several counties in east Texas (Fisher, 1972). Fisher believes it to be a rare inhabitant on the lower Trinity River in Liberty County. Although not officially considered rare in the United States, this species is considered rare in Texas (Fisher, 1972).

FIGURE I—5

SKETCH MAP OF THE TRINITY RIVER SHOWING GENERAL LOCATION OF THE TEN TRANSECTS WHERE MAMMAL AND BIRD STUDIES WERE CONDUCTED.



1.23.02.04 Black Bear (Ursus americanus). Once found throughout much of Texas, this species is now found only in small numbers in the western mountains (Davis, 1966). The last reports of black bear from east Texas were from Tyler, Polk, and Angelina Counties; however, these reports were made at least 25 years ago and Fisher (1972) feels it is very unlikely that this species now exists anywhere along the Trinity River. Although not officially considered rare in the United States, this species is considered rare in Texas (Fisher, 1972).

1.23.02.05 Houston Toad (Bufo houstonensis). Presently known from nine isolated south-central Texas localities, including Liberty County in the Trinity River Basin, this nearly extinct species is not believed to have been signficantly greater in the past. This species is closely associated with the loblolly pine areas, and the decline of these acreages by urban growth and lumbering activities has probably caused their decline. In addition, cross-breeding with other toad species is genetically eliminating this species.

1.23.02.06 American Alligator (Alligator mississippiensis). This species is a locally frequent inhabitant of many oxbow lakes, swamps and sloughs along the Trinity River from the midbasin downstream. Suitable habitat for these reptiles is gradually diminishing throughout the United States. Although protected, they still are illegally hunted in less populated areas of East Texas (Fisher, 1972).

1.23.02.07 Wood Ibis (Mycteria americana). While the present breeding range of this species in the United States appears to be restricted primarily to Flordia (AOU, 1957), wood ibises wander widely in mid- and late-summer, reaching coastal Texas by June and then continuing inland in many localities. Fisher (1972) found them to be frequent visitors, in small groups of up to twenty individuals, along the marshes, swamps, and lakes of the Trinity River Basin during the summer.

1.23.02.08 Bald Eagle (Haliaeetus leucocephalus). A few birds of this species commonly migrate through the Trinity River Basin and are winter inhabitants along the middle to lower portions. The more remote parts of the river and the less disturbed lakes and swamps are undoubtedly used for foraging, as are Cedar Creek Lake and Lake Livingston (Fisher and Hall, 1973).

1.23.02.09 Red-cockaded Woodpecker (Dendrocopus borealis). Since this species depends on mature pine stands, it is a very local species throughout its range across southeastern United States, including east Texas. Rarely does it find suitable habitat near the Trinity River, and Fisher (1972) cited only one known occurrence at that time along the north side of Lake Livingston in Trinity County.

1.23.02.10 Ivory-billed Woodpecker (*Campephilus principalis*). This species, if not already extinct, must certainly be on the verge of extinction. There have been numerous unconfirmed sightings in the Big Thicket area of East Texas during the past 10 years (Fisher, 1972), the most publicized being those of John Dennis (Dennis, 1967). Ivory-billed woodpeckers prefers forests with a large percentage of sweetgum trees. They nearly always seek forests where an abnormal tree mortality provides the habitat for its preferred food, the larvae of wood-boring beatles. The loss of the southern bottomland hardwood forests, due to disturbance by man's activities and other causes, may have resulted in the extinction of this magnificant bird.

1.23.02.11 Peregrine Falcon (*Falco peregrinus*). This species is probably a regular winter resident along the Trinity River in small numbers. These falcons are one of the few natural enemies of the hordes of pigeons that frequent public buildings and are thus often found in and around cities; however, no peregrine falcons have been reported from cities in the Trinity River Basin, and one single bird was seen by Fisher and Hall (1973) in the upper Trinity River Basin.

1.23.02.12 Attwater's Prairie Chicken (*Tympanuchus cupido*). This species was once found in abundance along the coastal prairies of Texas and Louisiana and was heavily hunted for market. Hunting pressure, along with the plowing of the native grassland habitat, has severely depleted its numbers. Although now protected by law, its numbers have been slow to increase. Many rice farmers along the Texas coast are currently working with the Texas Parks and Wildlife Department in an effort to provide suitable habitat for the enhancement of this species.

1.23.03 Species of Undetermined Status.

1.23.03.01 Mississippi Kite (*Ictinia mississippiensis*). This species is a locally common breeding bird in parts of the Texas Panhandle and North-Central Texas. Prior to the investigation of Fisher (1972), it was not known to occur as a summer resident anywhere in East Texas. While he found no nests, Fisher (1972) felt certain that some of the adults seen in Liberty, San Jacinto, and Polk Counties along the Trinity River were breeding in the area. Mississippi kites prefer open wooded areas or scattered trees near water and are known to breed locally from the southeastern part of the Great Plains across the southern part of the United States to the Atlantic coast.

1.23.03.02 Osprey (*Pandion haliaetus*). This species is found over much of the Old and New Worlds. However, it is not common anywhere, and North American populations have declined sharply during the past 20 years. While it does not appear to be nesting in the Trinity River Basin (Fisher, 1972), this bird is a regular migrant and winter inhabitant along the Texas coast and on the larger lakes and rivers. The osprey is a fisheater, and its recent decline has been attributed largely to chlorinated hydrocarbons (DDT, DDE, etc.) in its body tissues.

1.23.03.03 Caracara (Caracara cheriway). This species is reported to occasion the Basin as far north as Navarro County (Baxter, 1974). It is a carrion eater, but is known to kill live birds, rodents, etc.

1.23.03.04 Roseate Spoonbill (Ajaia ajaja). This species nests locally along the central and upper Texas coast and elsewhere around the Gulf to Florida. It is possible that a few pairs nest in the Old River heronry (just above the Liberty-Chambers County line). After the breeding season, some individuals wander inland and can be expected almost anywhere along the river, as far northward as Dallas.

1.23.04 Introduced Animal Species.

1.23.04.01 Nutria (Myocastor coypus) are native to both sides of the Andes from Peru southward, where the animals live in the banks of waterways in burrows that they dig. A few were introduced into the United States in the 1930's for rearing as fur-bearing animals. Flooding enabled several hundred to be washed free and they have since spread over a large portion of the Gulf Coast. Nutrias are in most of east to east-central Texas including a large portion of the Trinity River.

1.23.04.02 Carp (Cyprinus carpio) were intentionally introduced from Germany in 1877 (Ehrenfeld, 1970). They have had tremendous success and now are found in virtually every stream in the United States. They are disruptive to native fish, uproot aquatic plants, disturb nesting areas of more desirable fish species, and continue to defy control. The Trinity River Basin has a plentiful supply of carp.

1.23.04.03 The Argentine Fire Ant (Iridomyrex humilis) is believed to have been introduced from Brazil via shipments of coffee in the late 1800's. In addition to destruction of crops and native vegetation, these insects are quite destructive to native ant faunas (Ehrenfeld, 1970). Fire ants are now found in parts of the Trinity River Basin, as well as much of the rest of the State and southern United States.

1.23.04.04 The African Cattle Egret (Bubulcus ibis) was first brought from Africa to British Guiana in the early 20th Century (Stefferud, 1966). The birds rapidly spread over much of northern South America, then southward into Brazil. The swiftest migrations, however, occurred northward, into Florida in the 1940's. From there, they have rapidly spread throughout a large portion of the United States. In the middle to lower Trinity River Basin, cattle egrets are commonly found nesting in the numerous oxbow lakes and sloughs. Special mention is given here because, although they are not believed to directly compete with any other animal for food, they may well have an impact on the other nesting birds of the old oxbow lakes and sloughs, such as the anhinga (Anhinga anhinga) and snowy egret (Leucophoyx thula). The impact, if one exists, is not likely to be due to competition for food, since it is well established that the cattle egret's diet is almost entirely insects and spiders. The most significant impact may be that cattle egrets, being migratory, reach the rookery areas earlier than do the herons, anhingas, and other egrets. Cattle egrets' presence in the rookeries has been described by some observers to be "upsetting" to other rookery birds.

1.23.04.05 The Asiatic Clam (Corbicula sp.) was first discovered in this country in the 1930's on the West Coast. It is known to cause problems in the water pipes and conduits and has been found in many lakes in the Trinity River Basin.

1.23.05 Game Species.

1.23.05.01 The White-tailed Deer (Odocoileus virginianus). This species is locally abundant in wooded areas along the middle river reach from Henderson to Polk and Walker Counties (Fisher, 1972). Somewhat less common along the lower river, this species is particularly numerous in partially cleared flood plain forests, where it can most often be seen at dusk. Since the white-tailed deer is an extremely popular and important game animal, many landowners lease their property for deer hunting. There are several large hunting clubs in the Trinity River Basin, including the Arizona Creek Wildlife Club in Liberty County with approximately 100,000 acres and about 2000 members (Fisher, 1972). Many sportsmen, including Mr. Walt Daniels, Texas Parks and Wildlife biologist in Fairfield, feel that deer hunting along the middle regions of the river is among the best anywhere in the State (Fisher, 1972).

1.23.05.02 Small Game Mammals. Other mammals which are extensively hunted for sport are the gray and fox squirrels (Sciurus carolinensis and S. niger) and, to a smaller degree, the swamp and cottontail rabbits (Sylvilagus aquaticus and S. floridanus). Raccoon (Procyon lotor), opossum (Didelphis marsupialis), and fox (Vulpes fulva and Urocyon cinereoargenteus) hunting are also popular sports along the Trinity River. Most of these animals are inhabitants of forested areas and provide many hours of recreation in addition to accounting for a large amount of revenue in the region.

1.23.06 Fur-Bearing Animals.

1.23.06.01 Beaver (Castor canadensis). Beavers may well be more abundant in the Trinity River watershed than anywhere else in Texas (Fisher, 1972). Beavers were re-introduced to the Trinity River from west Texas populations in the 1930's and 1940's after almost total extermination in the early 1900's. Since that time, because of the protection given them, they have made a remarkable comeback, and some residents consider them to be nuisances. Although they have valuable pelts, and permits may be obtained from the Texas Parks and Wildlife Department to trap them, there appears to be little interest in commercial trapping of beavers along the river today (Fisher, 1972).

1.23.06.02 Mink (Mustela vison) are found along all section of the Trinity River but appear to be most abundant in the wooded areas along the middle and lower reaches. Like beaver, this species appears to be of little interest to commercial trappers.

1.23.06.03 Nutria (Myocastor coypus). A third fur-bearing species, the nutria, exists in quantities which have commercial potential in eastern Texas. A large, semi-aquatic rodent, this mammal prefers quiet waters of ponds and marches or sluggish streams. Although Fisher (1972) reported no current nutria trapping, Parker (1973) reported observing piles of nutria carcasses, with skins removed, in the lower Trinity River flood plain.

1.23.07 Birds. Texas has the largest bird fauna of any of the 50 states (Peterson, 1963). More than 540 species have been recorded, excluding some extinct species. Of these 540 species, 487 can be considered to be presently found in Texas, according to Peterson. An additional 57 species, including two hybrids, have been reported in Texas fewer than five times.

Inasmuch as birds are both abundant and conspicuous, it is generally easier to obtain quantitative data on birds than it is on mammals or other kinds of terrestrial animals. Furthermore, birds are quite sensitive to quantitative and qualitative changes in the environment and their fluctuations are often one of the first clues to ecological disturbances.

Fisher and Rainwater (1972), Fisher (1972), and Fisher and Hall (1973) have made rather complete studies of the bird fauna of the Trinity River flood plain and some adjacent upland territories. Interested scientists and laymen may consult their original works for detailed information on the locations and numbers of birds enumerated in those studies, which centered on the bottomland hardwood areas adjacent to the Trinity River. Appendix B gives only the numbers and general basin locations of the birds observed by Fisher and Hall (1973).

The Texas Ornithological Society uses an 8-Region breakdown of habitats, which are relatable to vegetational areas in extent and locations. These Regions are: 1, Panhandle; 2, North Texas; 3, East Texas; 4, Trans-Pecos; 5, Edwards Plateau; 6, Central Texas; 7, South Texas; and 8, Upper Coastal Plains. The Trinity River Basin traverses portions of four of these Regions: East Texas, Central Texas, Upper Coastal Plains, and North Texas. Appendix B contains a list of those species listed by Peterson (1963) and Oberholser et al (1974) as being found in at least one of the four Regions listed above. In addition, Appendix B lists relative abundance of bird species in Texas and the United States.

The middle and lower Trinity River Basin contain numerous swamps, oxbow lakes, and sloughs, and while second-home developments have encroached upon many of these areas, a number still serve as rookery areas for large populations of birds. One such area may be seen on Photo No. 2, Appendix A. Fisher (1972) made estimates of the breeding populations of herons, egrets, ibises and other birds at four representative rookery areas. The results of his survey are illustrated in tabular form in Appendix B.

1.23.08 Game Birds.

1.23.08.01 Waterfowl. The Trinity River watershed is one of the most valuable areas in east Texas for breeding wood ducks (*Aix sponsa*). They nest in moderate densities on the wooded swamps, sloughs, and oxbow lakes in the flood plain. These areas, along with stocks tanks and coastal bays and marshes, are also utilized by many species of wintering waterfowl from October through March. A large number of hunters seek these waterfowl. The Old River Heronry, which is located about one mile west of the river and two miles north of the Liberty-Chambers County line, is a 1700-acre duck hunting preserve.

1.23.08.02 Upland Birds. The mourning dove (*Zenaidura macroura*) and the bobwhite quail (*Colinus virginianus*) are regarded as upland game species. Doves are common in open areas throughout the Trinity River Basin and are actively hunted. Bobwhite quail are rather uncommon on the upper and middle river reaches and rare on the lower river reach, inhabiting open upland fields and brush areas (Fisher, 1972). Hunting is primarily adjacent to the larger lakes, and in the coastal areas, especially in the rice-growing areas.

1.24 Fish Fauna. In a recent literature review regarding the fishes of the Trinity River Basin, Ubelaker (1972) cited the evidence of Evermann and Kendall (1892) who reported 38 species of fish, Lamb (1957) who reported 57 species of fish, and the specialized studies of Hubbs (1954, 1955).

Hubbs' (1961) Checklist of Texas Fresh Water Fishes is a useful guide to the fishes of Texas and lists fishes by geographic regions rather than by river basins.

Studies by Boyd (1968) and Altaras (1972) have documented the presence of 42 and 32 fish species in Bedias Creek and Harmon Creek, respectively. Both these streams are tributaries of the lower Trinity River. Eleven species were reported by Boyd, which Lamb (1957) did not include, and five additional species were were reported by Altaras.

Hall (1972) documented the occurrence of 84 species. A subsequent study by Fisher and Hall (1973), plus additional personal communications, (Hubbs, Conner, and Kelly, 1973) have expanded the documented list to 130 species and hybrids.

Hynes (1972), Kleerekoper (1955), Rozenberg et al. (1972), and Fisher and Hall (1973) report the general rule that the number of fish species increases from the source to the mouth of a river. This rule is applicable to rivers flowing into fresh water as well as those which enter saline or estaurine waters and apparently holds true for the Trinity River Basin (Fisher and Hall, 1973). Fifty-five species are reported in the headwaters of the Trinity River and approximately 125 species are found in the mid-to-lower Basin. Since these numbers include ubiquitous species, the numbers should be regarded as comparative and not absolute. Appendix B lists the fish species documented from the Trinity River Basin, as well as their distribution and abundance.

The fish species of any definitive habitat are dependent upon the quantity of water (including the seasonal patterns of flow maximums and minimums) and the quality of water (including dissolved oxygen, temperature, BOD, silt load, dissolved substances, etc.), as well as the nature and diversity of their habitat and the other biota present as competitors, predators, and food supply. The fish species present in the Trinity River Basin are found both "because of" and "despite" existing conditions.

Upstream from Fort Worth, where the quality of water is relatively good, numerous fish species are found. However, the quality of water from the Dallas-Fort Worth Area downstream (for distances which vary from season to season and year to year) is not now suitable for most stream fishes.

From about river mile 265 (at Texas State Highway 7) downstream, there is a rather extensive sport and/or commercial fishery. The most significant commercial fishery appears to exist in the lower Trinity River where several tons of buffalo and gar are caught and sold each week, valued upward from $1000 (Hall, 1972). Most of these are sold locally, while some are converted into fish sticks, fish cakes, etc., by processors as far away as California. Refrigerated vehicles are used to transport these fish to distant processors.

There have apparently been rather rapid changes in fish species found in the Trinity River (Hall, 1973). Certain species, such as the paddlefish and pallid shiner, have apparently disappeared from the river within recent years. The frequent flooding causes dispersal of many species into typical habitats. River modification by the Lake Livingston Dam prevents upstream migration of such fishes as the American eel and provides a lacustrine environment for a number of species. Pollution in the upper-midbasin severely limits fish species.

Fisher and Hall (1973) summarized the usual habitat preferences for most of the existent Trinity River fish species (Appendix B). The listing of a species for one habitat is not meant to imply it is found only in that habitat, rather, that it has been collected from that area.

Information received from John V. Conner (1973) indicates that the Trinity River is not believed to have any endemic fish species. One species, the emerald shiner (*Notropis atherinoides*), appears to have its western limit (in Gulf-slope streams) in the Trinity River. Conner feels it most proper to consider the Trinity River area as a part of a combined Galveston Bay Drainage (with the San Jacinto River). Viewed in this manner, the drainage to which the Trinity River belongs, forms the western Gulf-slope limit for: southern brook lamprey (*Ichthyomyzon gagei*), paddlefish (*Polydon spathula*), emerald shiner (*Notropis atherionoides*), Sabine shiner (*N. sabinae*), redfin shiner (*N. umbratilis*), blacktail redhorse (*Moxostoma poecilurum*), freckled madtom (*Noturus nocturnus*), brook silverside (*Labidesthes sicculus*), and scaly sand darter (*Ammocrypta vivax*). Additional information furnished by Conner (1973) indicates that the Trinity River forms the eastern Gulf-slope limit for populations of the following species which also occur in parts of the Mississippi drainage: stoneroller (*Campostoma anomalum*), chub shiner (*Notropis potteri*), silverband shiner (*N. shumardi*), sand shiner (*N. stramineus*), plains killifish (*Fundulus kansae*), Mississippi silverside (*Menidia audens*), and orangethroat darter (*Etheostoma spectabile*).

Most of the above species are apparently confined to the extreme upper portions of the Trinity River Basin. Silverband shiner and chub shiner are large-river forms and seem to be confined to the coastal plain. Mississippi silverside, while doubted to occur naturally, is widely distributed throughout the Trinity River.

Conner (1973) notes that several species are known to occur in adjacent stream systems in central and/or east Texas and could logically be expected to be present in the Trinity River Basin, but for which no records can be found. These include: speckled chub (Hybopsis aestivalis), ironcolor shiner (Notropis chalybaeus), blue sucker (Cycleptus elongatus), and river darter (Percina shumardi).

Fish species profiles for 18 fish species are listed in Appendix B. These cover habitat preference; reproduction; food habits; morphological-, physiological- and behavioral-specializations; and economic value. Economically valuable species have been most carefully studied and are therefore emphasized.

1.25 Trinity Bay Biota. The Trinity River empties into Trinity Bay, an important part of the Galveston Bay complex, where it supplies water to the marshes in the delta area and across the north and west sides of Trinity Bay. This marsh area consists of approximately 12 square miles outside the Wallisville salt water barrier (Solomon and Smith, 1973). Trinity Bay depends upon the river for maintenance of its salinity gradient, as was pointed out by Copeland and Fruh (1970), Espey et al. (1971), Copeland et al. (1972), Parker et al. (1972), and Solomon and Smith (1973). As regards priority of water rights in Texas, fresh water to benefit the Trinity Bay biota (or any wildlife, etc.) currently ranks last in order of priorities. The above authors cite the Trinity Bay metabolism as being heterotropic and having an excess of respiration over photosynthesis. Solomon and Smith (1973) found large benthic bacteria populations in the Trinity Bay sediments (1 billion per ml and higher) and feel that they are of major importance in the trophic energy pyramid. These bacteria were found to be primarily organic decomposers, and marsh grasses, flushed free by high flows during spring floods, contributed much of the organic detritus for those bacteria. The sediments and nutrients carried by the rivers, especially during periods of high flow, are believed to be important to Trinity Bay productivity as they replenish and nourish the marshes which subsequently reliniquish organic matter to the Bay. Phytoplankton populations in Trinity Bay are quite low (Copeland and Fruh, 1970) and, in light of the above information on bacteria, may well be of much less importance in the food chains than is true in many bays and estuaries (Solomon and Smith, 1973). Phytoplankton productivity, however, is believed to account for a significant portion of the total organic carbon present in the bay, especially during the warmer periods of the year (Solomon and Smith, 1973). Appendix B lists the abundance and distribution of selected marsh plants measured by Solomon and Smith (1973) in the upper marshes of Trinity Bay below the Wallisville salt water barrier. They found that marsh vegetation in the delta area was dominated almost exclusively by alligator weed (Alternanthera philoxeroides). As they sampled westward across the upper end of

Trinity Bay, they found the dominants to be, successively, saltgrass (Distichlis spicata spicata) during fall and winter and alligator weed in May and June, with cordgrasses (Spartina spp.) dominant throughout the year in the western extremities.

Benthic invertebrates in Trinity Bay have been sampled in recent studies conducted by Baldauf et al. (1970), Copeland and Fruh (1970), Parker (1970), Conner and Truesdale (1972), Parker et al. (1972) and Solomon and Smith (1973). The most recent of these studies (Solomon and Smith, 1973) included 51 sampling sites in the Trinity Bay marsh area and Trinity Bay proper. All the above studies were conducted prior to the construction of the salt water barrier at Wallisville, which isolated approximately 7200 acres of marsh area from the remainder of the Trinity Bay system (Solomon and Smith, 1973). It has been pointed out by Moore (1973), Conner and Truesdale (1972), and others, that the 7200 acre section behind the salt water barrier at Wallisville was one of the more productive nursery areas in the Galveston Bay complex. It cannot be assumed that all areas of intertidal marshes in the Galveston Bay Complex are of equal importance as estuarine habitat.

A large portion of the estimated 82,800 acres of intertidal marsh in the Galveston Bay System outside the salt water barrier has problems with industrial and municipal pollution. This has been compounded by the construction of a large cooling lagoon in the northwest portion of Trinity Bay which receives warm waters from an electric generating plant (Donald Moore, 1973). Cooling waters are drawn into the plant from the Tabbs Bay area, near the Houston Ship Channel, and discharged into Trinity Bay via the cooling lagoon. The relatively poor quality of the effluent has been pointed out by Parker et al. (1972). Discharge from this generating plant is expected to reach 5000 cfs (EPA, 1971a) when the plant reaches its full capacity in about 1980.

The study of Baldauf et al. (1970) revealed 106 species of macrocrustaceans and fishes in the lower Trinity River and marsh waters. Of those, 25.4 percent could be classified as residents (all stages of their life cycles were found there). Seventy-nine species (six crustaceans and 73 fishes), 74.6 percent, were considered to be transients (their reproduction seldom, if ever, occurred there, and at least one portion of their development cycle was passed outside the area). They generally found, that by species composition and by total numbers, the preponderance were marine species. Most of the marine transients were young of the same year (Conner and Truesdale, 1972).

There have been virtually no data developed regarding the dependable yields of shrimp, crabs, oysters, menhaden croakers, and other species sought by the commercial fishing industry. Commerical fishing is a very specialized predation, which is quite selective both by species and by sizes (Cronin, 1967). This predation must be regarded as disruptive to ecosystems and, although shrimp trawling has not been seriously limited except within the bays and estuaries themselves (McHugh, 1967), the catch per unit effort has been declining in recent years.

Several recent studies have been made of the fishes and shellfish of Trinity Bay as portions of studies by Bauldaul et al. (1970), Copeland and Fruh (1970), Copeland and Bechtel (1971), Conner and Truesdale (1972), Parker et al. (1972), and Solomon and Smith (1973). In addition, National Marine Fisheries, with the cooperation of the Texas Parks Wildlife Commission, annually publishes data on the Gulf of Mexico and bay fisheries.

The value of the brackish water marsh areas of the upper Trinity Bay area as nursery areas has been pointed out by most of the above listed authors. In addition to commercially valuable species, the estuarine ecosystem has many other organisms which play significant roles in ecosystem diversity and productivity. It is highly probable that many of these species, which are of little or no commercial value, contribute to the productivity as they migrate in, are eaten, or die there, contributing to the organic matter of the area. Parker et al. (1972) feel that this may be a highly significant contribution to the Trinity Bay productivity.

Nine species of shrimp of the family Penaeidae contribute to the Gulf of Mexico shrimp fishery, although only three species are caught in significant numbers. These are the white shrimp (Penaeus setiferus), brown shrimp (P. aztecus), and pink shrimp (P. duorarum) (Bureau of Commercial Fisheries, 1969). Each of these has a similar life cycle in that spawning occurs offshore. Larvae are carried by currents into shallow estuaries where they grow rapidly for two to three months. As the juveniles mature, they leave the estuaries and return offshore. The life span of the penaeid shrimp is believed to be from 18 months to several years. Fishing for shrimp occurs both in estuaries and in the offshore areas. One of the largest offshore shrimp fisheries in the Gulf of Mexico is found along the Texas Coast. The Galveston Bay complex which includes Trinity Bay, provides a large proportion of those inshore shrimp caught each year. Shrimp trawlers unloading at commercial facilities at Texas ports made nearly 72,000 trips (over 9,000 more than in 1971) into bay and Gulf waters and landed 97.6 million pounds of heads-on shrimp in 1972 (the most recent year for published data) valued at more than $80 million to the industry -- an increase of 12 percent in volume and 25 percent in value over 1971. Ninety large vessels and forty small bay vessels were added to the shrimp fleet during 1972 (Farley, 1973). Galveston Bay ports in 1972 reported 10.6 million pounds of heads-on shrimp.

Although the catches and their values vary from year to year, the total annual catch of shrimp, both in the bay and offshore, has been increasing annually, due largely to increasing effort. Tables 1-26 and 1-27 list the latest available data on shrimp catches and their value. Currently important shrimp nursery areas are illustrated on Plate 33.

Oyster (Ostrea spp.) differ from other commercially valuable species of shellfish in that they are sessile, that is, they spend a large part of their life in oyster "reefs" where their shells attach to other oyster shells or materials. Females produce about 9 million eggs which hatch about five hours after fertilization to free-swimming forms. After about 3 weeks the shell has developed, and the young oysters become attached. Sexual maturity is reached in about two years.

Commercial oyster fishermen in Texas harvested 3.9 million pounds of oyster meats in 1972, valued at $2.5 million. This amount represented a decrease of 810,000 total pounds below 1971 totals but surpassed the 1971 value by $129,000. Galveston Bay produced 83 percent of the total harvest, worth about $2.1 million. The 1971 oyster season lasted from about October 15th until the end of April in some areas, although many reefs were closed during March and April because of flood waters (Farley, 1973). Currently important oyster reefs in the Galveston Bay system are illustrated on Plate 33. From 75 to 90 percent of the harvestable oysters are presently found in the reefs between Smith Point and the Houston Ship Channel (Baxter, 1973).

Blue crabs (Callinectes spaidus) prefer shallow salt or brackish water, usually with muddy bottoms near river mouths where vegetation is abundant. Fertilized eggs are carried by females in a mass on their abdomens to offshore locations, where they hatch into free-swimming forms. The younger forms are carried by currents to shallow areas along the shore. They go through a series of molts (shedding outer shell) and become sexually mature in the third summer.

Commercial fishermen in Texas harvested 6.5 million pounds of blue crabs, valued at $653,000 in 1972. This represented gains of 200,000 pounds and $53,000 over the previous record, set in 1969. A total of 1.87 million pounds, valued at $191,649, was caught in Galveston and Trinity Bays (Farley, 1973).

Conner and Truesdale (1972), in their sampling in the upper Trinity Bay marshland (completed before the construction of the Wallisville saltwater barrier), found three species of finfish

TABLE 1-26

TEXAS COMMERCIAL LANDINGS OF FISH AND SHELLFISH IN GALVESTON AND TRINITY BAYS

FISH	1970 pounds	1970 dollars	1971 pounds	1971 dollars	1972 pounds	1972 dollars
Croaker	37,000	1,882	7,400	520	8,900	817
Drum						
Black	39,000	3,779	25,200	2,706	72,700	7,970
Red (redfish)	35,300	7,398	18,100	4,322	33,600	8,433
Flounders	27,100	5,877	18,500	4,702	21,100	6,186
King whiting	9,000	523	8,600	608	15,700	1,469
Mullet	4,500	174	14,400	458	59,400	2,849
Sea catfish	13,600	687	4,100	226	3,200	216
Sea trout						
Spotted	89,200	19,002	75,900	17,760	128.400	32,764
White	300	34	1,900	207	18,700	2,677
Sheepshead	23,500	2,087	6,100	577	27,900	3,000
Unclassified						
Food fish	46,200	2,355	30,000	1,607	44,900	3,130
Animal food, bait, etc.	7,300	221	2,000	85	59,200	2,013
TOTAL FISH	332,000	44,019	212,200	33,778	493,700	71,524
SHELLFISH						
Crabs, blue	2,622,000	244,798	2,160,800	213,240	1,870,100	191,649
Oyster meats	3,850,000	1,700,547	4,021,700	2,054,624	3,259,700	2,114,613
Shrimp (heads-on)						
Brown & pink	1,556,000	291,480	2,050,100	409,246	1,398,500	430,982
White	4,069,500	1,682,877	2,963,800	1,645,695	2,956,700	2,132,363
Squid	3,600	274	2,900	387	2,400	334
TOTAL SHELLFISH, et al.	12,101,300	3,919,976	11,199,300	4,323,192	9,487,400	4,869,941
GRAND TOTAL	12,433,300	3,963,995	11,411,500	4,356,970	9,981,100	4,941,465

Data Source: Farley (1972, 1973).

TABLE 1-27

COMMERCIAL FISHERIES DATA

STATE	FISH Million Pounds	FISH Million Dollars	SHELLFISH ET AL Million Pounds	SHELLFISH ET AL Million Dollars	TOTALS Million Pounds	TOTALS Million Dollars
Florida (West)	63	10	44	21	107	31
Alabama	15	2	19	12	34	14
Mississippi	384	7	12	5	397	13
Louisiana	1,274	22	117	50	1,391	72
Texas	70	3	97	67	167	70
TOTAL	1,806	45	290	155	2,097	199

Note: Data rounded to nearest million; totals may not add.

SUMMARY OF OPERATING UNITS, 1971

ITEM	Florida West Coast	Alabama	Mississippi	Louisiana	Texas	Total
Fishermen on vessels	3,546	1,255	1,683	5,838	5,852	13,407
on boats & shore:						
Regular	1,998	462	439	3,382	754	7,035
Casual	1,524	241	535	1,868	470	4,368
TOTAL	6,798	1,958	2,657	11,088	7,076	24,810

Source: Current Fisheries Statistics No. 6231, NOAA XCFSA-6231-SR, 1973.

accounting for more than 81 percent of the 299,686 fish specimens taken during routine sampling. The Atlantic croaker (Micropogon undulatus) was by far the most abundant species taken, accounting for more than 43 percent of the total. The bay anchovy (Anchoa mitchilli) and the Gulf menhaden (Breoortia patronus) ranked second and third, respectively. Most of the major migrating marine fishes, like the commercial shrimps, tended to concentrate in shallow, semi-enclosed areas, such as lakes and blind bayous, during their peak occupancy periods in the marshland. It is the opinion of Connor and Truesdale (1972) that ". . . the waters of the shallow marsh lakes and blind bayous are the prime habitats sought out by the very earliest immigrants representing the following species: brown shrimp, white shrimp, ladyfish (Elops saurus), Gulf menhaden, bay anchovy, Atlantic croaker, sea sand-trout, pinfish (Lagogon rhomboides), bay whif (Citharichthys spilopterus), southern flounder (Paralichthys letostigma), and hogchoker."

The 1972 Texas catch of edible finfish was 6.5 million pounds valued at $1.7 million. This catch was slightly above the 1971 volume and value. The total of all fish landed in Galveston Bay and Trinity Bay during 1972 was 493,700 pounds, valued at $71,524. These finfish consisted primarily of menhaden, croaker, sheepshead, and spotted seatrout (Farley, 1973).

Whether or not the presence of the Wallisville saltwater barrier has had any significant effect to date on the commercial fisheries is unknown; nonetheless, the 1972 grand total commercial fish and shellfish landings were lower than the 1971 landings by 1,430,400 pounds (11,411,500 pounds minus 9,981,100 pounds), a 12.5 percent reduction. All of this reduction was in the shellfish, since the finfish catch more than doubled to 493,700 pounds in 1972 from 212,200 pounds in 1971 (Table 1-26). Precise estimates of causes of productivity changes would require long and detailed studies spanning many years and a variety of flows, salinities, etc.

In order to place the importance of the Gulf fisheries in perspective, the relationship of Texas-based fishing to the other major states which border the Gulf of Mexico is given in Table 1-27. The latest year for which data concerning fishermen, vessels, tonnage, etc., on commercial fishing in the Gulf of Mexico are available is 1971.

1.26 Amphibians and Reptiles. A checklist of the Trinity River Basin amphibian and reptile species, along with their general abundance and distribution, is given in Appendix B. As might be expected, a large proportion of these species is found in the flood plain of the Trinity River. None of these species listed is endemic, and most are widely distributed throughout eastern Texas and adjacent states to the north and east. The only rare and/or endangered species known to inhabit the Trinity River Basin are the American alligator, which can be found in some of the numerous sloughs, oxbow lakes, and swamps, and the Houston toad which has been identified from Liberty County. Alligator "holes" play important roles in providing aquatic habitats for small organisms during periods of drought.

1.27 Invertebrates. A checklist of the intervertebrate species reported from the Trinity River Basin is given in Appendix B. Where known, their general distribution and abundance are given. They generally are very cosmopolitan.

Invertebrates are important organisms in both aquatic and terrestrial habitats. They play important economic roles as well. Many pest species cause millions of dollars in damage to crops, gardens, lawns, houses, etc. Many environmental problems have resulted from the use of pesticides which have caused damages to species other than the target invertebrate species. Many invertebrates are ecto- or endoparasite of other organisms, including man, or act as vectors for various diseases. For example, ticks are common throughout the basin and are usually ectoparasites on birds during their juvenile stages and on domestic and wild mammals during later stages. Mosquitoes are frequently carriers for diseases in the Trinity River Basin and may be carriers for viral equine encephalitis, malaria, and other diseases of man and other animals.

Aquatic invertebrates, in addition to being important as part of the aquatic food chains, are often useful as indicators of water quality.

There are no compilations of lists of rare and/or endangered invertebrates, but the previous discussion on Trinity Bay biota offers some insight into potential future problem areas.

1.28 Archeological Features. Plate 20 delineates the cultural complexes and distribution of known archeological sites in the Trinity River Basin.

1.28.01 Early Man. Several archeological finds have been made in the Trinity River Basin, apparently indicating the presence of Early Man (prior to 9500 B.C.). These finds include three carved stone heads from Cedar Creek terraces near Malakoff, human remains from sand pits near the Dallas fairgrounds, and seemingly manmade hearths near Lewisville. The three carved stone heads were discovered among the bones of the Columbian Elephant and the great Mastodon, but no artifacts or weapons of the hunt were found in association. The age of these heads is not known. Human remains were discovered in the Lagow sand pits, east of the Dallas fairgrounds, in apparent association with extinct Pleistocene fauna.

Excavations near Lewisville contained artifacts, including a Clovis point, which initially were associated with 21 seemingly manmade hearths. Wood from these "hearths" was radiocarbon dated at 37,000 B.P. (before present) and the validity of these tests is widely accepted. Although it was postulated that all three areas represented occupany in this time frame, more recent testing indicates that artifacts in these areas are much younger than 37,000 B.P. None of these areas contain proven Early Man sites, although it is believed that they exist in the Trinity River Basin.

1.28.02 Paleo-Indian. The Paleo-Indian Stage of occupation in Texas (9500 B.C. to 5500 B.C.) coincides generally with the Llano (9800 B.C. to 8200 B.C.) and Folsom Cultures (9200 B.C. to 7500 B.C.). These were succeeded by the Plano Culture (7000 B.C. to early Archaic) of the American Southwest. Information about these cultures is derived mainly from sites in New Mexico and Arizona, and the relationship to the upper Trinity River Basin area is based on isolated surface dart point finds (Clovis, Llano, etc.). Few sites have been scientifically excavated in Texas, but due to the surface finds, they are presumed to exist within the Trinity River Basin.

Examples of clovis points are known from most parts of Texas including the Trinity River Basin. They characterize the Llano Complex or Culture on the basis of extensive excavation at Blackwater Draw near Clovis, New Mexico, where they are repeatedly associated with extinct mammoths.

The Folsom dart point is typically fluted throughout its length. Points described as unfluted Folsom points were found in a site near Midland, Texas. They have been designated as Midland points and may be slighely younger than the fluted Folsom points. Unfluted Folsom points were also found at Trinidad, Texas, in 1946. In that year, a levee broke below the Trinidad Power Plant, washing out "bushels" of artifacts from a buried campsite. One of the points was identified as an unfluted Folsom point by Alex D. Krieger, a University of Texas archeologist. In most areas of the American Southwest, the Plano Culture succeeded the Folsom and represents the period from about 7000 B.C. to early in the Archaic Stage. Typical Plano Culture dart points include the Plainview, Meserve, and Scottsbluff, which also occur as isolated surface finds in the Trinity River Basin.

1.28.03 Archaic. The Archaic Stage spans the period from 5500 B.C. to A.D. 800, and the general characteristics of this Stage include hunting of small game, gathering of wild plants, and seasonal movement of small bands composed of several families. This Stage, as contrasted to previous Stages, is characterized by efficiency in the use of the environment. This efficiency is illustrated by seasonal movement and a varied subsistence base, focusing on one species and then another with the attendant variations in specialized tools.

The Archaic Stage is represented in the upper Basin by the Trinity Aspect, encompassing the Carrollton and Elam Foci. Plate 20 indicates the general area of Trinity Aspect influence as presented by Suhm et al. (1954). Since 1954, additional knowlege has been gained about the distribution of these culture complexes. Some archeologists might argue that the Trinity Aspect does not extend as far south as indicated (Skinner, 1974).

The Carrollton and Elam Foci are typical of, but not restricted to, the Elm Fork watershed. These Trinity Aspect sites are found throughout parts of the Blackland Prairie physiographic section and may extend into the Eastern Cross Timbers. The sites are typically found on the first terrace in the Elm Fork area. The Elam Focus represents the period from about 4000 to 2000 B.C. while the Carrollton Focus is slightly older. (Skinner, 1972).

1.28.04 Neo-American. The Neo-American is the most evident and by far the richest archeologic Stage in northeastern Texas. The time span is roughly A.D. 800 to A.D. 1600 and is characterized by the use of pottery, marginal agriculture, the use of the bow and arrow, hunting and gathering, and tribal and confederacy groups. To the east the Caddoan influence is strongly felt, represented by the Alto Focus in the midbasin area. According to Sumn et al. (1954):

> Caddoan archeology may be fairly compared with that of the Puebloan cultural pattern in the Southwestern United States in area and time depth if not in complexity . . . .

The Caddoan culture spanned the Neo-American and the Historic periods, and the term "Caddoan" is used in Oklahoma, Texas, Arkansas, and Louisiana. At present, there is some question as to whether the Alto Focus, as shown on Plate 20, extended into the Basin as far as indicated by Suhm et al. (1954). Most of the Archaic dart points persisted into the Neo-American Stage (to about A.D. 1000), but the use of the bow and arrow is one of the more definitive facets of this later Stage. Some of the more common Neo-American arrow points found in the upper Trinity River Basin are the Fresno, Alba, Cliffton, Harrell and Perdiz. The Alba, Fresno and Perdiz are common in the Galveston Bay region.

In the Dallas area the Henrietta and Wylie Foci typify the Neo-American Stage. Cliffton points and Nocona Plain pottery are diagnostic of the Henrietta Focus, and the Wylie Focus is usually identified by the presence of large circular subterranean pits. Due to the presence of East Texas trade pottery, an early Neo-American age has been assigned to the Wylie Focus.

1.28.05 Reservoir Salvage Projects. The archeology of the Trinity River Basin is considerably better known and more closely studied in the upper reaches than in other parts of the Basin. This is probably because of the larger population centers at Dallas and Fort Worth and the high degree of interest and curiosity shown over the years by both amateur and professional archeologists. Most known sites have been well described in the literature (various Archeological Salvage Project Reports, 1949 to 1973, Bulletins of Texas Archeological and Paleontological Society, 1936 to 1970, *The Record*, 1940 to 1969, *American Antiquity*, 1949 to 1958, and others) but even in this area of the Basin there are believed to be still many more undiscovered sites. Despite the relative paucity of known sites and information in the middle and lower Trinity River Basin, there is no reason to believe that prehistoric Indian occupany was any more intense in the Dallas-Fort Worth Area than in the rest of the Basin. Sorrow (1973) has estimated that there are between one and two archeological sites per mile of river in the middle and lower reaches of the Trinity River flood plain.

Reservoir salvage projects have only partially filled this gap in the overall picture of Trinity River Basin archeology. The term, "Emergency Archeology" has been used to describe the effort to secure information from sites which may be disturbed or destroyed by construction. The program typically consists of a literature search for reported sites, a ground reconnaissance, and selective excavation and testing. The program is partially or totally funded by the Federal government. A summary of data from reservoir salvage projects is presented in Table 1-28.

1.29 Historical Era. The first Indians that the Europeans encountered when they arrived in the Trinity River Basin were the historic Caddo. The 25 tribes, joined together into three confederacies, possessed the richest and most highly developed culture of all the Texas Indians. The Hasinai Confederation of the Caddo is credited with providing the State of Texas with its name, which means ally or friend (Newcomb, 1971).

The Caddo were somewhat unusual among Indians in that they shed tears easily. The generally used tanned deer skins for clothing and lived in grass lodges in small villages. The Caddo hunted with bows and arrows, raised vegetables, and were generally peaceful.

South of the Hasinai Caddo, on the lower Trinity River and other rivers, were the Bidai, Deadose, Orcoquisac, and Attacapa tribes. They were hunters, gatherers, and fishermen, and they used the game of the region for food and clothing (McDonald, 1972).

TABLE 1-28

SUMMARY OF ARCHEOLOGICAL SALVAGE PROJECT DATA

Project	Report Completed	Sites Investigated	Stages Represented	Cultures Represented	Remarks
Proposed Aubrey Lake	1973	26	Late Archaic Neo-American Historic	Henrietta Focus	Artifacts collected at all 26 sites. Many more sites believed to exist.
Bardwell Lake	1964	15	Archaic Neo-American		Most sites were shallow middens.
Cedar Creek Lake	1961, 1965	30	Late Archaic Middle Archaic Neo-American	Neo-American: Wylie Focus and Caddoan Culture	Most sites were small shallow middens. Neo-American occupancy consisted of mixed Caddoan and Wylie Focus traits.
Lavon Lake	1949	25	Archaic Neo-American	Neo-American: Wylie Focus and Caddoan Culture	Evidence suggested that Wylie Focus people were somehow related to Caddoans of East Texas and to the Southern plains.
Lewisville Lake	1973	55	Archaic Neo-American	Neo-American: Henrietta Focus, Carrollton Focus, Frankston Focus	Henrietta Focus predominates. Evidence of trade pottery from Mississippi Valley and from Mexico (Tonto Polychrome sherd). Carrollton axe.
Livingston Lake	1968	40	Late Archaic Neo-American	La Harpe Aspect Caddoan Culture	Very little pre-ceramic evidence. Complex ceramic tradition. Pottery carbon-dated at AD 540.
Navarro Mills Lake	1959	19	Archaic Neo-American Historic	Wylie Focus	Archaic evidence is a blend of Edwards Plateau Aspect and Trinity Aspect. Metal points and trade pipes reportedly collected.
Lake Ray Hubbard	1963	33	Archaic Neo-American	Wylie Focus	Caddoan trade pottery found
Wallisville Lake	1970	215	Early Archaic Archaic Late Archaic Neo-American Historic	Late Archaic: Lost River Phase, Beginning Galveston Bay Phase Neo-American: Early Galveston Bay Phase, Galveston Bay Phase	Several early Archaic artifacts recovered at surface (Albany spokeshave and San Patrice point). Evidence of early Historic Akokisa tribe at the Presidio San Augustin de Ahumada.

Attacapa means "maneater" in the Choctaw language, and it is assumed the Attacapa were cannibalistic at some time. An Orcoquisac village, and later a Spanish mission, was located on the east bank of the Trinity River above Anahuac.

In the Trinity-Polk-Tyler County region, the Coushatta Indians made their home. The Coushatta and the Alabama Indians moved into this region from the Mississippi River area sometime after 1800. The two tribes belonged to the Creek Confederacy and were generally considered friendly. In 1854 they were given a 1280 acre reservation on State owned land, located in Polk County between Livingston and Woodville. In 1927, the U.S. Congress provided money for an additional 3000 acres to be added to this reservation, the State's oldest.

The Cherokee Indians took refuge in the upper Trinity River Basin after being forced off other lands to the south and east. Several skirmishes with the military in 1839 resulted in large Indian losses. In 1843, a treaty, negotiated by Sam Houston, was signed at Bird's Fort. The fort was located about seven miles north of the present town of Arlington near the Trinity River along the road from the Red River to Austin (McDonald, 1972).

According to McDonald (1972) the history of Europeans in Texas, especially in conjunction with the Trinity River, began in 1519 when the expedition of Alonso Alverez de Pineda explored the Gulf Coast. Pineda was acting on orders from Governor Garay of Jamaica to explore from Florida to Vera Cruz. His encouraging reports to Garay resulted in several unsuccessful attempts to establish Spanish settlements.

In 1528 Cabeza de Vaca's vessel was wrecked on Galveston island near the mouth of the Trinity River. He was held captive by the Indians for what they believed to be his faith healing powers. After a period of several years he was able to make his way to Mexico. Several other expeditions by the Spanish were conducted in search of cities of gold. Their inability to locate these cities eventually led to a declining interest in eastern Texas.

Spanish interest in Texas was restimulated, and expeditions into the Trinity River Basin took place in the late 1600's. This newfound interest was due mainly to activities of the French in the area claimed by the Spanish. The threat of French activity and the friendliness of the Indians caused the Spanish to establish several missions in the north and east sections of Texas. One of these early missions, San Francisco de los Tejas, was founded in 1690 in Houston County, near the Neches River. While traveling in this region the Spanish crossed and named the Trinity River. Alonso de Leon called it the Rio de la Santisima Trinidad, or the River of the Holy Trinity (McDonald, 1972).

In 1705, A Frenchman, Louis Juchereau de St. Denis, established trade relations with the indians. In 1714, he traveled from Natchitoches to the Rio Grande, creating the Old San Antonio Road, which was later used by the Spanish to connect missions and presidios. St. Denis, while in Mexico City, married the granddaughter of Diego Ramon, a Spanish official, and in 1716 he accompanied Ramon on an expedition to establish a number of missions in east Texas. Most of these missions were abandoned by 1730 (McDonald, 1972).

In the mid-eighteenth century French activity near the mouth of the Trinity River was again of concern to the Spanish. Don Jaquin de Orobio de Basterra led a party to the region in 1745 to investigate French dealings with the Indians (McDonald, 1972). In 1754, three Frenchmen and two Negro slaves were arrested near the mouth of the river for selling guns and ammunition to the Indians. It was reported in 1755, that a boat had come from New Orleans and sailed into the mouth of the river and other Frenchmen had come by horseback. This activity caused the Spanish viceroy to convene a council of war in 1756. The council declared that a presidio, with thirty soldiers and a mission, under the direction of the Franciscan College at Zacatecas should be established among the Indians of the lower Trinity River. The presidio, San Agustin de Ahumada, was built and Father Romero from Los Ais founded the mission Nuestra Senora de la luz del Orcoquisac. Prior to abandoment of this area in 1771, the Spanish established the military highway, Atascosito Road, which extended eastward from Refugio to the Trinity River (Plate 21).

In 1773, all Spanish settlers were ordered by Governor Ripperda to withdraw to San Antonio. After reaching San Antonio they petitioned the Governor for permission to return to their homes. Ripperda did not permit them to return to their homes but did allow them to go as far as Paso Tomas, at the crossing of the Trinity River on the Old San Antonio Road. It was here the Spanish, in 1774, established the settlement known as Nuestra Senora del Pilar de Bucareli. The settlement was raided by Comanche Indians in May and October of 1778. The spring of 1779 brought Trinity River floodwaters, and the settlers decided to abandon the settlement and traveled eastward. In April of 1779, they established the community of Nacogdoches, the third permanently settled area in Texas (McDonald, 1972).

The nineteenth century ushered in some changes in the Trinity River Basin, although Anglo-Americans had already entered Spanish Texas illegally. In 1800, Charles Boyles was allowed to establish a ferry on the Trinity River. This franchise was revoked, however, when it was discovered that he had permitted smuggling by admitting a boat from New Orleans. The purchase of Louisiana by the United States in 1803 increased the Spanish fears of an American takeover, as did the regional activities of mustanger Philip Nolan. As a result of these activities, the commander of Spanish forces in Texas, Nomesio Salcedo, ordered troops to occupy the old presidio at the mouth of the Trinity River. Another result of this action was the founding of Villa Santisima Trinidad de Salcedo in 1806 on the bank of the Trinity River near the crossing of Old San Antonio Road (McDonald, 1972). After a slow start this settlement attained a population of nearly one hundred persons by 1809, but thereafter the population dwindled, and it was abandoned in 1813 (Sorrow, 1973).

Barr and Davenport's large cattle ranch preceded the 1821 establishment of Robbins' Ferry at the crossing of the Trinity River and Old San Antonio Road. The agricultural potential of the valley had already attracted settlers who anticipated using the river as a means of transporting their produce. Settlers who came by land generally located near one of the three earliest established crossings, Magnolia, Robbins' Ferry, or Liberty.

In the 1820's the Trinity River had several impressarial grants along its banks. Stephen F. Austin was among those given permission to settle portions of these grants, which, according to McDonald (1972), included Cameron's Grant in the headwaters, Filisola's Grant, the western half of David G. Burnet's Grant and Joseph Vehlein's Grant on the Trinity's western edge near Galveston Bay. McDonald (1972) stated that:

> Among the early American visitors to the Trinity River was Frederick Law Olmstead, one of the famous early nineteenth century traveler-observers. Olmstead was touring Texas and reporting on his adventures for the land-hungry American audience. His descriptions are valuable both for what he saw and for what his writings produced in America. He approached the Trinity River by land and had an eventful and perilous crossing at a ferry. He observed that the Trinity River was considered the "best navigable stream of Texas," but noted that there had been no rise in the winter and that no rise meant no navigation for six months. At high water he was told that it was navigable all the way to the Forks region, but this is questionable. Travelling the river, he reported that the lower regions were filled with canebreaks and thick undergrowth, especially vines, among the hardwood trees. Farther up-river, however, this gave way

to a prairie that was well suited to grazing, and in the headwaters region the country was fine for planting cotton, wheat, and corn.

Apparently the only significant role the Trinity River played in the Texas Revolution had to do with the "Wild melee known as the Runaway Scrape" (McDonald, 1972). In March of 1836, Americans were attempting to flee into Louisiana ahead of General Santa Anna's armies and were temporarily stopped by the floodwaters of the Trinity River. The established route of travel through the Liberty area was by way of the Atascosito Road. Because of the swollen river, most of the belongings of those fleeing were discarded along the western banks of the river.

After the Texas Revolution, new towns were established because of the influx of people. This in turn was followed by the advent of steamboats and river landings. In the late 1830's, a mail route was established that crossed the Trinity River. Of special interest, although not in the Trinity River Basin, two brothers from New York, John C. and Augustus K. Allen, purchased some land on Buffalo Bayou in what is now Harris County. There in August of 1836, was established the settlement named for Sam Houston. The city of Houston was destined to have a great impact on the Trinity River and its Basin.

The development of the upper Trinity River did not begin until the early 1840's. In 1840, Jonathan Bird established a fort on the military road that ran from the Red River to Austin, near where the road crossed the Trinity River, and it was there in 1843 that Houston negotiated an important peace treaty with the Indians (McDonald, 1972). It was also in 1840 that John Neely Bryan established a ferry at the confluence of the West Fork and Elm Fork of the Trinity River. Although early growth of this settlement, which became the City of Dallas, was relatively slow, the river and rail connections gave it the impetus to become a fast growing city. On the bluffs along the West Fork, the settlement of LaReunion was established by Victor Considerant in 1855. This settlement was abandoned in 1858, however, and many of the inhabitants moved to Dallas.

Fort Worth, which was originally Camp Worth, came into being in 1849. The military abandoned the fort in 1853, however, and a civil settlement replaced it. In contrast to Dallas which became a mercantile center, Fort Worth became one of the world's largest cattle markets and is still referred to as "Cowtown."

1.30 Navigation History. Although early Spanish explorers recognized navigation possibilities on the Trinity River, they did not pursue this possibility. It was not until the nineteenth century that serious consideration was given to navigating the Trinity River. McDonald (1972) states:

The most important aspect of Anglo-American utilization of the Trinity River in the nineteenth century deals with its steamboat activity. Long considered a prime prospect for such utilization, it was regularly open only as far as Liberty and/or some distance above, but gradual efforts were put forth to make it navigable all the way to the Forks Region. Serious traffic on the Trinity began as early as 1836. In that year Mrs. Mary Austin Holly said that the river was navigable for about two hundred miles. In 1838 the Branch T. Archer ascended the river to Cincinnati, taking advantage of a series of rains in May that had swollen the stream. The captain agreed to establish a regular run between Galveston and Cincinnati, when possible, and the proprietor of that city, James C. Dewitt, agreed to provide sufficient business and donate some town lots. In the next year other vessels, the Pioneer, the Corerreo, the Friend, the Trinity, and others made the voyage to Cincinnati. In the early 1840's the Ellen Frankland and the Vesta joined in plying the river, the latter going as far as Magnolia, the landing place that serviced Fort Houston, and later a thriving town in its own right. In 1843, the English observer, William Bollaert, descended the Trinity River aboard the Ellen Frankland. By spring 1843, some smaller vessels were making it all the way to the Forks Region, near the soon-to-be established community of Dallas, although regular sailing that far inland was not regularly established. In 1868 Captain James Garvey tied up his sixty-foot sternwheeler in Dallas, the first steamer to ascend the river that far. He had taken one year and four days for the trip, with time out for removing logs and snags.

In 1871, a Federal project was authorized to provide a navigation depth of 5 feet from Galveston Bay to Liberty, Texas. In May, 1893, the "H. A. Harvey, Junior" arrived in Dallas. This small steamboat was greeted by a mass of people and gave rise to celebrations and festivities. However, the wide variations in streamflow, coupled with the influx of railroads, caused the decline in steamboat activities on the Trinity River.

In 1902, Congress authorized a 6-foot navigation project to Dallas to be achieved by channel modification and a system of 37 locks and dams. Seven of the locks and dams and one auxiliary dam had been completed in several disconnected reaches by 1917. The difficulty of maintaining open river navigation between the widely separated navigation pools led the Congress to abandon the project in 1922, except for the 41-mile reach from the mouth of the river to Liberty, Texas. The locations of several of these old locks and dams are shown on Plate 21.

A list of nineteenth century boat landings on the Trinity River, as compiled by McDonald (1972), is presented in Table 1-29. This list shows the approximate distance these landings were located from Galveston. The locations of some of these landings are also shown on Plate 21. Some of these settlements existed only a short time, while others are still in existence. Although a number of these small communities were short-lived, their contributions to the growth of the Trinity River Basin were important.

1.31 National Register of Historic Places. Sixteen of the many historic sites currently listed in the National Register (National Park Service, 1975) are located in the Trinity River watershed. Those sites located in the Trinity River Basin from Tarrant County through Chambers County follow:

CHAMBERS COUNTY

Cove vicinity, Site 41 CH 110, east of Cove and north of U.S. 10.
Wallisville vicinity, Orcoquisac Archeological District, north of Wallisville on Lake Miller.

DALLAS COUNTY

Dallas Swiss Avenue Historic District, Swiss Avenue between Fitzhugh and LaVista.

ELLIS COUNTY

Waxahachie, Waxahachie Chautauqua Building, Getzendaner Park.

HOUSTON COUNTY

Crockett, Monroe-Crook House, 707 East Houston Street.

LIBERTY COUNTY

Dayton vicinity, Site 41 LB 4, 12 miles southeast of Dayton.

TARRANT COUNTY

Fort Worth, Flatiron Building, 1000 Houston Street.

Fort Worth, Gulf, Colorado & Sante Fe Railroad Passenger Station, 1601 Jones Street.

TABLE 1-29

BOAT LANDINGS ON THE TRINITY RIVER, NINETEENTH CENTURY

Name of Landing	Distance from Galveston (Miles)	Name of Landing	Distance from Galveston (Miles)
Mouth of Trinity River	55	Washington's West Side	201
Wallisville	60	Drew's Landing (East Side)	204
McManus Landing	68	Summer's	207
Moss Bluff	83	McCardell's or Willow Bluff (East Side)	208
Moors Bluff	90	R. Smith's	210
J. Garner's	102	Cedar Landing	215
Liberty	103	Victory (East Side)	219
Rodger's	104	Swartwout (East Side)	221
Green's Ferry	109	Pinkney's Bluff	227
Green's Mill	110	Green's Landing	242
Hardin's	127	Johnson's Bluff (West Side)	244
Robinson's Bluff	147	Harrell's Landing (West Side)	252
Tanner's	149	O. Wheler's Landing	258
General J. Davis Landing	157	Wood's Landing	261
Farrior's	165	Patrick's Ferry	262
Field's	168	Foster's Yard	267
Long's	182		
Nevill's	183		
Ellis & Cherry	184		
Cut Off	192		
Smithfield	200		

(Continued)

Name of Landing	Distance from Galveston (Miles)	Name of Landing	Distance from Galveston (Miles)
Fry's & Lumpkin's Landing	270	Tuscaloosa or Weiser's	315
West Lumpkin Lodge	271	Goree's Landing	320
Ryan's or Bern's Ferry	272	Osceola or Calhoun	321
Sol Adam's Landing	274	Mrs. Wright's	325
Sebastopol	276	Spanish Bluff	335
White Rock	278	Westmoreland	336
Carolina	282	Clark's Bluff	339
F. B. Sublett's	283	Clapp's Ferry	347
McDonald's Landin	284	Bogman's Landing	353
Thomas' Landing	285	Cairo	362
Newport	286	Warren's Landing	372
Stubblefield	289	Alabama	377
D. Ferris Bluff	293	Robins Bluff	380
Harrison's Bluff	294	Adair's Landing	382
Mrs. McKinley's Landing	298	Brookfield Bluff	388
		J. Still Landing	389
Alfred's Bluff	302	Beaver's Landing	395
J. C. Dunlap's	304	Kickapoo	396
Whites Old Ferry	311	Hall's Bluff	398
Cincinnati	313	Barkley's or Hogpen Bluff	400

(Continued)

Name of Landing	Distance from Galveston (Miles)
Dangerfield's	406
J. Smith's Landing	410
Navarro	418
Bannerman's	425
Magnolia (Near Palestine)	440
Blacksher's	448
Bonner's Ferry	458
Parker's Bluff	461
Haygood's Ferry	467
West Point	469
Evan's Landing	481
Pine Bluff Ferry	496
Green's Bluff	512
Ingrum's Bluff	521

Source: McDonald, 1972.

Fort Worth, Knights of Pythias Building, 315 Main Street.

Fort Worth, Pollock-Capps House, 1120 Penn Street.

Fort Worth, Tarrant County Courthouse, bounded by Houston, Belknap, Weatherford, and Commerce Streets.

1.32 State Historical Markers. In addition to the aforementioned National Historical Places, numerous other sites are registered in the Texas State Historical Survey Committee's publication of State Historical Markers (1971). The large number of markers located in the counties of the Trinity River watershed indicates a growing interest in local historical happenings.

1.33 Water Resource Development History. The end of the nineteenth century gave rise to a new era in the Trinity River Basin. Wells, river water, and cisterns were no longer considered the most feasible ways to supply the citizens of Dallas and Fort Worth with sufficient water, and dams began to be built to assist in supplying water. As the population of the region increased and the region became more urbanized, more water storage facilities were needed for a variety of purposes. As a result, many levels of government became involved in water development projects. A chronological listing of the major lake projects in the Trinity River Basin, citing their original purposes, is shown in Table 1-30.

1.34 Ethnic Cultures. Because of the pattern of settlement in the Trinity River watershed, only remnants of ethnic cultures exist. The early pioneers that entered the Basin originated mostly from southern states, and the intermingling of the immigrants tended to further reduce traditions generally attributed to ethnic cultures (Texas Tech University, 1972).

The city of Ennis, located on Interstate Highway 45 south of Dallas, contains a large Czech population which settled in the area in the 1800's. This group maintains close cultural ties with Czechoslovakia, and during the first weekend in May, the community stages a polka festival. The festival is devoted to Czech music, foods, and dances (Texas Tech University, 1972). There is also a major Czech settlement in Dallas, but it is less conspicuous in this large metropolitan city, according to Henderson (1973).

The cities of Dallas and Fort Worth presently have concentrations of Swedes, Swiss, Greeks, and Lebanese. In the 1840's the Peters Colony brought English colonization in the upper Trinity River Basin, and the La Reunion colonial experiment near Dallas in 1855 added French flavor. Included in the Basin's melting pot are people of Italian, Polish, Russian, German, and Irish descent. Henderson (1973) states that the largest immigrant group to Texas has been predominately of English, Irish, and Scottish ancestry, and they account for over half of the Texans enumerated in 1970.

TABLE 1-30

BASIN LAKES HISTORICAL DATA

Name	Tributary or River	County(ies)	Owner	Completion Date	Original Purpose
Record Crossing Dam	Elm Fork	Dallas	City of Dallas	1895	1
Bachman Lake	Bachman Branch	Dallas	City of Dallas	1903	1
California Crossing	Elm Fork	Dallas	City of Dallas	1910	1
Carrollton Dam	Elm Fork	Dallas	City of Dallas	1911	1
White Rock Lake	White Rock Creek	Dallas	City of Dallas	1912	1,3,4
Lake Worth	West Fork	Tarrant	City of Fort Worth	1914	1
Lake Halbert	Elm Creek	Navarro	City of Corsicana	1921	1,3
Trinidad Lake	Unnamed Slough	Henderson	Texas Power & Light Company	1925	4
Lake Dallas	Elm Fork	Denton	City of Dallas	1927	1
Bridgeport Reservoir	West Fork	Wise, Jack	Tarrant County WC&ID No. 1	1931	1,2
Eagle Mountain Reservoir	West Fork	Tarrant	Tarrant County WC&ID No. 1	1932	1,5
Mountain Creek Reservoir	Mountain Creek	Dallas	Dallas Power & Light Company	1936	4
Benbrook Lake	Clear Fork	Tarrant	U.S. Government	1950	1,2,7
Grapevine Lake	Denton Creek	Tarrant, Denton	U.S. Government	1952	1,2,7
Lavon Lake	East Fork	Collin	U.S. Government	1952	1,2
Anahuac Lake	Turtle Bay	Chambers	Chambers-Liberty Navigation Dist.	1954	5
Lewisville Lake	Elm Fork	Denton	U.S. Government	1955	1,2,3
Terrell Reservoir	Muddy Cedar Creek	Kaufman	City of Terrell	1955	1,3
Lake Amon G. Carter	Big Sandy Creek	Montague	City of Bowie	1956	1
Lake Waxahachie	South Prong Waxahachie Creek	Ellis	Ellis County Water Improvement Dist.	1956	1
Weatherford Lake	Clear Fork	Parker	City of Weatherford	1957	1
Lake Arlington	Village Creek	Tarrant	City of Arlington	1957	1,4
North Lake	South Fork, Grapevine Creek	Dallas	Dallas Power & Light Company	1957	4
Marine Creek Lake	Marine Creek	Tarrant	Tarrant County WC&ID No. 1	1958	1,2
Navarro Mills Lake	Richland Creek	Navarro, Hill	U.S. Government	1963	1,2
Cedar Creek Reservoir	Cedar Creek	Henderson	Tarrant County WC&ID No. 1	1965	1,3
Bardwell Lake	Waxahachie Creek	Ellis	U.S. Government	1965	1,2
Lake Ray Hubbard	East Fork	Kaufman	City of Dallas	1967	1
Houston County Lake	Little Elkhart Creek	Houston	Houston County WC&ID	1968	1
Lake Livingston	Trinity River	Walker, Trinity, Polk, San Jacinto	Trinity River Authority	1968	1,5
Fairfield Lake	Big Brown Creek	Freestone	Industrial Generating Company	1969	4
Wallisville Lake	Trinity River	Chambers	U.S. Government	under const.	1,3,6,7

1. Water Supply
2. Flood Control
3. Recreation
4. Condenser-Cooling Water for steam electric generators
5. Irrigation
6. Salinity Control
7. Navigation

With the influx of settlers from the southern states after 1821, many Negroes were brought to Texas as slaves. Henderson (1973) reported that since 1880, emigration of Negroes has exceeded immigration, and that in 1970, approximately 12.5 percent of the population of Texas was Black.

About 20 percent of the State's current population is composed of Mexican Texans. Ample evidence of the influence attributed to their culture exists in the form of food, language, music, and architecture throughout the Trinity River Basin.

There is little difference between Texas and the remainder of the United States in the trends of ethnic cultures. As the citizens have become increasingly more mobile and have acquired more formal education, practices and modes of life attributed to ethnic cultures have tended to become blended and modified. This trend is expected to continue into the future, with some portions of cultural patterns being retained and others being modified or discontinued.

1.35 <u>40-County Survey Area</u>. An area consisting of 37 counties in the Trinity River watershed, together with Montgomery, Harris, and Galveston Counties, was selected for surveying past, present, and future trends in specified parameters of socio-economics. This area, referred to as the "40-County Survey Area," or "Survey Area," was selected because of its proximity to the Trinity River and the influences the Trinity River and the Survey Area have on one another. The latest available census data were used in analyzing these parameters.

1.35.01 <u>Demography</u>. The State of Texas, comprised of 254 counties, had a population of 11,196,730 in 1970. Of these, 4,898,615, or 44 percent, resided in the 40-County Survey Area (Plate 23). Concentration of the Texas population in the Survey Area has steadily increased since 1930. The majority of the 1970 Survey Area's population, 77.3 percent, was concentrated in three counties: Dallas, Harris, and Tarrant. The nuclei for these three county populations are the cities of Dallas, Houston, and Fort Worth.

Population changes from 1960 to 1970 for the State of Texas and the 40-County Survey Area are shown on Plate 23. One-third of the counties in the Survey Area had population losses ranging from 1.3 to 12.2 percent, while two-thirds of the counties in the area had population gains of 1.9 to 84.3 percent. If present trends continue, the 40-County Survey Area population will double by the year 2010 and contain over half of the State's people. The graph depicting population change (Plate 23) indicates that those counties surrounding the metropolitan areas generally are gaining in population while those in rural areas are declining. Development of water supply lakes in the Survey Area has contributed to rapid growth in the areas immediately surrounding the lakes. A continuation of the accelerated population growth around Lake Livingston and Cedar Creek Lake is expected.

In 1970, 79.8 percent of the population of Texas resided in urban areas of 2500 or more, while in the United States 73.5 percent of the population was classified as urban. The 40-County Survey Area, with an 87.3 percent urban population in 1970 (Table 1-31), was more urbanized than either the State or the Nation, principally because of the high urban percentage (97.6 percent) of three counties: Dallas, Harris, and Tarrant.

1.35.02 Standard Metropolitan Statistical Area. Population growths from 1960 to 1970 in the Standard Metropolitan Statistical Areas (SMSA) of Texas (Plate 22) ranged from a decrease or moderate increase in population in south and west Texas to a substantial gain in population in the 40-County Survey Area. Dallas, Fort Worth, Galveston-Texas City, and Houston SMSA's contained 39.9 percent of the State's entire population in 1970. This represents an increase of 6 percent over 1960. Dallas, Harris, and Tarrant Counties contained 33.8 percent of the State's population in 1960.

1.35.03 Rural Population. The number of rural families in the United States has remained relatively constant since 1940, about 14 million. The total number of families in the United States had increased by 1970 to 52 million, some 20 million more than in 1940. Thus, the increase in number of U.S. families has all occurred in urban areas.

Although the number of rural families has remained relatively constant, the number of farm families has decreased. Farm families constituted one-third of all families in 1900, one-fifth in 1940, and only one-twentieth in 1970. Thus, in 1970, 27 percent of all families were considered rural families, but only 5 percent were classified as farm families. The 22 percent difference between farm families and total rural families is evidently made up of persons living in rural areas but traveling to urban areas for employment.

1.35.04 Population Density. The United States had a population density of 57.4 persons per square mile in 1970. The State of Texas in 1970 had a density of 42.7 persons per square mile, an increase of 6.3 persons per square mile in a ten year period. The urban counties of Dallas, Harris, and Tarrant had an average density of 1099 persons per square mile (Table 1-32). The remaining 37 counties in the 40-County Survey Area had a density of only 34.4 persons per square mile. Considering the 40-County Survey Area as a unit, the influence of Dallas, Harris, and Tarrant Counties'

TABLE 1-31

POPULATION DISTRIBUTION

	State Population 1970	40-County Survey Area Population 1970	Dallas, Harris, & Tarrant Counties 1970
URBAN	79.8%	87.3%	97.6%
RURAL	20.2%	12.7%	2.4%

	Total Population	Urban Population	Total Rural Population	Farm Population	Rural Non-farm Population	Civilian Labor Force
State Population Percentages (1970)	100.0	79.8	20.2	3.4	16.8	38.4
Percentage of State Population in 40-County Survey Area (1970)	44.0	47.9	27.5	20.0	29.0	47.7
Percentage of State Population in Dallas, Harris & Tarrant Counties (1970)	33.8	41.3	5.1	1.7	5.8	37.9
Percentage of 40-County Survey Area Population in Dallas, Harris & Tarrant Counties (1970)	77.3	86.4	18.4	8.5	19.8	79.4

Data compiled
from: U. S. Bureau of the Census County and City Data Book, 1972.

TABLE 1-32

TEXAS AREAS AND POPULATION DENSITIES

	Percent of State Population (1970)	Percent of 40-County Survey Area Population (1970)	Percent of State Land Area (1970)	Percent of 40-County Land Area (1970)	Population density (per square mile) (1970)
State of Texas	100.0	---	100.0	---	42.7
40-County Survey Area	44.0	100.0	13.65	100.0	137.0
37 County Area (excludes Dallas, Harris & Tarrant Counties)	10.2	22.7	12.33	90.38	34.4
Dallas, Harris & Tarrant Counties	33.8	77.3	1.32	9.62	1,099.
Dallas County	11.85	27.1	0.33	2.40	1,545.
Harris County	15.56	35.6	0.66	4.81	1,011.
Tarrant County	6.40	14.6	0.33	2.40	832.

Data compiled from: U. S. Bureau of the Census County and City Data Book, 1972.

populations becomes apparent. Mainly because of these three counties, the Survey Area has an average density of 137 persons per square mile.

The trend toward population concentration appears to be continuing and will result in an even greater density in the eastern portion of Texas, especially within the 40-County Survey Area.

1.35.05 Standard Metropolitan Statistical Area Population Density. Table 1-33 indicates the population densities of various SMSA's of comparative size within the United States. The ranking, based on populations of all SMSA's within the United States, was utilized as the basis for selecting the SMSA's for comparison.

It can be determined from the table that, although the metropolitan areas within the Survey Area have population densities greater than some of the other SMSA's, the majority of the statistical areas of comparative size have densities exceeding the SMSA's within the Survey Area.

1.35.06 Median Age. The median age of Texas citiziens in 1970 was 26.6 years (Table 1-34). Thirty-five of the 40 counties in the Survey Area had residents whose median age was greater than that for the State. Of the five counties that were at or below the State level, three were the metropolitan counties of Dallas, Harris, and Tarrant.

1.35.07 Birth Rate. The birth rate in the State of Texas in 1968 was 19.3 per 1000 population. Only one county in the Survey Area, Dallas, with 20.3 per 1000 population exceeded the State level (Table 1-34).

1.35.08 Death Rate. In 1969, Texas had a death rate of 8.5 per 1000 population (Table 1-34). Thirty-three of the 40 counties in the Survey Area exceeded this rate. The death rates in the metropolitan counties of Dallas, Harris, and Tarrant were all below the State level.

The above statistics indicate that the three metropolitan counties of Dallas, Harris, and Tarrant will continue to grow in population, and that the rural county tendency toward population loss may also continue, based on median age, birth rate, and death rate data.

1.35.09 Civilian Labor Force. In 1970, 38.4 percent of the Texas population was in the civilian labor force (Table 1-31). Nearly one-half, 47.7 percent, of this force was in the 40-County Survey Area. Dallas, Harris, and Tarrant Counties contained 37.9 percent of the State's total civilian labor force, and this accounted for

TABLE 1-33

STANDARD METROPOLITAN STATISTICAL AREAS(SMSAS) POPULATION DENSITIES

Population Rank in U.S.	SMSA	Land Area (Sq. Mi.)	Density (Persons/Sq.Mi.)
12	Cleveland, Ohio	1,519	1,359
13	HOUSTON, TX	6,286	316
14	Newark, NJ	701	2,654
15	Minneapolis-St. Paul, Minn.	2,107	861
16	DALLAS, TX	4,564	341
17	Seattle-Everett, Wash.	4,229	337
42	Memphis, Tenn.-Ark.	1,363	565
43	FORT WORTH, TX	1,607	474
44	Birmingham, Ala.	2,721	272
162	Racine, Wis.	337	508
163	GALVESTON-TEXAS CITY, TX	399	426
164	Lincoln, Nebr.	845	199

Data compiled from: U. S. Bureau of the Census County and City Data Book, 1972.

TABLE 1-34

CENSUS DATA

Area	1970 Urban	1970 Median Age	1968 Birth Rate	1969 Death Rate	1969 Per Capita Money Income
United States	73.5%	28.3 yrs	17.5*	9.5*	$3,119
State of Texas	79.8%	26.6 yrs	19.3*	8.5*	$2,792
Number of Counties of 40-County Survey Area above State Level	4	35	1	33	8
Number of Counties of 40-County Survey Area at, or below, State Level	36	5	39	7	32
Dallas County	99.0%	26.4 yrs	20.3*	7.4*	$3,660
Harris County	95.5%	25.8 yrs	19.2*	7.0*	$3,391
Tarrant County	96.7%	26.6 yrs	18.9*	7.7*	$3,307

*Per 1,000 population

Data compiled from: U. S. Bureau of the Census County and City Data Book, 1972.

79.4 percent of the Survey Area's total. The concentration of a labor force in urban areas is to be expected since employment opportunities and labor forces tend to compliment one another.

1.35.10 Business and Industrial Activity.

1.35.10.01 Retail Trade. In 1967 (latest available data year), the 40-County Survey Area contained 38.8 percent of the State's 110,805 retail trade establishments. These establishments accounted for 45.8 percent of the State's sales and employed 45.6 percent of the State retail trade paid employees (Table 1-35). Dallas, Harris, and Tarrant Counties housed 27.7 percent of the State's retail trade establishments. These three counties also transacted 23.5 percent of the State's retail sales, accounted for 37.9 percent of the State's retail trade paid employees, and provided 41.1 percent of the payroll attributed to retail trade.

1.35.10.02 Wholesale Trade. The 40-County Survey Area contained 46.2 percent of the State's 19,136 wholesale trade establishments in 1967 (Table 1-35). The establishments in this Survey Area accounted for 66.1 percent of the total State sales, 56.3 percent of its paid employees, and 63.1 percent of its wholsesale trade payroll. Dallas, Harris, and Tarrant Counties, with 86.1 percent of the Survey Area's wholesale trade establishments located within their boundaries, had 96.6 percent of the Survey Area's wholesale trade sales. Of the 40 counties in the Survey Area, these three urbanized counties employed 95 percent of the paid employees and accounted for 96.6 percent of the industry's payroll.

1.35.10.03 Manufacturers. Over one-half (53.7 percent) of the State's 12,722 manufacturing establishments in 1967 were located in the 40-County Survey Area, and 82 percent of these (44.1 percent of the State's total) were located in Dallas, Harris, and Tarrant Counties (Table 1-35). The establishments within the Survey Area employed 59 percent of the industry's employees, with 87 percent of these being employed in Dallas, Harris, and Tarrant counties. Value added by manufacture (VAM) in the 40-County Survey Area in 1967 was 56.1 percent of the State's total VAM. Dallas, Harris, and Tarrant counties accounted for 84.5 percent of the Survey Area's VAM and 47.4 percent of the State's VAM.

1.36 Drilling and Mining. The Trinity River Basin counties with an area comprising about 12.4 percent of the state of Texas, produced about 9.4 percent of the State's mineral value in 1972 (latest data). Chambers, Van Zandt, Wise, Henderson, Anderson, and Denton Counties led the Trinity River Basin, in that order, in mineral production value, each exceeding $40 million. Table 1-36 shows the quantity and value of 1972 mineral production and relates State production to National production quantities. Trinity River

TABLE 1-35

BUSINESS AND INDUSTRIAL ACTIVITY, 1967

	State Totals (1000's)	Percentage of State Industries in 40-County Survey Area	Percentage of State Industries in Dallas, Harris & Tarrant Counties	Percentage of 40-County Survey Area Industries in Dallas, Harris & Tarrant Cos.
RETAIL TRADE				
All Establishments	110.8	38.8	27.7	71.4
Sales	16,448,608.0	45.8	23.5	51.4
Payroll	1,804,815.0	48.1	41.1	85.5
Paid Employees	513.7	45.6	37.9	83.3
WHOLESALE TRADE				
All Establishments	19.1	46.2	39.8	86.1
Sales	23,929,334.0	66.1	63.8	96.6
Payroll	1,218,719.	63.1	60.9	96.6
Number Paid Employees	198.7	56.3	53.5	95.0
MANUFACTURES				
Total Establishments	12.7	53.7	44.1	82.0
Total Number of Employees	957.5	59.0	51.3	87.0
Payroll	4,340,400.0	63.2	56.5	89.4
Value Added by Manufacture	10,922,400.0	56.1	47.4	84.5

Data compiled from: U. S. Bureau of the Census County and City Data Book, 1972.

TABLE 1-36

TEXAS MINERAL PRODUCTION

Mineral	1972 Quantity	1972 Value (thousands)	Quantity as % of U. S.	Number of operations by principal producers in Texas	Number of operations by principal producers in Trinity Basin Counties
Cement:					
Portland----------------thousand short tons	7,813	$ 171,642	10.0	17	4
Masonry--------------------------do--------	217	5,812	5.7	-	-
Clays----------------------------do--------	5,175	11,554	8.7	31	14
Lime-----------------------------do--------	1,631	22,181	8.0	13	2
Natural gas (marketed)-------million cubic feet	8,657,840	1,419,886	38.4	-	-
Natural gas liquids-----thousand 42-gallon barrels	319,061	722,482	50.0	-	-
Petroleum (crude)------------------do-------------	1,301,685	4,536,077	37.7	-	-
Salt----------------------thousand short tons	9,744	36,544	21.6	12	2
Sand and gravel--------------------do--------	35,151	56,328	3.8	26	7
Stone------------------------------do--------	49,314	66,573*	5.3	21	9
Sulfur (recovered)--------thousand long tons-	847	11,135	- -	47	3
Sulfur (Frasch)--------------------do--------	3,847	- -	50.5	8	1

*Excludes value of dimension stone.

Data Source: From Bureau of Mines Minerals Yearbook, 1972, as measured by mine shipments, sales, or marketable production (including consumption by producers)

Basin contributions to total production in Texas are indicated by the proportional number of principal producers operating in Trinity River Basin counties. The value of mineral production in 1972 for individual counties is shown in Table 1-37.

1.36.01 Oil and Gas. Texas has led the Nation in the production of oil and gas since 1934. Oil and gas accounted for about 93 percent of Texas' mineral production in 1972. Since 1946, Texas' contribution to the value of U.S. natural gas production has ranged from a high of 52.2 percent in 1953 to a low of 37.9 percent in 1972. Texas' share of U.S. value of natural gas liquids also ranged from a high of 54.6 percent in 1953 to a low of 46.3 percent in 1971. Developmental well drilling reached its peak in Texas in 1956, as did wildcat well drilling. Since that year the total number of wells drilled per year has declined steadily from 21,519 in 1956 to 8,088 in 1972. Wildcat drilling has also steadily declined from 5610 wells in 1956 to 1973 wells in 1972. The proportion of successful completions has remained fairly stable through this period. About one-third of all wells drilled were dry while about four-fifths of all wildcat wells were unsuccessful. Crude oil, natural gas, and natural gas liquids accounted for over 90 percent of the mineral value in the Trinity River Basin in 1972, and hydrocarbons were first in order of value in every Trinity River Basin county reporting mineral production, except: Dallas, Denton, Ellis, Freestone, Hill, Johnson, Tarrant, and Walker Counties. There are over 100 oilfields located wholly or partly in the Trinity River Basin. This number includes only seven of the 87 major fields in Texas that have produced as much as 100 million barrels of oil. The following list of major Trinity River Basin oilfields includes both the oldest (Powell) and the youngest (Fairway) in the State:

Major Field	County	Discovery Date
Powell	Navarro	1900
Hull-Merchant	Liberty	1918
Mexia	Limestone	1920
Van	Van Zandt	1929
Anahuac	Chambers	1935
Neches	Anderson	1953
Fairway	Anderson-Henderson	1960

Table 1-38 shows the distribution of Trinity River Basin counties within Texas Railroad Commission Districts, average annual crude oil production since discovery, and crude oil production in 1972 (Texas Almanac, 1973). Chambers County was the leading crude oil producer in the Basin in 1972, with substantial production from offshore drilling in Trinity and Galveston Bays. Significant

TABLE 1-37

TRINITY BASIN COUNTIES REPORTING MINERAL PRODUCTION IN 1972

County	Petroleum	Natural Gas	Natural Gas Liquids	Sand & Gravel	Stone	Clay	Cement	Lime	Salt	Sulfur	Value of Mineral Production Report in $1,000
Anderson	X	X	X								47,132
Archer	X	X									16,496
Chambers	X	X	X			1			1		125,882
Clay	X	X			X						10,621
Collin					X						W
Cooke	X	X	X		X						36,556
Dallas				4	1	2	1				16,102
Denton	X	X		2	X	1					1,997
Ellis	X	X			2	2	2				41,202
Freestone	X	X			X	X					7,541
Grayson	X	X	X	X	X						30,757
Grimes	X	X									52
Hardin	X	X	X	X							26,683
Henderson	X	X	X	X		3					52,076
Hill								1			W
Hood		X									W
Houston	X	X	X								7,240
Hunt	X	X									132
Jack	X	X	X		X						13,690
Johnson				1	1			1			4,557
Kaufman	X	X			X						2,690
Leon	X	X									3,053
Liberty	X	X	X							1	34,673
Limestone	X	X		1		2					4,951
Madison	X	X									2,719
Montague	X	X	X	X							13,835
Navarro	X	X			X	X					10,513
Parker	X	X	X	X	X	1					5,097
Polk	X	X									6,226
San Jacinto	X	X									1,212
Tarrant		X		3	1		1				19,862
Trinity	X	X									18
Van Zandt	X	X	X			1			1		73,268
Walker	X	X				1					167
Wise	X	X	X	X	4	1					47,444
Young	X	X	X	X							11,471
										TOTAL	675,915

Numbers indicate principal producers operating in County
X = Production reported
W = Withheld
Data Source: Bureau of Mines Mineral Yearbook, 1972

TABLE 1-38

TRINITY BASIN COUNTIES CRUDE OIL PRODUCTION

County	Production Discovered	Produced from Prod. Discovery to 1-1-73 (bbls.)	Avg. Annual Production Since Discovery (bbls.)	1972 Production
Dist. 9				
Archer	1911	402,751,468	6,496,000	4,719,242
Clay	1902	148,082,707	2,085,700	2,953,285
Cooke	1926	274,166,611	5,833,300	9,804,973
Denton	1937	3,012,613	83,700	13,695
Grayson	1930	159,344,947	3,705,700	6,661,988
Jack	1923	142,995,605	2,859,900	2,295,949
Montague	1924	221,513,829	4,520,700	3,692,112
Wise	1942	52,095,883	1,680,500	1,897,471
Young	1917	221,096,875	3,948,200	2,880,534
Dist. 7B				
Hood	1958	(gas only)	-	-
Parker	1942	822,713	26,600	19,947
Dist 5				
Collin	1963	53,000	5,300	0
Dallas	-	-	-	-
Ellis	1953	626,471	31,300	10,431
Freestone	1916	33,192,574	582,300	156,417
Henderson	1934	79,299,245	2,033,300	11,539,359
Hill	1949	9,393	400	0
Hunt	1942	1,716,764	55,400	10,028
Johnson	1962	194,000	17,600	0
Kaufman	1948	17,357,722	694,300	690,468
Leon	1936	13,128,184	354,800	467,857
Limestone	1920	111,827,005	2,109,900	184,772
Navarro	1895	192,853,287	2,472,500	1,873,322
Rockwall	-	-	-	-
Tarrant	1969	(gas only)	-	-
Van Zandt	1929	385,283,939	8,756,500	16,157,962
Dist. 6				
Anderson	1929	205,160,197	4,662,700	12,006,555
Houston	1934	27,779,082	712,300	1,252,172
Dist. 3				
Chambers	1916	676,776,089	11,873,300	27,712,275
Grimes	1952	308,072	14,700	13,081
Hardin	1893	344,573,796	4,307,200	5,908,624
Liberty	1905	421,222,851	6,194,500	7,027,836
Madison	1946	5,285,779	195,800	246,226
Polk	1930	72,294,473	1,681,300	1,550,802
San Jacinto	1940	18,722,175	567,300	193,364
Trinity	1946	12,021	400	3,959
Walker	1934	204,248	5,200	6,330

Data Source: Texas Almanac, 1973

increases in recent production were also indicated in Van Zandt, Anderson, Cooke, and Henderson Counties. In 1972, crude oil production from the nine Trinity River Basin counties in District Five was almost twice that for the District in 1971. Texas proved recoverable natural gas reserves reached a peak of 125,415,064 million cubic feet at the end of 1967 and have declined steadily to 95,042,043 million cubic feet on January 1, 1973. A similar decline in proved recoverable reserves of Texas liquid hydrocarbons occurred at the same time frame, from 18,597,104,000 barrels to 15,035,640,000 barrels. The American Petroleum Institute (A.P.I.) has computed the ratio of reserves to production for Texas and the Nation. The following list shows the magnitude by which reserves exceed production:

	1970		1971		1972	
	Texas	U.S.	Texas	U.S.	Texas	U.S.
Crude oil	10.6	11.1	11.0	11.7	9.7	11.1
Natural gas	12.7	13.3	12.4	12.6	11.5	11.8
Natural gas liquids	11.1	12.8	9.2	9.8	8.6	9.0

Data are not available on reserves in individual Trinity River Basin counties. Almost all Railroad Commission Districts in the State declined in all three categories from December 31, 1971, to December 31, 1972. Except for portions of four counties (Hood, Parker, Anderson, and Houston), all Trinity River Basin counties are contained in Railroad Commission Districts 3, 5, and 9. The following chart indicates the percentage of the Texas reserves contained in these three Districts at the end of 1972.

	Crude Oil %	Natural Gas %	Natural Gas Liquids %
District 3	12.6	21.8	19.7
District 5	0.8	1.2	2.5
District 9	2.7	1.6	2.4
Totals	16.1	24.6	24.6

1.36.02 Cement. Cement is produced using limestone as the chief raw material at two plants near Midlothian in Ellis County and one each in Dallas and Tarrant Counties.

1.36.03 Sulfur. Texas accounts for about one-half of the U.S. production of Frasch sulfur and about one-half of the U.S. production of recovered sulfur. Most of the Frasch sulfur in Texas is produced from wells drilled into the caprock of subsurface salt domes along the Texas Gulf Coast. Of the five operations of this type in Texas, one is in the Trinity River Basin, at Moss Bluff in Liberty and Chambers Counties. Cumulative production at Moss Bluff from 1948 to

1968 was 5,272,576 long tons. Production of recovered sulfur from sour natural gas and oil is more widespread throughout the State. In 1972, sulfur was recovered at 47 plants in 26 Texas counties spread throughout the State. Two operations of this type are located in Van Zandt County and one is located in Freestone County.

1.36.04 Stone. Most of the counties in the upper Trinity River Basin produce crushed and/or dimension stone from Cretaceous and Paleozoic limestones. Several operations in Wise County, near Bridgeport, are producing from the Chico Ridge limestone of middle Pennsylvania age. In 1972, Wise County led the State in stone production. Stone production for the Dallas-Fort Worth area in 1971 (latest data) was 9,895,000 tons, mostly from the Chico-Bridgeport Area. Crushed stone usage in the Houston-Galveston area in 1971 was 1,316,000 tons from the San Antonio and Georgetown areas. Crushed sandstone, used mainly for roadbase material, is produced in Archer, Clay, and Grimes Counties, while sandstone is mined as dimension stone in Parker County. Cemented sand from the Sparta formation is mined at Butler dome in Freestone County for riprap, aggregate, and base material.

1.36.05 Sand and Gravel. Reserves of sand and gravel are very large in the Trinity River Basin market area. The sites for potential development are concentrated along the main stem and tributaries of the Trinity, upper and lower Brazos, lower Colorado, and Guadalupe Rivers. Most potential sites occur in the flood plain and low terraces. Other occurrences are unconsolidated Pleistocene and Pliocene deposits capping interstream divides in the lower Trinity River Basin and Tertiary or older unconsolidated geologic formations. Individual deposits may contain as much as several million cubic yards. Principal uses are concrete aggregate and as fill material, consequently the maximum demand is near large population centers. The four leading sand and gravel producing counties for the year 1972, Colorado, Dallas, Victoria, and Tarrant, are within the Trinity River Basin sand and gravel market area. Colorado and Victoria Counties supply Houston from the Colorado and Guadalupe Rivers deposits.

1.36.05.01 Dallas-Fort Worth Area. In the Dallas-Fort Worth area, gravel and sand has been mined extensively over the years, and pits with high gravel to sand ratios have been practically depleted. A common gravel to sand ratio for concrete is 2 to 1, and in recent years, recovery of aggregates in the area has involved a significant stockpiling or wastage of sand. Many abandoned pits in Dallas and Tarrant Counties are now being reworked for their sand content. The Seagoville deposits, southeast of Dallas, are, at present, the best sand and gravel source. Much of the gap in gravel supplies is now being filled by crushed limestone from the Chico-Bridgeport area.

Active and inactive sand/gravel pits in the Trinity River flood plain and terraces cover 16,000 acres or 24.5 square miles in the Dallas-Fort Worth Area. This is the largest area of concentrated mining activity of any type in the State. Most of these pits are depleted and abandoned, and very few have been reclaimed. In 1971 (latest data), the Dallas-Fort Worth Area sand and gravel usage was 8,594,000 tons. Most of the sand and gravel was taken from the Seagoville pits.

1.36.05.02 Dallas-Houston Interarea. In the study of sand and gravel and stone, it was estimated that undeveloped sand and gravel reserves along the Trinity River exceed 5 billion tons (US Corps of Engineers, 1968). Gravel reserves were estimated at about one billion tons. The estimate included both accountable reserves (based on limited testing) and unaccountable reserves. Very little development of these reserves has occurred since the study, and these estimates are still considered valid. As of February 1969, there were about 800 acres of active and inactive sand and gravel pits in the Trinity River flood plain in Kaufman and Ellis Counties and about 600 acres within about three miles south of the Highway 105 bridge in northern Liberty County. The ten counties between these areas (Navarro, Henderson, Anderson, Freestone, Leon, Houston, Walker, Trinity, Polk, and San Jacinto) contain about 700 acres of sand and gravel pits and are virtually undeveloped.

1.36.05.03 Houston-Galveston Area. Sand and gravel consumption in the Houston-Galveston area in 1971 (latest data) was 12,789,000 tons. Most of the concrete quality sand and gravel sources are in the Columbus-Altair-Eagle Lake and La Grange deposits on the Colorado River and the Victoria deposits on the Guadalupe River. The Columbus-Altair-Eagle Lake Area in Colorado County has undergone intensive mining activity, similar to that in the Dallas-Fort Worth area. Active and mined-out areas comprise some 8,970 acres or 14 square miles, which is substantially unreclaimed.

Fill sand is supplied to the Houston-Galveston area from the Trinity River deposits in the Dayton-Liberty area and the San Jacinto River deposits. Sand in these two areas is of sufficient quality for fill sand and reserves are enormous.

1.36.05.04 Industrial Sands. Three of the eight leading industrial sand-producing counties of Texas are in the Trinity River Basin area. Hardin, Liberty, and Limestone Counties produce abrasive, blast, enamel, engine, filtration, foundry, glass, hydraulic-fracturing, molding, and pottery sands. Specialty or industrial sands account for over 40 percent of the total tonnage and value of sand and gravel produced in the State. Reserves of specialty sands in the Trinity River Basin appear to be almost limitless.

1.36.06 Shell. Shell is used in the Houston-Galveston area principally as road base material and in cement manufacture. In

1971, shell production from Galveston, Matagorda and San Antonio Bays for Houston-Galveston consumption was 6,858,000 tons.

1.36.07 Salt. Salt is produced in two Trinity River Basin counties. Brine is obtained through wells drilled into the Barbers Hill salt dome in Chambers County. Rock salt is mined, and evaporated salt is prepared, at the Grand Saline salt dome in Van Zandt County.

1.36.08 Lime. Texas production in 1972 was about evenly divided between quick lime and hydrated lime. Plants in Hill and Johnson Counties produced lime from Cretaceous limestones, and Johnson County ranked second in the State in 1972.

1.36.09 Clay. Almost every county in Texas has potential clay sources, but most of the clay industry in the Trinity River Basin is located in the northern counties. Ceramic or burning clays are widespread throughout the Trinity River Basin but are especially abundant in outcrops of the Woodbine, Eagle Ford, Austin, Taylor, and Navarro formations of Cretaceous age. Much of the brick and tile industry has for many years been centered around the Athens-Malakoff district in Henderson County. Non-ceramic, or bleaching, clays have a wide variety of uses, notably as bleaching and absorbing agents and in drilling muds. Non-ceramic clays, such as bentonite and fuller's earth, are prevalent in the coastal areas. Although Texas produces all five "special" clays, only kaolin from Limestone County and bentonite from Walker County are produced in appreciable quantities in the Trinity River Basin. In 1972, Chambers County was third and Limestone County fifth in total clay production in the State. Texas produced 8.7 percent of the clay in the United States, but the value of production represented only 4 percent since almost 95 percent of Texas clay production consisted of common clay and shale.

1.36.10 Recent Trends. In 1973, Texas led the nation in mineral output value for the 39th consecutive year and ranked first in the production of crude oil, natural gas, natural gas liquids, and value of cement and recovered sulfur (Table 1-39). Important quantities of clays, lime, salt, sand, and gravel were also produced. The Railroad Commission of Texas promulgated 100 percent market demand factor for petroleum allowable proration for each month of 1973 and production was virtually at capacity. Value was up, but output decreased fractionally from 1972, as it did in each of the preceding five years. Production of sand and gravel and crushed stone was stimulated in 1971-72 by the construction of the Dallas-Fort Worth Regional Airport. Over 3,875,000 tons of aggregate were required, derived mainly from the Bridgeport-Chico area and Dallas and Tarrant Counties. Production of sand and gravel in Texas dropped 27 percent in 1973, while stone production increased by 13 percent over 1972. Production and value of most other minerals increased in 1973.

TABLE 1-39

MINERAL PRODUCTION IN TEXAS 1/

Mineral	1972 Quantity	1972 Value (thousands)	1973 p/ Quantity	1973 p/ Value (thousands)
Cement:				
Portland---------------thousand short tons---	7,813	$171,642	8,350	$198,000
Masonry--------------------------do---------	217	5,812	240	6,980
Clays----------------------------do---------	5,175	11,554	5,237	12,057
Lime-----------------------------do---------	1,631	22,181	1,711	23,515
Natural gas-------------million cubic feet----	8,657,840	1,419,886	8,540,223	1,622,642
Natural gas liquids:				
Natural gasoline and cycle products thousand 42-gallon barrels-	92,437	294,163	88,100	308,350
LP gases-------------------------do--------	226,624	428,319	225,700	474,000
Petroleum (crude)----------------do--------	1,301,685	4,536,077	1,299,367	4,974,576
Salt-------------------thousand short tons--	9,744	36,544	10,264	40,054
Sand and gravel------------------do--------	35,151	56,328	25,501	39,526
Stone----------------------------do--------	49,314	2/ 66,573	55,619	2/ 81,271
Sulfur (Frasch)----------thousand long tons---	3,847	W	W	W

p/ Preliminary

1/ Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

2/ Excludes value of dimension stone

W Withheld to avoid disclosing individual company confidential data.

Source: Bureau of Mines Minerals Yearbook, Preliminary Report.

1.37 Power Production. While electric power consumption in the nation is doubling about every 8 to 10 years, the doubling rate in Texas from 1952 to 1970 was slightly less than six years. Consumption of electric power per consumer more than doubled during the same period. Individual companies are constantly expanding their production capacities by adding or enlarging generating units almost yearly and by constructing new plants every few years.

There are fourteen power plants in the Trinity River Basin with capacities greater than 25 megawatts. Three privately owned companies: Dallas Power and Light (DP&L), Texas Power and Light (TP&L) and Texas Electric Service Co. (TESCO), service the Dallas-Fort Worth metropolitan area. Gulf States Utilities Company (GUSU) services several towns in the lower basin, and the small towns and rural families in the remaining areas are serviced by at least eleven county cooperatives. Most of the power sold and distributed by these cooperatives is purchased from TP&L, GUSU, and the Brazos Electric Cooperative Inc. (BREP). Power from the plants is transmitted by a maze of lines with connections between companies to offset varying household and industrial peak demands. Several plants located outside the Basin have the majority of their capacity allocated for areas within the Trinity River Basin. DP&L operates six plants of which four are within the Basin. TESCO has three of its eight plants within the Basin, while only one of the eleven TP&L plants is within the Basin. In addition, the Industrial Generating Company, owned jointly by DP&L, TESCO, and TP&L, operates Big Brown in Freestone County, the only lignite-fired electric generating plant in the Basin. All other power plants in the Basin are fueled almost exclusively by natural gas (some plants have small oil-fired auxiliary units). The fourteen plants in the Trinity River Basin a e lisited in Table 1-40 with generating capacity as of 31 December 1973. The eleven electric cooperatives that service small towns and rural areas are shown on Table 1-41.

1.37.01 Hydroelectric Development. In 1971, approximately 266 billion kwh or 18.5 percent of the Nation's electricity was supplied by hydroelectric plants. National hydroelectric power generation is expected to double by the year 2000.

Of the 170 power plants in the State of Texas at the close of 1972, 21 were hydroelectric plants with a total generating capacity of 517,460 kilowatts, representing less than 2 percent of the capacity of all Texas plants. There are no hydroelectric plants in the Trinity River Basin at present, but power from plants in the immediate area is transmitted by the Brazos River Electric Cooperative, Inc. and distributed through various county cooperatives (Table 1-41).

TABLE 1-40

TRINITY BASIN POWER PLANTS

Plant	County	Capacity (Megawatts)	Company	Ownership
North Texas	Parker	75.0	BREP	COOP
Eagle Mtn	Tarrant	706.2	TESCO	PRI
North Main	Tarrant	116.3	TESCO	PRI
Handley	Tarrant	523.4	TESCO	PRI
Denton	Denton	188.8	DENT	MUN
North Lake	Dallas	708.6	DP&L	PRI
Mountain Ck	Dallas	989.7	DP&L	PRI
Collin	Collin	156.3	TP&L	PRI
Lone Star	Dallas	32.9	LOSS	IND
Parkdale	Dallas	340.6	DP&L	PRI
Olinger, Ray	Dallas	188.6	GARL	MUN
Lake Hubbard	Dallas	396.5	DP&L	PRI
Trinidad	Henderson	417.3	TP&L	PRI
Big Brown	Freestone	1,186.8	IGC	PRI
	Total	6,027.00		

COOP	Cooperative
PRI	Privately or investor-owned
MUN	Municipal
IND	Industrial
BREP	Brazos Electric Power Cooperative Inc.
TESCO	Texas Electric Service Company
DP&L	Dallas Power and Light
TP&L	Texas Power and Light
LOSS	Lone Star Steel Corp.
IGC	Industrial Generating Co., jointly owned by DP&L, TESCO & TP&L.

Data Source: Electrical World - Directory of Electric Utilities 1972-73.

TABLE 1-41

TRINITY BASIN COUNTY COOPERATIVE ELECTRICAL SERVICE IN 1971

Cooperative	Counties Served	Sales (kwh)	Number of Customers	Power Source
Wise Elec. Coop. Inc.	Wise, Montague, Jack, Clay, Cooke, Parker, Denton	49,260,000	4,805	BREP
Tri Co. Elec. Coop.	Hood, Jack, Johnson, Parker, Tarrant	104,699,000	9,519	BREP
Denton Co. Elec. Coop, Inc.	Denton, Collin, Grayson, Wise, Tarrant, Cooke	72,044,000	6,870	BREP
Johnson Co. Elec. Coop. Assn.	Ellis, Hill, Johnson, Tarrant	47,788,000	5,519	BREP
Hill Co. Elec. Coop.	Dallas, Ellis, Hill, Johnson	41,755,000	6,334	BREP
Kaufman Co. Elec. Coop. Inc.	Kaufman, Van Zandt, Hunt, Henderson, Dallas	60,163,000	8,360	TP&L
Navarro Co. Elec. Coop, Inc.	Navarro, Ellis, Hill, Freestone, Limestone	27,875,000 (1970)	5,974	BREP
Limestone Co. Elec. Coop.	Limestone, Hill, Freestone	32,334,000	3,456	BREP
New Era Elec. Coop.	Henderson, Anderson, Van Zandt	40,248,000	6,906	TP&L
Robertson Elec. Coop.	Leon, Freestone, Limestone	15,746,000	3,262	BREP
Houston Co. Elec. Coop.Assn.	Anderson, Freestone, Houston, Leon, Trinity, Madison, Walker	65,115,000(1970)	8,637	TP&L & GUSU

Data Source: Electrical World - Directory of Electric Utilities 1972-73.

1.37.02 Lignite Development. Before the development of sustantial natural gas reserves, power plants depended on coal or lignite for fuel. The first power plant in Texas was built in 1882, but by 1910, power distribution was still limited to isolated plants in local communities. Texas' first long-distance gas pipeline was built in 1909 to supply Dallas and Fort Worth, and in succeeding years the distribution of electricity and development of natural gas supplies seemed to go hand in hand. In 1912, the first high-voltage transmission line in Texas was built by TP&L, connecting Waco and Fort Worth. Rural electrification began after that year. The Trinidad Power Plant (Photo #14) operated by TP&L and some Dallas plants were originally designed to burn coal and lignite, but with the expanding development of natural gas supplies, these units were converted to the new fuel. Power companies are now anticipating the depletion of natural gas reserves, and are constructing lignite-fired generating plants. At present, gas-fired plants are more economical, but lignite-fueled plants of similar design to that of the Big Brown plant at Fairfield are being constructed, and future production costs are expected to become competitive with natural gas.

Supplies of coal and lignite are vast. The most recent estimate of identified resources in Texas is 6,824 million short tons of lignite and 6,048 million short tons of bituminous coal (Averitt, 1973). The use of lignite as fuel entails potential pollution problems. At the Big Brown Plant (Photo #12) in Freestone County, a 13-foot seam of lignite is mined from Eocene deposits between Fairfield and the Trinity River. The smokestack emissions from this plant, owned by Texas Utilities Corporation, were the subject of a study by Jones, H. L. (1973). By determining the amounts of mercury and other metals in the lignite being mined, and the amounts of these elements being retained in the ash, he obtained an approximation of the amounts being emitted yearly from the smokestacks. The possibility exists that fallout from the smoke emissions could settle on vegetation and soil and eventually combine with surface water runoff. The tests were made in the latter part of 1972 after the plant had been in operation for about a year. Based on an ash content of 14 percent and an annual consumption of 3.6 million short tons, the tests indicated that the following quantities would be emitted yearly.

Metals	Quantity (Short tons)
Mercury	1.23
Lead	40.33
Cadmium	0.45
Selenium	27.88
Arsenic	2.63

The Big Brown plant has a capacity of 1186.8 megawatts and most of its power production is allocated to the Dallas-Fort Worth Area.

The Company also operates a lignite-fired plant in Milam County and is constructing two additional plants near Rusk and Mt. Pleasant in Northeast Texas.

Many of the adverse environmental effects normally associated with the strip mining process have been avoided at Fairfield. An initially successful program to reclaim mined out areas is being carried out. Overburden is replaced in open pits and the surface is being leveled, fertilized and seeded with coastal bermuda and native plants and grasses. Reclaimed land is contoured to prevent excessive erosion and surface runoff is monitored using a series of collection ponds. A research facility has been established at the site, operated by University researchers, to monitor effects on the land, air, and lake water and to conduct environmental studies of a broader nature.

1.38 Transportation Systems. Existing surface transportation systems of the Trinity River Basin are shown on Plate 24. Well developed highway systems exist throughout the basin. A 9-foot navigation channel from Liberty to Trinity Bay is currently the only water transportation in the Basin. This channel is connected to the Houston Ship Channel and to the Gulf Intracoastal Waterway (GIWW) within the Galveston Bay system (Plate 24). The principal coastal and inland waterways of the eastern half of the continental United States are shown on Plate 25.

1.39 Agricultural Production. Agriculture is of major importance in the Trinity River Basin, contributing substantially to the state and national production and economy. Farms, ranches, and woodlands occupy 10,033,000 acres, or about 88 percent of the basin land area. The remaining 12 percent, or 1,338,000 acres, is in urban or other uses. A wide range of climate and soil conditions provides an environment favorable for the production of a wide diversity of economic crops and livestock. In 1972, the 38 counties with land in the Basin produced the quantities of agricultural products shown in Table 1-42.

1.39.01 Cotton. The Trinity River Basin counties grow 7.5 percent of the Texas cotton. Texas has been the nation's leading cotton producing state since 1880. Its four million bale average since 1957 was 30 percent of the total production in the United States. Cotton traditionally has been the most valuable crop in Texas. Only in recent years has grain sorghum challenged this supremacy. Total cotton and cottonseed produced in Texas in 1972 was valued at about $454 million, a clear lead over other crops. Domestic mill use of 7.7 million bales provides the primary demand for Texas cotton, followed by export market demand which has risen to a 10-year high of 4.8 million bales. The value of the 1973 Texas crop is estimated to have exceeded $800 million.

TABLE 1-42

TRINITY BASIN COUNTIES AGRICULTURAL PRODUCTION, 1972

Product	Quantity Produced by 38-County Area	Percent of Texas Production
Cotton	316,885 bales	7.5
Wheat	3,511,500 bushels	8.0
Oats	4,339,100 bushels	44.6
Barley	170,100 bushels	8.6
Rye	36,500 bushels	5.8
Sorghum	16,908,800 bushels	5.3
Corn	1,098,200 bushels	2.8
Soybeans	1,210,000 bushels	22.2
Peanuts	35,719 tons	14.9
Hay	954,800 tons	23.2
Rice	1,822 tons	16.5
Peaches	146,900 bushels	24.3
Pecans	5,221 tons	16.1
Eggs	25,472,000 dozen	11.4
Laying hens	1,375,000 head	11.5
Broilers	3,834,000 head	2.2
Turkeys	1,386,000 head	17.7
Hogs	158,600 head	12.6
Sheep	12,000 head	0.4
Wool	147,000 pounds	0.5
Goats	18,000 head	1.3
Mohair	118,000 pounds	1.2
Milk	489,689 tons	29.0
Cattle marketed	114,000 head	2.7
Cattle on farms	2,705,000 head	17.6

Data Source: 1972 Texas County Statistics

1.39.02 Feed Crops. Grain sorghum is the major cash grain crop of Texas. Texas produces 40 percent of the nation's crop. About 5.3 percent of Texas production comes from Trinity River Basin counties. Demand for grain sorghum is continuing to grow. The expanding commercial cattle feeding industry is the major grain consumer with poultry, swine, and other livestock utilizing relatively large quantities. Approximately 7 million acres of grain sorghum harvested in Texas are exported to markets throughout the world.

Texas produces less than one percent of the total U.S. corn harvested, and only 2.8 percent of that comes from counties in the Trinity River Basin. Major consumers include the Texas poultry and livestock industries, and some production is processed for food uses.

Oat production is used primarily in support of livestock operations in the form of winter grazing. The Trinity River Basin counties harvested 44.6 percent of the Texas crop in 1973.

Barley production in the Trinity River Basin counties was 8.6 percent of the 1973 State's total. Most of this production moves into feed lots as a supplementary grain to either corn or grain sorghum.

Rye is grown in Texas primarily as a cover crop and for winter grazing. The 1973 production of this grain in the Trinity River Basin counties amounted to only 5.8 percent of the State's total.

1.39.03 Food Grains. Wheat is a major cash income producer for Texas growers. Its farm value ranks third among Texas' cash grain crops, and it produces grazing income to those who pasture wheat during winter. The Trinity River watershed counties produced 8.0 percent of the Texas total, of which 90 percent is stored in off-farm facilities. Hard red winter wheat is primarily used in making flour, pastries, and bread. Although the quantity is still small, increasing amounts of wheat are being included in beef cattle rations when the price is competitive with other grains. Soft wheats provide a wider variety for milling and feeding. The export market is important for Texas wheat. Most of the wheat passes through export marketing facilities along the Texas Gulf coast. These facilities handle over two-thirds of the hard red winter wheat exported from the United States.

Rice production is concentrated in the upper Gulf coast area of the state. In about 13 counties where it is produced intensively, rice is the lifeblood of the agriculture industry. About 16.5 percent of the state's total rice production is grown in counties with land in the Trinity River Basin.

The rice milling industry is concentrated around Houston and the five rice mills located there have a reported milling capacity of 1.5 million pounds of white milled and 650,000 pounds of parboiled rice per 8-hour run. At the miller level, the 1972 Texas rice crop represented a value of approximately $210 million in terms of milled or processed rice, millfeed, bran, and brewers rice. About 60 percent of U.S. rice production is exported. This is the third major agricultural export commodity in Texas, bringing in about $80 million in export revenues in 1971-72.

U.S. consumption of specialty rices, such as precooked, special mixes, and parboiled, is increasing rapidly and now comprises a fifth of a fourth of the total domestic market. Texas mills supply about 55 percent of this.

1.39.04 Oilseed Crops. The major oilseed crops in Texas are cottonseed, peanuts, soybeans, flaxseed, and castors, the last two of which are not important in the Trinity River Basin. Oils and protein meals from these crops are important ingredients for foods, feeds, and industrial products.

Although cottonseed is a byproduction of cotton lint production, it is the major source of income from oilseeds. Production has decreased from a 20-year high of 1.9 million tons in 1965 to 1.1 million in 1971.

Texas ranks second in peanut production behind Georgia with about 14.9 percent of Texas' production coming from Trinity River Basin counties. Spanish peanuts are grown almost exclusively in Texas and are used primarily for peanut butter, oil, and other edible products.

Soybean production is limited to higher rainfall or irrigated areas, with the Trinity River Basin counties growing 22.2 percent of the state's production. Texas produced 5.5 million bushels in 1972 with a value of $12.3 million.

1.39.05 Vegetables. Texas ranks third behind California and Florida as a producer of fresh market vegetables. Texas ranks first for cabbage, watermelons, and spinach and second for onions, carrots, and cantaloupes. Cantaloupes (including honeydews) accounted for 7.2 percent of Texas' vegetable cash receipts in 1972.

Texas leads the nation in watermelon production, with more than 70,000 acres of watermelons planted annually. During 1972, the value of the Texas watermelon crop was $15.9 million. Watermelons accounted for 28.9 percent of the acreage and 10.8 percent of the value of total vegetable production.

The Trinity River Basin counties also produce significant quantities of tomatoes, potatoes, sweet potatoes, sweet corn, and cucumbers.

1.39.06 Fruits and Nuts. Texas fruit and nut production is very diversified; however, pecans and peaches are the two principal items grown in the Trinity River Basin.

Pecans are native to essentially every major river basin in the state, with the Trinity River Basin producing 16.1 percent of the state's production of 65 million pounds in 1972. Texas is the leading producer of native "seedling" pecan trees and third in the production of all pecan meats.

Peaches grow beautifully in many areas of the state and especially East Texas, the hill country, and the West Cross Timbers areas. The peach is the leading deciduous fruit grown in Texas, with a production of 604,000 bushels in 1972 valued at $3,190,000. Counties in the Trinity River Basin accounted for 24.3 percent of the total.

1.39.07 Livestock. Livestock production is the major segment of Texas agriculture, utilizing about 75 percent of all land in farms and ranches and contributing more than 60 percent of Texas' agricultural cash receipts. Total value of livestock on the 170 thousand farms and ranches in the state was $3.68 billion on January 1, 1973.

Cattle raising continues to be the most extensive agricultural operation in Texas during the 1970's, as it has been for many years. Cattle and calves on Texas farms and ranches numbered 15.4 million on January 1, 1973, 14 percent more than a year earlier, and were valued at $3.5 billion. Beef cattle accounted for 14.6 million head valued at $3.3 billion. Texas has 15 percent of the nation's beef cattle herd. Of this, 2.7 million head, or 17.6 percent of the cattle on farms, were located in counties in the Trinity River Basin. There are 38 feed lots located in the Basin.

Texas farmers received $107 million from the sale of hogs and pigs during 1972. Total hog numbers dropped 10 percent during 1972 to a December 1 estimate of 1,264,000 head valued at $44,240,000. Of this number, 12.6 percent were in Trinity River Basin counties. Texas produces less than 30 percent of the pork consumed in the State, and some areas have a potential for expansion.

Texas has been the leading sheep and wool producing state for many years, with about a fifth of the Nation's production. Only a small number, about 0.4 percent, are raised on Trinity River Basin land.

The number of goats in the Trinity River Basin is very small also, comprising less than 0.5 percent of the State's total of 1.4 million head.

The 1972 gross income from poultry and eggs amounted to $211 million for Texas producers The Trinity River Basin counties accounted for 11.4 percent of the eggs and 2.2 percent of the broilers. The Texas poultry industry's fast adaptation to new technology in production, processing, and business management has led to the creation of large, integrated, commercial units. The industry continues to change in order to serve its markets better and to bargain effectively with large retail and institutional organizations.

The Texas dairy industry, which produced 3.4 billion pounds of milk in 1972, ranked ninth in the Nation. About 29.0 percent of this is produced in the Trinity River Basin counties. Nearly all Texas dairy producers are members of strong, well organized marketing organizations. Most of the milk produced in the State is controlled by the cooperative's class 1 base milk plan and is priced under Federal milk marketing orders.

During the past 15 years, the number of Texas farms reporting milk for sale decreased from 20,000 to 4,300. During the same period, the number of milk cows decreased from 700,000 to 358,000, but total milk production has remained about the same, approximately 3 billion pounds per year. The decrease in the number of milk cows was offset by a proportional increase in milk production per cow from 3,300 pounds to 9,400 pounds per year. It is in the area of increased milk output per cow that Texas dairymen probably made the greatest achievement compared with the United States as a whole during the past 15 years. In 1957, the average milk cow in Texas produced only about two-thirds as much milk as the average cow in the United States. In 1972, average production per cow in Texas amounted to 94 percent of the average cow in the United States. Another change is that 15 years ago, about 30 percent of all milk produced in Texas was used on the farm where it was produced and only 70 percent was marketed. In 1972, about 99 percent was sold and only 1 percent was used on the farms.

1.39.08 Timber. Pine growing stock volume is increasing despite increasing harvests. This volume has increased an estimated 17 percent since completion of the last forest survey in 1965. The total pine volume in East Texas now stands at 7.4 billion cubic feet. Softwood harvest totals have spiraled some 73 percent since 1964. The annual harvest of these species is now equal to three quarters of the annual growth. The annual harvest/growth ratio has been increasing over the past seven years at the rate of 3.7 percent annually.

The hardwood picture looked quite bleak during the mid-sixties with regard to a decline of growing stock volumes. The 1971 harvest was 31 percent less than the harvest seven years earlier. Total hardwood inventory is slowly recovering from earlier years when harvest exceeded growth. The Texas hardwood inventory is presently estimated at 2.9 billion cubic feet, which is slightly higher than it was in 1965.

The total growing stock of all species in Texas increased 12 percent between 1965 and 1971. The total annual volume of commercial timber increased from 9.2 billion cubic feet in 1965 to 10.3 billion cubic feet in 1971. The total harvest since 1964 increased by 38 percent, largely due to increased pine usage. Over 75 percent of the commercial lumber harvested in Texas is grown in Trinity River Basin counties.

1.39.09 Agricultural Flood Damage. The annual value of crops being grown on agricultural land subject to flooding is estimated to be $32,000,000 at July 1973 price levels. Most of the crops subject to flood damage are concentrated along the main stem of the river below Dallas.

Most cultivated row crops have neither the physical size nor water tolerance to withstand the depth and duration of flooding experienced in the Trinity River flood plain. Most crops suffer some losses if inundated for 24 hours and the loss could be total if the inundation lasts over 48 hours. Many areas are cultivated with full knowledge of the risk of potential crop loss due to flooding. The risk is accepted because the price of the crops is high enough to make a profit during favorable years to offset the losses suffered during floods. Prison farms, levee districts, and individuals have constructed levees that afford some degree of protection.

Cattle losses have also been experienced in the Trinity River flood plain. Cattle are movable and these losses could be avoided provided there is adequate flood warning and action is taken. Moving cattle out of the flood plain could avoid the largest probable loss, but the temporary loss of productive grazing land could also result in financial setback. Floodwaters of the Trinity River usually carry a high sediment load. When the water overflows the banks and its velocity is reduced outside of the channel, it deposits large loads of silt and clay on existing vegetation. Cattle will not eat the vegetation until the sediment is washed off the plants.

1.40 Recreation. There are numerous recreational opportunities existing in and near the Trinity River Basin. These opportunities are provided by both the private and public sectors, and in some instances, a combination of the two. Plate 25 indicates the State and Federal public outdoor recreation areas in and adjacent to the Trinity River Basin.

1.40.01 Hunting. A number of private hunting clubs provide their members facilities for hunting deer, waterfowl, doves, etc., on either leased lands or club owned lands. In addition to these lands, many rural landowners lease their lands to hunters as a means of augmenting their incomes. Whitehead (1972) has listed the following paper and timber companies in East Texas that make their forested lands available to the public for hunting.

Company	Area Acres
Southland Paper Mills, Inc.	50,500
Temple Industries	144,000
International Paper Company	264,000
Kirby Lumber Corporation	35,000
Southwestern Timber Company	36,100

Publicly owned State and Federal lands are also available for some types of hunting. Those located in and near the Trinity River Basin are shown on Table 1-43. A permit from the Texas Parks and Wildlife Department is required to hunt deer at the Engeling Wildlife Management Area (Whitehead 1972). It is advisable to check in at the project headquarters before hunting on public lands.

TABLE 1-43

PUBLIC HUNTING LANDS

	Area Acres
Federal	
Corps of Engineers	
Bardwell Lake	2,800
Benbrook Lake	1,254
Grapevine Lake	400
Lavon Lake	9,000
Lewisville Lake	13,500
Navarro Mills Lake	2,000
National Forest Lands	
Sam Houston National Forest	158,233
Davy Crockett National Forest	161,566
State	
Engeling Wildlife Management Area	10,941

The above represents vast acreages of land available for hunting, but their location in relation to the population centers of the 40-County Survey Area allows only limited use by those creating the greatest demand. It is anticipated that the demand will increase as the population increases and as extended leisure time becomes more prevalent due to shortened work weeks. The energy crisis may cause a decrease in visitation to the more distant, isolated areas.

1.40.02 Surface Water Activities. Activities such as motor boating, water skiing, fishing, and sailing are conducted on existing lakes in the area. Streambank fishing and canoeing are popular activities on suitable streams, creeks, and rivers in the basin.

Current trends for water based recreation are evidenced by the increase in visitation to existing lakes under the jurisdiction of the Corps of Engineers, the number of hunting and fishing licenses being issued, and increases in sales of equipment used for fishing, water skiing, and associated water activities.

Increased pressure on existing facilities in the past has been due to increases in population, combined with a more affluent society with larger blocks of leisure time. A continual increase of users on existing facilities will gradually lead to a diminished recreation experience because of overcrowding and degradation of facilities. There is some indication that land based activities on lake shores will increase, and water surface activities will decrease. This may degrade present recreation sites near urban centers unless management practices are instigated to prevent it.

Table 1-44 relates current usage of Corps of Engineers public recreation areas in the Trinity River Basin to existing facilities in these areas and to optimum visitation that could be accommodated if these park areas contained fully developed facilities. As may be noted, Corps of Engineers public recreation areas on the fringes of the Dallas-Fort Worth metroplex are already experiencing full or excessive use of the facilities available. The installation of additional facilities in these park areas to attain optimum development presently would require assurances of 50 percent cost participation by local sponsors prior to Federal funding consideration. Since very few of these assurances have been forthcoming, local governing units in this area have apparently accorded them a low priority amounting to deferral.

1.40.03 Latent Recreation Desires. Not included in recreation statistics are those people that desire to participate in various available recreation activities but do not for some reason. The reasons for not participating vary, but include the following: overcrowding, transportation or financial difficulties, lack of time, poor or insufficient facilities, and bad facility management. The difficulties in gathering these data are self evident, but as the population increases and if the trend of larger blocks of leisure time continues, it is almost a certainty that there will also be an increase in latent desires for recreation. In addition, there are those latest preferences that are not being fulfilled because the opportunities do not exist.

1.40.04 Commercial Recreation. Most commercial recreation in the 40-County Survey Area is concentrated in the counties of Dallas, Harris, Galveston, and Tarrant. Enterprises such as professional football, baseball, basketball, soccer, and hockey require the support of large populations and are therefore found in metropolitan areas. Also found in these metropolitan counties are: Six Flags Over Texas, Astrodomain, Lion Country Safari, and Marine World, all well known tourist attractions.

TABLE 1-44

CURRENT AND OPTIMUM RECREATION VISITATION AT CORPS LAKES IN THE TRINITY BASIN

Lake	Conservation Pool surface Acreage	1973 Visitation (Recreation Days)	Percent Usage of Existing Facilities	Optimum Facility Visitation (Recreation Days)	Potential Additional Visitation at Optimum Facility Development (Recreation Days)
Aubrey 1/	29,350	-	-	7,000,000	7,000,000
Bardwell	3,570	651,351	75	1,500,000	848,649
Benbrook	3,770	2,286,519	150	3,000,000	713,481
Grapevine	7,380	3,682,959	150	4,650,000	967,041
Lakeview 2/	9,510	-	-	6,300,000	6,300,000
Lavon 3/	21,400	1,599,128	100	6,900,000	5,300,872
Lewisville 4/	29,700	2,595,608	100	9,500,000	6,904,392
Navarro Mills	5,070	610,519	75	1,500,000	889,481
TOTAL	109,750	11,426,084		40,350,000	28,923,916

1/ Project expected to be operational between 1980-1983. Initial use estimated to be 3,500,000 recreation days annually. Future facilities needed in 25 years.

2/ Project expected to be operational between 1980-1983. Initial use estimated to be 3,800,000 recreation days annually. Future facilities needed in 15 years.

3/ Project's conservation pool is presently being raised. Optimum use based on larger conservation pool. Initial use estimated to be 4,000,000 recreation days annually. Future facilities needed in 35 years.

4/ Project's conservation pool will be raised after completion of the Aubrey Lake Project. Optimum use based on larger conservation pool. Initial use estimated to be 4,197,000 recreation days annually. Future facilities needed in 20 years.

In addition to these major commercial attractions, there are available to the interested public numerous other facilities and attractions such as bowling alleys, golf courses, theatres, movies, etc.

The four counties surrounding Lake Livingston had 47 commercial marinas and/or campgrounds in existence in 1972 to serve the demand created by the lake (TRA, 1973). Nineteen of these facilities were located in Polk County, 13 in San Jacinto County, 12 in Trinity County, and 3 in Walker County. Two of the marinas, one in Polk County and the other in Trinity County, were restricted to subdivision residents.

1.41 Project Area Current Land Use. A breakdown of the land use within the area that would be acquired for Tennessee Colony Lake is shown on Table 1-45. The acreages for the conservation pool and the flood control pool were extracted from 1969 aerial photographs. The real estate acquisition line acreages were extrapolated from the land use acreages in the adjacent flood control pool, since the real estate acquisition line is not yet specifically delineated. Ninety percent of the land within the lake acquisition line is either forest or grasslands, indicating that the majority of land use in the area is for livestock grazing. Although several years have elapsed since the aerial photographs were made, it is expected that the acreages for the various categories of land use are reasonably accurate with the exception of forest lands. Since 1969, several thousand acres of forest land have been converted to grasslands; therefore, the acreage shown for forest is probably high, and the acreage shown for grasslands is probably low.

Table 1-46 displays the existing land use in the Trinity River 100-year frequency flood plain from Fort Worth to Trinity Bay as interpreted from 1969 to 1973 aerial photographs. The 1973 photographs were principally used to obtain more current estimates on rural and residential developments within the flood plain downstream from Lake Livingston. Seventy-three percent of the flood plain acreage is either forest or grasslands, indicating primary land use is for livestock grazing. Croplands make up 13 percent of the flood plain acreages, and a large part of this acreage is behind agricultural levees. Water surfaces and marshes make up 7 percent of the flood plain land area. The remaining 7 percent contains manmade structures, oil and gas fields, and sand and gravel mining. Eighty-eight percent of the forested areas is downstream from Tennessee Colony Lake (reaches one through four, Table 1-46).

1.42 Future Environmental Setting. The future environmental setting will be determined to a great extent by the activities of man in and adjacent to the Trinity River Basin. Population growths attributed to birth rate, death rate, and migrations will influence and be influenced by these activities. The total environment will undergo modification due to the influence of these activities of man. There

TABLE 1-45

TENNESSEE COLONY LAKE AREA LAND USE

LAND USE	Conservation Pool		Flood Control Pool		Real Estate Acquisition Line		Totals
	Within Floodplain (Ac)	Outside Floodplain (Ac)	Within Floodplain (Ac)	Outside Floodplain (Ac)	Within Floodplain (Ac)	Outside Floodplain (Ac)	(Ac)
Forest	30,083	13,202	10,915	15,471	8,129	11,523	89,323
Grasslands	31,334	12,126	4,356	15,163	3,940	13,713	80,632
Croplands	1,082	874	32	308	60	574	2,930
Sand, Gravel & Lignite Mining	387	-	23	4	97	17	528
River, Tributary & Lake Water Surfaces	3,115	297	888	275	974	301	5,850
Highway & Railroad Right-of-Ways	767	292	76	313	79	325	1,852
Rural Housing & Structures	27	35	7	253	3	93	418
Industrial	-	-	18	3	-	-	21
Oil & Gas Fields	3,114	1,206	-	1,057	-	1,151	6,528
Drainage & Irrigation Ditches	59	-	38	-	21	-	118
Totals	69,968	28,032	16,353	32,847	13,303	27,697	188,200

TABLE 1-46

TRINITY RIVER 100-YEAR FLOOD PLAIN LAND USE (ACRES)

(Excludes Wallisville, Livingston and Tennessee Colony Lakes)

Land Use	Reach and River Mile							Totals
	Reach 1 0.0-96.4	Reach 2 96.4-207.9	Reach 3 207.9-313.4	Reach 4 313.4-374.5	Reach 5 374.5-459.8	Reach 6 459.8-505.7	Reach 7 505.7-551.5	
Forest	89,667	30,768	41,337	29,881	11,905	11,336	2,916	217,810
Grasslands	14,594	17,534	66,247	9,652	20,521	19,776	8,189	156,513
Croplands	191	2,048	14,126	2,636	25,009	20,108	3,677	67,795
Sand & Gravel Mining	669	5	126	73	649	3,722	5,570	10,814
River Water Surface	3,610	1,810	3,752	800	686	594	284	11,536
Tributaries & Lakes Water Surfaces	5,527	530	486	1,009	345	1,051	1,095	10,043
Highway & Railroad Right-of-Ways	910	543	1,101	239	248	470	398	3,909
Rural Housing & Structures, Residential Developments, & Industrial Areas	6,432	1,077	439	218	102	2,717	473	11,458
Oil & Gas Fields	5,956	-	1,059	-	-	-	-	7,015
Freshwater Marsh	3,979	-	-	-	-	-	-	3,979
Brackish Water Marsh	11,185	-	-	-	-	-	-	11,185
Totals	142,720	54,315	128,673	44,508	59,465	59,774	22,602	512,057

is little doubt that changes will continue to occur. The difficulty lies in the inability to predict accurately the types of changes and the rates at which they will take place. It is essential, however, that these changes be evaluated if necessary procedures are to be implemented to prevent further degradation to the environment.

1.42.01 Population Growth. The projected population growth for the 40-County Survey Area is shown in Table 1-47. The 1970 population for this area represented 44 percent of the state population (Plate 23). It is projected that by 2020, this area will account for 56 percent of the total state population. Assuming current trends, this growth will occur mostly in the large metropolitan segments of the study area.

TABLE 1-47

POPULATION 40-COUNTY SURVEY AREA

Year	Population	Factor of Change From 1970	Average Annual % Change
1970	4,898,615	1.000	
			2.05
1985	6,638,000	1.355	
			1.89
2000	8,961,000	1.794	
			1.93
2010	10,639,000	2.172	
			1.93
2020	12,873,000	2.628	
			1.93
2035	17,148,000		

Data Source: Population for 1970 from U.S. Census. Projections by OBERS, Series C, interpreted by Southwestern Division, U.S. Army Corps of Engineers.

1.42.02 Dallas and Fort Worth SMSA. Tables 1-48, 1-49, 1-50, and 1-51 indicate the projected population, employment, personal income, earnings by industry, and production by selected industries in the Dallas and Fort Worth SMSA's to the year 2020. These SMSA's were combined in 1973 and, with the addition of Hood, Parker, and Wise Counties, formed the Dallas-Fort Worth SMSA. However, data projecting future population and economic activities for this newly formed SMSA are not available.

It is anticipated that population growths and economic activities within the 40-County Survey Area that are not included in the SMSA predictions will continue to follow present trends.

TABLE 1-48

SMSA-DALLAS# POPULATION, EMPLOYMENT, PERSONAL INCOME, AND EARNINGS BY INDUSTRY
SELECTED YEARS, 1970 - 2020

	1970	1975	1980	1985	1990	2000	2020
POPULATION, MIDYEAR	1,563,908	1,785,100	2,057,000	2,319,900	2,616,400	3,239,900	4,832,300
PER CAPITA INCOME (1967$)*	3,755	4,455	5,066	5,725	6,469	8,615	14,628
PER CAPITA INCOME RELATIVE (US=1.00)	1.08	1.09	1.06	1.06	1.05	1.04	1.03
TOTAL EMPLOYMENT			862,200	968,400	1,087,700	1,385,200	2,088,000
EMPLOYMENT/POPULATION RATIO			.42	.42	.42	.43	.43
	IN THOUSANDS OF 1967 $						
TOTAL PERSONAL INCOME *	5,872,005	7,952,200	10,421,300	13,281,700	16,927,100	27,912,800	70,689,400
TOTAL EARNINGS	5,006,258	6,634,400	8,462,700	10,678,100	13,473,400	21,843,500	53,901,600
AGRICULTURE, FORESTRY & FISHERIES	37,012	32,700	37,500	42,200	47,600	56,500	98,800
MINING	85,555	84,100	90,000	93,100	96,200	105,400	123,900
CONTRACT CONSTRUCTION	312,896	413,500	520,900	659,900	836,000	1,363,200	3,377,200
MANUFACTURING	1,259,284	1,797,200	2,271,500	2,824,600	3,512,300	5,541,700	13,163,800
TRANS., COMM. & PUBLIC UTILITIES	474,536	577,100	703,400	863,300	1,059,400	1,633,100	3,715,000
WHOLESALE & RETAIL TRADE	1,150,918	1,469,200	1,851,500	2,326,300	2,922,800	4,709,400	11,465,400
FINANCE, INSURANCE & REAL ESTATE	432,120	561,400	707,800	877,700	1,088,200	1,706,600	3,972,600
SERVICES	784,960	1,057,100	1,409,300	1,839,100	2,400,000	4,104,900	10,870,000
GOVERNMENT	468,975	635,700	870,200	1,146,500	1,510,500	2,622,300	7,114,300
Civilian Government	432,609	596,800	829,600	1,100,600	1,460,100	2,559,400	7,014,400
Armed Forces	36,366	37,500	40,500	45,100	50,300	62,900	99,800

Note: # Includes: Collin, Dallas, Denton, Ellis, Kaufman, and Rockwall Counties.

Data Source: Bureau of Economic Analysis, 1972.

TABLE 1-49

SMSA - DALLAS* INDEXES OF PRODUCTION FOR SELECTED INDUSTRIES, PROJECTED, 1980 - 2020

(1970 Equals 100)

	1970	1975	1980	1985	1990	2000	2020
MINING	100	103	112	119	126	142	176
METAL	100	(S)	(S)	(S)	(S)	(S)	(S)
CRUDE PETROLEUM & NATURAL GAS	100	103	113	119	126	142	174
NONMETALLIC, EXCEPT FUELS	100	83	95	106	119	153	257
MANUFACTURING	100	151	197	250	320	525	1309
FOOD & KINDRED PRODUCTS	100	126	151	175	204	281	510
TEXTILE MILL PRODUCTS	100	113	124	136	151	189	301
APPAREL & OTHER FABRIC PRODUCTS	100	137	171	205	245	357	726
LUMBER PRODUCTS & FURNITURE	100	171	221	267	323	475	968
PAPER & ALLIED PRODUCTS	100	130	160	195	237	360	798
PRINTING & PUBLISHING	100	129	161	199	245	381	877
CHEMICALS & ALLIED PRODUCTS	100	162	223	296	392	693	1970
PETROLEUM REFINING	100	111	140	169	204	298	599
PRIMARY METALS	100	158	195	233	279	400	775
FABRICATED METALS & ORDNANCE	100	156	207	263	335	548	1027
MACHINERY, EXCLUDING ELECTRICAL	100	130	158	196	244	383	899
ELECTRICAL MACHINERY & SUPPLIES	100	162	231	312	421	754	2126
MOTOR VEHICLES & EQUIPMENT	100	178	185	222	268	397	851
TRANS. EQUIP., EXCL. MTR. VEHS.	100	176	215	258	311	463	988
OTHER MANUFACTURING	100	129	163	202	252	398	949

*Includes: Collin, Dallas, Denton, Ellis, Kaufman, and Rockwall Counties.

Note: (S) Too small to project.

Data Source: Bureau of Economic Analysis, 1972.

TABLE 1-50

SMSA-FORT WORTH# POPULATION, EMPLOYMENT, PERSONAL INCOME, AND EARNINGS BY INDUSTRY
SELECTED YEARS, 1970 - 2020

	1970	1975	1980	1985	1990	2000	2020
POPULATION, MIDYEAR	765,983	816,100	895,700	988,200	1,090,300	1,300,100	1,835,300
PER CAPITA INCOME (1967$)*	3,286	4,067	4,716	5,351	6,072	8,144	13,974
PER CAPITA INCOME RELATIVE (US=1.00)	.95	.99	.99	.99	.98	.98	.98
TOTAL EMPLOYMENT			374,900	411,900	452,500	554,800	791,100
EMPLOYMENT/POPULATION RATIO			.42	.42	.42	.43	.43
			IN THOUSANDS OF 1967 $				
TOTAL PERSONAL INCOME *	2,516,923	3,319,700	4,224,100	5,288,400	6,620,800	10,589,100	25,646,500
TOTAL EARNINGS	2,040,694	2,762,000	3,543,300	4,417,300	5,507,000	8,740,400	20,852,500
AGRICULTURE, FORESTRY & FISHERIES	13,586	13,800	15,100	17,000	19,200	22,800	39,800
MINING	23,146	26,200	29,200	30,100	31,100	33,900	39,400
CONTRACT CONSTRUCTION	96,134	128,300	156,500	193,000	238,000	370,100	854,900
MANUFACTURING	737,016	1,039,500	1,317,300	1,597,800	1,937,900	2,922,600	6,420,900
TRANS., COMM. & PUBLIC UTILITIES	122,747	153,400	185,600	224,600	271,800	409,100	899,000
WHOLESALE & RETAIL TRADE	350,620	469,200	605,700	765,900	968,400	1,578,200	3,917,400
FINANCE, INSURANCE & REAL ESTATE	98,336	126,600	161,100	198,200	243,800	377,300	860,200
SERVICES	300,620	414,600	549,600	705,400	905,300	1,505,800	3,831,900
GOVERNMENT	298,489	388,000	522,800	682,500	891,100	1,520,300	3,988,400
Civilian Government	254,013	346,500	481,200	635,600	839,500	1,455,800	3,886,000
Armed Forces	44,476	39,700	41,500	46,300	51,600	64,500	102,400

Includes: Johnson and Tarrant Counties.

Data Source: Bureau of Economic Analysis, 1972.

TABLE 1-51

SMSA-FORT WORTH* INDEXES OF PRODUCTION FOR SELECTED INDUSTRIES, PROJECTED, 1980 - 2020

(1970 EQUALS 100)

	1970	1975	1980	1985	1990	2000	2020
MINING	100	118	134	142	150	170	208
METAL	100	(S)	(S)	(S)	(S)	(S)	(S)
CRUDE PETROLEUM & NATURAL GAS	100	118	134	142	150	169	206
NONMETALLIC, EXCEPT FUELS	100	(S)	(S)	(S)	(S)	(S)	(S)
MANUFACTURING	100	151	191	233	284	433	951
FOOD & KINDRED PRODUCTS	100	119	138	158	182	246	433
TEXTILE MILL PRODUCTS	100	104	[illegible]	124	141	184	311
APPAREL & OTHER FABRIC PRODUCTS	100	124	142	166	193	268	505
LUMBER PRODUCTS & FURNITURE	100	168	213	254	303	436	856
PAPER & ALLIED PRODUCTS	100	142	171	202	239	344	708
PRINTING & PUBLISHING	100	138	170	210	260	404	931
CHEMICALS & ALLIED PRODUCTS	100	130	166	213	271	448	1149
PETROLEUM REFINING	100	110	129	154	182	260	502
PRIMARY METALS	100	170	199	233	273	378	696
FABRICATED METALS & ORDNANCE	100	126	157	197	246	391	703
MACHINERY, EXCLUDING ELECTRICAL	100	178	236	294	365	573	1346
ELECTRICAL MACHINERY & SUPPLIES	100	155	237	321	433	774	2183
MOTOR VEHICLES & EQUIPMENT	100	143	157	193	237	364	822
TRANS. EQUIP., EXCL. MTR. VEHS.	100	167	219	264	318	473	1010
OTHER MANUFACTURING	100	135	176	224	285	467	1169

* Includes: Johnson and Tarrant Counties.

Note: (S) Too small to project.

Data Source: Bureau of Economic Analysis, 1972.

1.42.03 Recreation. Participation in public water related recreation and fish and wildlife at Corps of Engineers lakes in the 40-County Survey Area totaled 85.7 million user-days in 1970 (Corps of Engineers, 1974b). Using the actual per capita use rate for 1965 as determined by user surveys, this visitation is expected to increase to 105.8 million user-days by 1980, 156.8 million user-days by 2000, and 225 million user-days by the year 2020. However, the per capita use rate has been increasing at a faster rate than the population growth rate, causing the above estimates to be conservative at best. Assuming full cooperation from local entities for the cost sharing of recreation facilities, existing Corps of Engineers lakes in the Survey Area could provide for an optimum visitation of approximately 40 million user-days annually (Table 1-44). Present facilities at existing Corps lakes in the area can accommodate an optimum visitation of about 9.8 million user-days annually. These facilities provide only about 86 percent of those needed for the 11.4 million user-days recorded for these lakes in 1973. It is predicted that this increasing preference for recreational facilities will bring about completion of optimum development at Corps lakes in the future regardless of any new water resource development within the 40-County Survey Area.

1.42.04 Water Quality. Public Law 92-500, the Federal Water Pollution Control Act Amendments of 1972, being administered by the Environmental Protection Agency, working with the Texas Water Quality Board and others, is expected to result in improved water quality in the Trinity River. The above agencies are committed to working toward the goals set forth in Public Law 92-500.

The switch to low lead gasoline (often called "no lead gasoline") is expected to reduce the toxic lead contributions to streams from urban and highway runoff. Industrial pollutants are expected to be markedly reduced or eliminated. The more persistent pesticides may be expected to be more strictly controlled, thus reducing their toxic effect in the aquatic ecosystem. There are at present, however, no provisions planned for removing nutrients from treated municipal effluents. It is probable that nonpoint source nutrient contribution would be of such magnitude that removal of nutrients from point sources would be both inordinately expensive and futile. Thus, it may be expected that problems with eutrophication downstream from the Dallas-Fort Worth metropolitan area will continue for some time to come.

1.42.05 Drilling and Mining. Reserves of sulfur, salt, limestone, miscellaneous clay, and fire clay are almost limitless in Texas, and production in the State and the Trinity River Basin is expected to continue in the next century at the present growth rate (Ellison, 1971; Hosterman, 1973; Smith et al., 1973; U.S. Army Corps of Engineers, 1968).

The Seagoville area southeast of Dallas is presently the major source of sand and gravel for the Dallas-Fort Worth area. It is anticipated that, as these pits are depleted, the sand and gravel industry will move south into Ellis and Kaufman Counties where reserves are expected to provide about 50 percent of the natural aggregate needs until exhausted, about 1995. After this period, the demand for natural aggregate for the Dallas-Fort Worth area is expected to be filled from sources south of Trinidad along the Trinity River and from sources outside the Trinity River Basin. It is predicted that the Houston-Galveston market for concrete quality sand will be supplied from Trinity River deposits in the Urbana-Romayor area and that gravel will be supplied from s ources north of La Grange on the Colorado River and north of Cuero on the Guadalupe River after the year 2000 (U.S. Army Corps of Engineers, 1968).

The Trinity River Basin counties probably contain less than 10 percent of the total State petroleum reserves. It appears inevitable that domestic production of oil and gas will decline over the next 100 years but at a rate dependent on economkc pressures, technological advances, and exploitation effectiveness. The decrease in natural gas production will encourage the use of lignite as a source of energy for the production of electricity. Trinity River Basin sources, already being utilized, will continue to be used until other energy sources can be developed. Texas is predicted to have enough low sulfur lignite (1 to 3 percent sulfur) to supply the State's total electricity needs for the next 300 years (Texas Transportation and Energy Report, 1974).

1.42.06 Future Water Supply Requirements. A 24-County Study Area in the Trinity River Basin was developed to determine future water supply requirements (U.S. Army Corps of Engineers, 1974b). Based on this study, future water supply needs for this area are expected to be generally for the same types of uses now served. The high water use activities are projected to be the chemicals and allied products and the food and kindred industries. Consumptive water needs for thermoelectric cooling are expected to increase considerably from the 1970 needs of about 20,000 acre-feet per year to 269,000 acre-feet per year by 2020, and 392,000 acre-feet per year by 2085. Table 1-52 shows a summary of future water needs as determined by the above study.

The Dallas-Fort Worth SMSA will need additional water somewhere between the years 1990 and 2000. The lower Trinity River Basin area is not expected to require additional water during the 1985-2085 time period covered by this study.

1.42.07 Flood Plain Vegetation Trends. The forested areas within the 100-year flood plain of the Trinity River, along with the other categories of land use, are shown in Tables 1-45 and 1-46. It is expected that past trends will generally continue as regards the vegetation associated with the flood plain of the Trinity River.

TABLE 1-52

TRINITY RIVER BASIN
MUNICIPAL AND INDUSTRIAL WATER NEEDS
(1000 acre feet/year)

Subarea/ County	1970 High	1970 Low	1985 High	1985 Low	2020 High	2020 Low	2085 High	2085 Low
UPPER TRINITY BASIN								
Anderson	2.9	2.9	4.2	3.7	6.9	5.7	12.7	11.1
Collin	7.4	7.4	17.8	16.5	41.6	38.1	100.7	90.8
Cooke	2.8	2.8	4.9	4.2	9.9	6.8	42.2	15.8
Dallas	269.9	269.9	506.1	450.9	1057.4	874.3	2888.0	1495.3
Denton	9.2	9.2	18.8	17.9	41.5	38.2	82.1	74.2
Ellis	4.6	4.6	7.4	6.5	13.4	10.8	40.5	23.8
Freestone	.6	.6	.7	.7	.9	.8	1.8	1.6
Henderson	1.7	1.7	2.8	2.7	5.3	4.8	13.1	12.1
Jack	.7	.7	.8	.8	1.0	.9	1.9	1.8
Kaufman	3.6	3.6	5.5	5.1	10.1	8.8	29.0	23.6
Montague	a/	a/	a/	a/	a/	a/	.8	.5
Navarro	4.7	4.7	7.7	6.2	14.9	10.1	114.0	74.3
Rockwall	1.5	1.5	3.9	2.5	9.5	4.7	29.9	15.4
Tarrant	156.4	156.4	299.0	241.1	622.9	439.9	3628.5	1089.6
Van Zandt	1.4	1.4	5.4	4.8	15.4	12.1	134.8	113.6
Wise	1.2	1.2	2.0	2.0	3.8	3.6	8.5	8.1
Upper Basin Thermal Electric Cooling	20.0	20.0	56.4	56.4	267.6	267.6	389.8	389.8
Total Gross Needs of Upper Basin	488.4	488.4	943.4	822.0	2122.1	1727.2	7518.3	3441.4
Available Supply of Upper Basin			1,192.7		1,192.7		1,192.7	
Net M&I Water Supply Needs of Upper Basin (Gross Needs - Supply)			0	0	929.4	534.5	6325.6	2248.7

a/ Montague County municipal and industrial requirements will be met by Farmers Creek Lake with a yield of 5800 ac-ft per year. This lake is not tabulated as a source, so gross needs of the county have been reduced by 5800 ac-ft per year. The result is no gross needs for the county until about year 2085.

(1000 acre feet/year)

Subarea/ County	1970 High	1970 Low	1985 High	1985 Low	2020 High	2020 Low	2085 High	2085 Low
LOWER TRINITY BASIN								
Houston	2.1	2.1	3.7	2.5	7.3	3.1	21.4	10.6
Leon	.1	.1	.1	.1	.4	.3	1.0	.9
Liberty	2.4	2.4	5.0	3.6	11.0	6.7	44.1	27.2
Madison	.3	.3	.6	.6	1.0	.9	3.7	3.4
Polk	1.8	1.8	3.5	2.3	7.4	3.2	22.2	10.4
San Jacinto	.1	.1	.2	.1	.6	.4	1.2	1.0
Trinity	.3	.3	.4	.4	.7	.6	1.3	1.2
Walker	3.0	3.0	5.8	4.7	12.2	8.8	26.6	18.2
Lower Basin Thermal Electric Cooling	.1	.1	.5	.5	1.4	1.4	2.6	2.6
Total Gross Needs of Lower Basin	10.0	10.0	19.8	14.8	42.0	25.4	124.1	75.5
Available Supply of Lower Basin			147.5		147.5		147.5	
Net M&I Water Supply Needs of Lower Basin (Gross needs - supply)			0	0	0	0	0	0
Total Trinity Basin Summary								
Total Gross Needs of Basin (includes recycling)	498.4	498.4	963.2	836.8	2164.1	1752.6	7642.4	3516.9
Total Available Supply			1,340.2		1,340.2		1,340.2	
Net M&I Water Supply Needs of Trinity Basin (Gross needs - supply)			0	0	823.9	412.4	6302.2	2176.7

Data Source: U.S. Army Corps of Engineer, 1974b.

Bottomland hardwood areas will continue to be cleared by landowners as economics warrant the expenditure. As food and fiber shortages become more acute throughout the world, more land will be utilized for agricultural production, and the unit land use will intensify.

The upper portion of the Trinity River Basin has very little forested area remaining. As land becomes more valuable with the projected population growth of the area, this will diminish still further. Downstream from Dallas, the levees will probably be maintained and strengthened so that agricultural activities and sand and gravel removal may continue. Considerable forested areas presently exist in many parts of the proposed Tennessee Colony Lake site. Much of this area will probably be cleared for agricultural use and sand and gravel mining in the future.

There is a strong likelihood that should the proposed Tennessee Colony Lake not be built as a Federal multiple purpose project, a lake in the general vicinity would be built as a water supply lake by a state agency or by local interests.

There are only a few relatively large bottomland hardwood forest areas between the proposed Tennessee Colony Damsite and the headwaters of Lake Livingston. These remaining forested areas are being diminished, and this trend is expected to continue.

Although some clearing has occurred and is continuing for agricultural purposes downstream from Lake Livingston, much clearing or partial clearing is also taking place for residential developments. There are about 20 sizable residential developments in this area, many in flood prone areas, and this development is expected to continue unless curtailed by regulations. Habitat loss caused by more intensive land and water use in the future will decrease both fauna populations and species diversity.

1.42.08 Flood Damages. Average annual damages due to flooding of about $30.3 million are predicted to occur from Fort Worth to the mouth of the Trinity River from 1985 to 2085 (U.S. Army Corps of Engineers, 1974a). Leveeing or other flood protection measures, including various land use regulations, could be undertaken by local entities to somewhat relieve these damages. The reduction in damages because of these actions would be proportional to the protection provided.

1.42.09 Air, Water, and Noise Pollution. The pollution problems of greatest concern to man are the direct result of population growths and an increased standard of living. Technology developed in the past was generally designed to increase the production needed to meet the demands of an increasing population. Future technology, and regulations therefor, must be capable not only of reducing existing pollution problems, but also of preventing the additional pollution of the environment by an ever enlarging population.

The anticipated continued growth of the metropolitan areas in and near the Trinity River Basin can be expected to create additional air, water, and noise pollution in the future. Any activities which tend to further concentrate the population and industry within the metropolitan areas would aggravate the situation. Larger and improved sewage treatment plants will be necessary to reduce water pollution, and unless urban runoff is treated prior to reaching the Trinity River, this source of pollution will increase corresponding to the expansion of the urban areas.

The sounds generated by a highly mechanized society will increase as the population places greater demands on services provided by such entities as the Dallas-Fort Worth Regional Airport, the highway system, and other noise generators.

As regional electric generating plants convert from natural gas to coal and lignite for energy sources, an increase in air pollution can be anticipated. The continued development of sand and gravel operations within the basin will add to the air, water, and noise pollution already present. The anticipated conversion of more forest land to agricultural use will increase the pollutants added to the Trinity River, in addition to removing the sound buffering capabilities and air purifying aspects of the forests.

It will take the continued efforts of the responsible Federal and state agencies, working with local entities, to maintain desirable air and water qualities and acceptable noise levels.

1.42.10 Solid Wastes. In the future, it is expected that a large part of the solid waste that is now being placed in landfills will be reclaimed. Glass, metals, paper, and waste food will probably all be reused to a much greater extent than is currently practical from both the exhaustion of natural resources and the economics of waste disposal viewpoints.

1.42.11 Trinity Bay. There are a large number of private and public entities involved in water development and water use activities affecting Trinity Bay. While individual activities have usually had minor effects upon the bay system, all the activities taken together are producing adverse effects on the estuarine ecosystem, and this trend is expected to continue. In addition, as the future demand for fresh water increases in the lower Trinity River Basin and ground water supplies become more scarce or are depleted, the total demand on the fresh water flows in the Trinity River can be expected to virtually equal the supply available for those who hold the rights to that water, especially during the periods of drought. It could be that in the future, flood flows and local rainfall and runoff will be the only water entering Trinity Bay, unless there is a change in the current list of water rights priorities.

The trend of increasing the fishing effort by the oyster, shrimp, and commercial fish industries is expected to continue, along with reduced catches per unit effort. This will result in even greater pressure on the developing forms of fauna in Trinity Bay and adjacent coastal waters.

SECTION 2 - PLANNING OPTIONS

2.01 General. Prior to commencement of detailed planning, a search was conducted for alternatives that appeared to have some current potential for satisfying Trinity River Basin water resource problems. Suggestions were gathered from the three separate environmental planning meetings held at Arlington, Liberty, and Fairfield, Texas, on 12, 13, and 14 December 1972; from constructive coordination with other Federal, State, and local agencies; and from literature review and background experience within the Corps of Engineers. General rules of reasonableness were then applied to select and define those alternatives that were proper for evaluation. This procedure recognized several germane considerations. Technological feasibility of an alternative is of significance both from the standpoint of achievability per se and of achievability within the time frame of project needs. It is also incumbent that an alternative exert its primary influence on the study area and be considered feasible within common law or specific statutes, either existing or enactable by legislative processes. Another consideration of significance evolves from the size and diversity of the study area. The area contains a wide range of economic considerations, social attitudes, cultural backgrounds, and natural elements. Perhaps the greatest potential for controversy lies with the different viewpoints adopted by various segments of the population; these include the views of individuals, landowners, special interest groups, and State, regional, and national groups, each of whom is likely to approach problems differently.

These widely factional approaches could produce several alternatives for each relatively small land increment, such as an acre or section. Rules of reasonableness therefore require that an alternative must be viewed for its ability to benefit significant segments of the public and by its ability to serve the broad public interests of health, safety, convenience, and overall public welfare.

This section discusses three general categories of alternatives: (a) those alternatives which may provide only a partial solution to the purposes of the proposed project, (b) those alternatives which could accomplish more than one of the purposes of the proposed project, and (c) the no action alternative. Modification of project components that result from design changes during subsequent planning phases are not considered to be alternatives to the project.

Comparative analysis of the numerous alternatives was conducted by testing the capability of each to achieve one or more of the project purposes that are among the Basin planning objectives. These planning purposes are set forth in terms of general planning objectives and Trinity River Basin planning objectives as described below:

2.02 National Planning Objectives. The Principles and Standards for Planning Water and Related Land Resources published in the Federal Register on September 10, 1973 by the Water Resources Council included the establishment of two national planning objectives for water resources: (1) national economic development and (2) environmental quality. Within these two broad objectives, adverse and beneficial effects of the proposed actions are to be examined in terms of four separate accounts that were set forth by section 209 of Public Law 91-611. These four accounts are defined as follows:

2.02.01 National Economic Development. Enhancement of national economic development by increasing the value of the nation's output of goods and services and improving national economic efficiency.

2.02.02 Environmental Quality. Enhancement of the quality of the environment by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural or cultural resources and ecological systems.

2.02.03 Regional Economic Development. Enhancement of regional development through increases in a region's income; increases in employment; distribution of population within and among regions; improvement of the region's economic base and educational, cultural, and recreational opportunities; and enhancement of its environment and other specified components of regional development.

2.02.04 Social Well Being. Enhancement of social factors, including the real income of relevant classes or groups; life, health, and safety; reserve capacities and flexibilities in water resource systems; protection against interruption of the flow of essential goods and services at times of national disaster or critical needs; and other relevant social factors.

2.03 Basin Planning Objectives. In addition to the aforementioned national planning objectives and accounts, the seven more specific planning objectives of the Trinity River Basin were considered in some detail during preconstruction planning. They are as follows:

2.03.01 Flood Control. This objective is to alleviate the recurring flood damages in the Dallas-Fort Worth area, along the agricultural middle reaches, and residential developments along the lower reaches of the river. A greater degree of protection should be afforded to areas of greatest potential flood threats to property and inhabitants. Flood control objectives should incorporate wise use of flood plain management principles in the prevention of future flood damages.

2.03.02 Water Supply. Develop all feasible alternative sources of water supply to satisfy projected water needs of the region.

2.03.03 Navigation. If feasible, provide for waterborne transportation on the Trinity River in accordance with the request of local interests and the criteria and responsibilities of the Federal Government.

2.03.04 Recreation and Fish and Wildlife. Provide convenient opportunities for the people of the area to enjoy water oriented outdoor activities while preserving natural areas of significance for present and future generations.

2.03.05 Water Quality. Trinity River Basin objectives are essentially those of the Federal Water Pollution Control Act amendments of 1972, Public Law 92-500. These water quality objectives basically are to restore and maintain the chemical, physical and biological integrity of the national waters through the following goals: prohibiting the discharge of toxic pollutants in toxic amounts; wherever possible provide quality suitable for propagation and protection of fish, shellfish, and wildlife, and for recreation in and on the water by July 1, 1983; and elimination of the discharge of pollutants by 1985.

2.03.06 Hydroelectric Power. Assess the overall feasibility of providing hydroelectric power facilities in accordance with the criteria and responsibilities of the Federal Government and the needs and preferences of local interests.

2.03.07 Streambank Erosion. To the extent feasible, prevent streambank erosion in terms of undesired loss of lands, damages to structures, etc.

Of these seven planning objectives, the proposed Trinity River Project includes five as its purposes: flood control, water supply, navigation, recreation and fish and wildlife, and hydroelectric power. Discussion of an alternative includes a description of the alternative and an assessment of its ability to accomplish its project purpose.

2.04 Structural Flood Damage Control Alternatives.

2.04.01 Channel Enlargement. This alternative would require a channel of sufficient capacity to accommodate a Standard Project Flood through the Dallas-Fort Worth area and a flood of 50-year frequency downstream. The channel would be wider, deeper, and straighter than the existing river channel and would be 700 to 800 feet wide through the Dallas-Fort Worth area and 200 to 400 feet wide downstream from Dallas to Wallisville Lake. An excavation of this magnitude would provide severe, immediate, and detrimental effects on vegetation and wildlife in the river and flood plain and would result in widespread and permanent alteration of the flood plain's remaining biological assemblages. Much of the time between flood occurrences, and particularly during dry periods, the Trinity River base flow would constitute a relative trickle down the excavated channel. Flood plain water tables would be lowered and wetlands would drain naturally or be drained into this enlarged channel. This channelization would cause oxbows and meanders to drain and thus would reduce riparian water supplies to many adjoining landowners.

There are 44 highway bridges, 13 railroad bridges, 145 gas or oil pipelines, 13 water or sewer pipelines, 44 powerlines, and 18 telephone or telegraph lines presently crossing the flood plain. Extensive alterations would be required to these facilities in order to accommodate a channel of this size. In addition, the existing Dallas Floodway presents a particular hydraulic problem to construction of this channel along the West Fork of the Trinity River from the end of the Fort Worth Floodway to the Dallas Floodway. The existing Dallas Floodway channel bankfull capacity is 13,000 cfs. Floodwater conveyed down an enlarged mid-cities channel would thus be funneled into the smaller capacity Dallas Floodway channel. Resulting backwater effects could cause localized problems near the constriction unless the Dallas Floodway channel were also enlarged. This could be done, but it would duplicate the work previously done on the Dallas Floodway and make the existing levee system unnecessary.

By confining floodwaters to an excavated channel, this alternative would significantly benefit economic considerations and reduce flood damage anxiety of the landowners in the flood plain of the metropolitan area and downstream from Dallas. Flood plain land presently under cultivation or used for grazing could be more intensively used if the flood threat were reduced. In addition, forested areas and wetlands that are presently flood prone could be cleared, drained, and converted to agriculture. Some of this flood prone land would also become much more attractive to second-home seekers and thus considerably more valuable to land developers, particularly in the reach downstream from Lake Livingston. This alternative is technologically feasible and, in terms of accomplishing objectives, it would have beneficial effects on national economic development. It would benefit the regional development account by providing a high degree of flood damage prevention, the benefits of which would accrue to land and property owners in the flood plain, including the Texas Highway Department and railroad companies with transportation facilities in the flood plain. It would, however, have a severe adverse effect on riverine and flood plain ecosystems.

2.04.02 <u>Channel Enlargement for Reservoir Regulation Flows</u>. This alternative would correct Trinity River channel hydraulic deficiencies by channelization to accommodate all flows up to the combined flood release flows of upstream lakes. Although possibly on a different alignment, this channel would be a smaller variation of the preceding alternative. It would have the same beneficial and adverse effects accruing to the same interests and would accomplish the same planning objectives, but to a lesser degree.

2.04.03 Multiple Tributary Lakes. This flood control alternative contemplates the construction of several smaller flood control lakes located off the main stem of the Trinity River. To investigate this alternative, flood control feasibility evaluations were conducted for approximately 40 sites, both singularly and in various combinations.

Twelve sites were found to possess the best flood damage prevention potentials, but all were found to be primarily effective for minimizing localized flood damages immediately downstream from each site. These sites, with the exception of the Richland Creek and Tehuacana Creek sites located on the west side of the Tennessee Colony Lake site, are shown in brown on Plate 1, Appendix A. If existing development and population trends continue, all sites may eventually be developed for flood damage prevention and/or water supply.

A relatively small amount of flood damage currently occurs downstream from these sites, either individually or collectively. However, a large storm with heavy rainfall in the drainage area encompassed by these tributaries can cause major lower basin flood damage. Unfavorable benefit to cost ratios prevent this alternative from achieving the planning objective of national economic development. It does not accomplish a significant portion of the flood control project purpose. A single purpose flood control lake is usually designed and operated to catch only flood-causing storm runoff and apportion its flow over a period of time to the capacity of the downstream channel. During periods when it is not operating to retard flood flows, it is essentially dry. Single purpose flood control lakes are normally drained between rainfall runoffs. These widely fluctuating pool levels would do little to enhance the environmental quality account.

2.04.04 Leveed Metropolitan Floodways. Portions of the Trinity River in Fort Worth and Dallas have previously been channeled and leveed to provide protection from floods up to and including the Standard Project Flood. This alternative considers connecting the existing Fort Worth and Dallas Floodways with levees along the intervening 31 miles and extending them from the Dallas Floodway approximately 9 miles downstream to Five Mile Creek. This alternative would provide both adverse and beneficial effects to the metropolitan area f ood plain in terms of national economic development. The owners of land and property outside the levees would benefit economically from the flood protection provided by the levees. An adverse effect of the same nature would be experienced by the land and property owners between the levees. Current land use in this area includes grazing, crop production, and residential, commercial, and industrial developments. Such facilities as sewer plants, railroad and highway bridges, and habitable structures would receive varying degrees of flood protection by the levee systems. The planning objective of national economic development and the flood damage reduction purpose could be achieved to a fairly high degree by this alternative. There would also be a secondary beneficial effect in that specific delineation of the flood plain by the levee systems would prevent structural development in the leveed floodway. Some beneficial effect would also accrue to the social well being account by enhancement of public health and safety factors. This alternative would have an adverse effect on ecosystems in terms of vegetative destruction and the encouragement of more intensive development in the flood plain outside the levees. A beneficial visual effect could be achieved in the leveed flood plain if suitable preservation/enhancement procedures were followed.

2.04.05 Levee Strengthening from Five Mile Creek to Cedar Creek. There are presently 16 non-Federal levee systems along this reach of the Trinity River. The flood protection afforded to approximately 70,000 acres of agricultural land by these levees varies from 50-year to 100-year flood frequencies. This alternative contemplates extending and strengthening these levees into a system providing 100-year flood frequency protection along the entire 80-mile reach, with subsequent maintenance to be carried out by local interests.

The present bankfull channel capacity of the Trinity River near Rosser, just below the confluence of the Trinity River and East Fork of the Trinity River, is 9,000 cfs. This represents only about 28 percent of the total design flood release flows of 32,000 cfs from upstream lakes. At this release rate, about 37 days are required for flood storage evacuation of these lakes.

During the years prior to construction of these upstream flood control lakes, essentially the same volume of water flowed through this channel reach, but, without regulated releases, this water passed a given channel reach more quickly. This resulted in more widespread flooding, but the floods were usually of shorter duration, and the waters accumulated behind the levees from local runoff could usually be drained through levee valves into the more rapidly receding river before substantial damage to crops and pasture land occurred. Now, however, sustained upstream releases keep the overbank condition within the levees at a high level for extended periods of time. This delays gravity drainage of fields behind the levees and, although water levels may be generally lower, this delay often causes substantial agricultural damage. Thus, while levee extension and strengthening would reduce flood induced damages from heavy upstream rains, it would still result in essentially the same behind-the-levee ponding from local runoff that currently exists.

The installation of pumps, and their operation to remove sump water, is economically infeasible when related to agricultural operations in this area.

Flood plain land use along this reach is predominately agricultural. Strengthening and extending levees along this reach would not affect the pattern of land use. Newly protected areas would still be employed for agricultural purposes but would be less flood susceptible. Thus this alternative would have a somewhat beneficial impact on the area economy, even though it would not alleviate all behind-the-levee water problems associated with local runoff.

Flood damage anxiety would be reduced, but damages to roads, bridges, and railroads would still occur.

The remaining wooded areas in this reach are gradually being thinned or cleared as landowners seek higher income by more intensive agricultural production of livestock and crops. While it is recognized that these environmental impacts will probably occur along this river reach regardless of whether or not this alternative were implemented, flood leveeing, along with any other flood control alternatives, would tend to accelerate this process.

This alternative is technologically feasible and, by increasing agricultural development, would achieve the planning objective of national economic development and produce a beneficial effect on the regional economic development account as applied to flood plain landowners and the recipients of the agricultural products. In addition, this alternative would have a favorable effect on the social well being account by the enhancement of factors such as public health, safety, convenience, and the real income of relevant classes or groups, particularly the sand and gravel mining industry and agriculture. The flood control project purpose would be partially met by this levee system.

2.04.06 Levees from Cedar Creek to Wallisville Lake. This alternative considers construction or strengthening of existing flood control levees along approximately 380 miles of the Trinity River from Cedar Creek to Wallisville Lake, excluding Lake Livingston. While the average riverbed gradient from Fort Worth to Cedar Creek is about 1.7 feet per mile, the gradient from Cedar Creek to the Trinity Bay averages only about 0.6 foot per mile. As a result, the wetlands and meandering characteristics typically exhibited by more mature rivers become increasingly apparent as the Trinity River proceeds downstream from the vicinity of Cedar Creek. Wooded areas and wetlands increase in both extent and number, and all have been extensively logged at some time in the past. A few have naturally reforested and reverted to a state approaching vegetative climax conditions.

Because initial cost reviews by the Corps of Engineers (1974a) showed an unsatisfactory benefit to cost ratio, no definite levee alignment studies have been conducted for this alternative. However, any levee alignment in this report reach would probably involve significant channel straightening and some vegetative clearing between the levees. Increased flood protection would induce accelerated land conversion, through wetland drainage and timber clearing, to agricultural and real estate development. Construction operations, although more temporary, would also produce locally adverse effects on ecosystems. Other aspects such as natural flood plain values and populations of American alligator, red wolf, southern bald eagle, and other rare and/or endangered species of the area would be adversely affected.

Among the life quality considerations, anxiety factors associated with flooding would be reduced, but aesthetic values related to natural resources would be adversely affected in the view of many people.

Economic considerations such as real estate development would probably benefit through this alternative. Economic benefits would accrue to four units of the Texas Department of Corrections through increased protection of their agricultural activities situated along this reach of the river.

This alternative does not fulfill the planning objective of national economic development but does enhance the regional economic development account to some degree. The social well being account would also be benefited by an increase in such factors as public health, safety, and convenience and by an increase in the real income of some flood plain landowners.

The project purpose of flood control would be acheived by these levees, but they would contribute little or nothing to the management, conservation, creation, restoration, or improvement of the quality of natural resources and ecological systems. Therefore, the environmental quality objective would not be accomplished by this alternative.

2.04.07 Modification of Lake Livingston. This alternative contemplates providing flood control storage capability in Lake Livingston, either by raising the Lake Livingston dam to a higher elevation or by lowering the conservation pool level to provide flood storage capacity behind the existing dam.

Although Lake Livingston dam is downstream from much of the Trinity River flood plain, the dam height could be raised in order to impound floodwater and thus provide flood protection along downstream reaches of the Trinity River. However, recent private lakeside development along the shore of Lake Livingston would entail excessive costs in relation to the flood damage protection benefits provided.

Lowering of the lake water supply design level for flood control would result in drastically decreased water yield during droughts and a detriment to the present recreational use of the lake, since 2 to 3 million acre-feet of flood storage would be necessary for impoundment of historical flows. In view of these two considerations, this alternative was not considered capable of fulfilling the flood control project purpose to a meaningful degree.

2.05 Nonstructural Flood Control Alternatives. Nonstructural flood control measures lessen the damaging effects of floods by molding or restricting flood plain development rather than by physically altering or restricting the flow of floodwaters. Flood plain development regulation implies the adoption and implementation of legal tools by affected communities or governmental agencies.

2.05.01 Selective Flood Plain Acquisition. This alternative contemplates public acquisition of selected Trinity River flood plain areas. In broad terms, all land susceptible to inundation by a 100-year frequency flood would be acquired in fee simple, with certain specific exceptions. These exceptions would include agricultural or other presently developed areas that have been leveed and those lands already owned by non-Federal government agencies. Existing levees would be strengthened to assure 100-year flood frequency protection. Easements permitting only those structures not susceptible to flood damage would be acquired on unleveed lands owned by non-Federal governmental agencies. Only uninhabited structures of historical significance or that contribute in other ways to the general public welfare would be retained within the areas acquired in fee simple.

Flood plain agricultural land currently levee protected totals approximately 134,000 acres. This land would continue under private ownership. Therefore, environmental enhancement of these acres would be secondary to agricultural productivity interests.

Approximately 36,000 acres within the 100-year flood plain are currently owned by the State of Texas. This land comprises parts of the Texas Department of Corrections system and is predominantly devoted to inmate-operated agricultural activities. This land, together with other tracts that may be owned or acquired by other State or local governmental agencies, would be retained by these agencies, but acquisition of Federal easements on the land would prevent their future disposal and subsequent use for purposes not compatible with easement restrictions.

Effects of this alternative on about 400,000 acres of the natural environment would be highly beneficial for those areas. Nearly complete recovery of terrestrial ecosystems could take place if development were prohibited and access limited. Aquatic ecosystems could also benefit, providing that water quality from the upstream metropolitan area is improved. In general, acquired areas could be allowed to revert to their native and wild state by discouraging human intrusion except in recreation areas, specified and controlled hunting areas, or wildlife study areas. In the specific instances of producing oil and gas wells, access might be permitted during their remaining useful life with the provision that strict housekeeping and environmental safeguards be adhered to. Strip mining for coal or sand and gravel would be prohibited as would commercial logging.

By requiring the evacuation and removal of all habitable dwellings and commercial enterprises in the acquired areas, this alternative would impose adverse effects on some business and industrial activity within the flood plain. Although there are no towns or cities in the flood plain that would require evacuation, the rapid land development on the numerous oxbow lakes below Lake Livingston (Photographs 5 and 6, Appendix A) would require several thousand private dwelling relocations.

All known and undiscovered archeological sites, together with sites of present or potential historical significance within the acquired area could be preserved. Although it could not be guaranteed, the survival prospects for possible rare, endangered and/or endemic plant and animal species would also be enhanced. Other environmental considerations such as the natural river regimen and area ecosystems would likewise be enhanced.

This alternative would accomplish the national economic development objective, with an overall benefit-cost ratio of 1.3 to 1. It would not benefit the regional economic development account but would provide limited educational, cultural, and recreational opportunities.

The flood control project purpose would be achieved in areas of greatest potential flood threat, except for residual annual damages of about $2.6 million to roads, bridges, and utilities.

The environmental quality objective would be achieved through the preservation or enhancement of the quality of many natural and cultural resources and ecological systems.

2.05.02 <u>Selected Flood Plain Easement Acquisition</u>. Essentially, this alternative is a modification of the fee acquisition alternative described in the previous paragraphs. Easements would be acquired in flood susceptible areas in place of fee acquisition. All habitable dwellings would be removed from the easement areas and future development, including habitation, commercial, or industrial expansion, and conversion of woodlands to pasture or crop agriculture, would be prohibited. Present crop and livestock production with improvements resulting from technological advances could be retained, but flood loss indemnification and future flood protective measures such as levees would be precluded.

This alternative would probably reduce the rate at which detrimental effects to the natural environment are present accumulating in the Trinity River flood plain, but, with most of the land remaining in private ownership and many of the current land uses continuing, there could be no assurance that overall beneficial effects would accrue to the natural environment, particularly on those lands that would remain in their present agricultural uses.

While large scale environmental impacts such as surface mining (Photograph 16) and hardwood forest clearing would be prevented on easement land, smaller scale, but at the same time widespread, adverse environmental impacts would continue to accrue as the result of various human activities. Only continuous and widespread surveillance and efficient law enforcement would prevent these activities from eventually producing blighted rural areas similar to those currently existing. Examples of these include abandoned oil and gas fields, substandard housing, rural junkyards, etc.

Although the immediately preceding paragraph must be recognized as a forecast, it results directly from consideration of a fundamental issue grounded in the basic difference between fee simple land acquisition and easement acquisition. This issue concerns not only the common law judicial interpretations of the "taking clause" founded in the Fifth Amendment to the United States Constitution, but also the many public concepts and lay interpretations of this taking clause as it relates directly to an individual and his rights to use his real property as he alone sees fit. Since many conflicting judicial decisions on the taking issue exist, and since the American ethic concerning this vital land use right is undergoing rapid evolution as environmental concerns grow, there can be little doubt that the inception of this alternative would involve extensive litigation over this taking clause, particularly in Texas where there exists a strong heritage and tradition of private land ownership. The social implications resulting from the effective implementation of this alternative would be profound and widespread throughout the State of Texas.

By requiring the evacuation of all habitable dwellings and commercial enterprises in the easement areas, this alternative would produce adverse economic effects on business and industrial activity within the flood plain. Although there are no towns or cities within the flood plain that would require evacuation, the rapid land development on numerous river sites and oxbow lakes below Lake Livingston (Photographs 5 and 6) would require several thousand private dwelling relocations to accomplish this alternative. The number of private dwelling relocations required by the time of inception of this alternative could approach 15,000 with about 20 percent of these classified as permanent dwellings.

This alternative is technologically feasible and fulfills the national economic development objective and flood control project purpose with an overall benefit-cost ratio of 1.1 to 1. The regional economic development account would also be benefited by improvement of the regional economic base, although residual flood damages of about $9.3 million annually to structures and crops would remain.

Over the long term, the social well being account would be benefited by increased public health and safety, but the shorter term social well being question of affected landowners would depend to a large extent on the general acceptance of this plan by the property and landowners.

2.05.03 Flood Plain Land Use Controls. This alternative would achieve land use control in the Trinity River flood plain through the enactment of local zoning ordinances, subdivision control ordinances, and building codes. These types of ordinances would be designed to mold future flood plain development in such a manner as to lessen the damaging effects of floods. Enactment of such ordinances implies public understanding of flood problems and a widespread, cooperative, and progressive approach to program implementation and functioning. To be effective throughout 17 counties of the flood plain, numerous small communities, many levee and improvement districts, and other political subdivisions of the Trinity River Basin, this plan would require a high degree of coordinated effort in order to impose uniform regulations, to be consistent in variance and enforcement policies, and to otherwise perform equitably in the eyes of the public.

The Federal role in this alternative would be limited to providing guidance, technical information, and general plan support. Implementation of land use regulations, which must include police enforcement powers, rests initially with the State, but the State can, and often does, delegate these powers to its various political subdivisions.

It is questionable that all political subdivisions would enact and enforce consistent and equitable land use regulations with variance requests scrupulously and uniformly rejected. Intermunicipal competition to entice desirable business and industry and to cater to provincial aspirations could seriously jeopardize the long term viability of the alternative. This gradual erosion of the program would adversely affect the life quality and economic considerations.

An autonomous flood plain commission, delegated by the State with the responsibility to institute and enforce land use regulations throughout the flood plain, could effectively and equitably accomplish the task.

By controlling the use of land, the methods of subdividing large land parcels, and the minimum elevation and flood proofing criteria for structures, regulatory agencies could minimize the increase of flood damages. However, these regulations would likely contain "grandfather" clauses which, by permitting current land use to continue and structures to remain, would neither significantly reduce current flood damage losses nor enhance the natural environmental, economic, and life style considerations for large portions of the flood plain.

The primary attraction of this alternative is its cost effectiveness in allaying the continuing rise in flood damage losses. This alternative has a benefit-cost ratio of 39 to 1. It should be noted, however, that about two-thirds of the damages (mostly to agricultural property) would continue, and thus it is the low implementation cost and the alternative's effectiveness in reducing the future flood losses that contributes to this high ratio.

As population pressures increase, natural resource utilization, including those of the flood plain, will become more widespread, and thus, in a trade-off between conservation of natural environments and human utilization, the latter will probably prevail.

This alternative is technologically feasible and fulfills the national economic development planning objective. The regional economic development account would be not benefited through improvement on the region's economic base or by improving educational, cultural, or recreational opportunities.

The planning account of social well being would be slightly benefited by the eventual enhancement of public health, safety, and convenience factors. The flood control project purpose would also be partially fulfilled with residual annual flood damages of about 70% of the total annual projected losses.

2.05.04 Flood Insurance. The National Flood Insurance Program was initiated in 1968 by title XIII of Public Law 90-448. The recently enacted Flood Disaster Protection Act of 1973 (Public Law 93-234) was signed into law on 31 December 1973. The acts are administered by the Department of Housing and Urban Development (HUD).

The latest act substantially expands the National Flood Insurance Program to provide higher indemnity to the public and to reduce annual disaster assistance outlays through the increased availability and limits of flood insurance. It is intended to substantially expand flood insurance and to substitute an organized program of federally subsidized flood insurance for the present relief program. Arlington, Dallas, Dallas County, Fort Worth, Grand Prairie, Haltom City, Hurst, Irving, and Tarrant County in the

Trinity River project area were participating in the program as of March 1974. All of these governmental units lie in the Dallas-Fort Worth Metroplex. The act directs that by July 1, 1975 all communities which contain flood prone areas enact new building and zoning codes which would either prohibit building in flood prone areas or require that construction in these areas be adequately flood proofed or built above the 100-year flood level. Persons who live in such communities will not be able to purchase Federal flood insurance unless the responsible political entity has enacted such regulations. Without the insurance, no federally regulated bank or savings and loan association will be permitted to make any mortgage loan on property situated in flood prone areas.

The Department of Housing and Urban Development is directed by the act to publish information on known flood prone communities and to nofify them within six months of enactment of their tentative identification as such. Some identifications have been published, and it is expected that most communities in the Trinity River Basin which contain areas susceptible to inundation by a 100-year frequency flood will be notified as expeditiously as possible.

Utilization of flood insurance provided under this act as a flood control alternative has two facets of consideration. The first is its effect on existing damage prone property. Reduced annual disaster assistance outlays are planned through better insurance protection and wider availability of insurance. Increased indemnity and wider availability will result in higher claim outlays but no reduction in total losses to currently flood susceptible property that exists in the flood plain. The second consideration is future property improvements and construction. Because of the strong incentives for flood plain zoning and structure flood proofing, the potential for losses from future development in flood plains would be significantly reduced. It is therefore expected that, on balance, future flood losses would be reduced, but not significantly below the level of present losses.

The insurance will indemnify policy holders for their losses and will spread the losses among other policy holders and the public in general through its Federal subsidization, but it will not reduce the total losses per se. Whether it is termed flood disaster relief or flood insurance, the net effect remains: people suffering flood damages will receive some form of recompense. Thus it cannot be stated that increased insurance limits and reduced premiums under the Flood Disaster Protection Act of 1973 will provide sufficiently small flood loss indemnifications to induce owners of flood susceptible property to vacate flood prone areas in sufficient numbers to markedly reduce present flood damages.

Structures of the Flood Disaster Protection Act of 1973 are designed to achieve broader participation in flood plain zoning.

Together with structural flood proofing, strengthened incentives should significantly reduce the continued historic rise of flood losses. Broadened flood zoning will also benefit natural environmental considerations to the extent that the present rate of degradation should be slowed.

This alternative is considered technologically feasible, assuming that cooperative participation can be achieved at the local level. The regional economic development account would not be significantly affected.

The social well being account would be benefited to some extent by the eventual enhancement of public health, safety, and convenience. The flood control project purpose would also be partially fulfilled with residual annual flood losses reduced by 30%, as indicated for the previous alternative of Flood Plain Land Use Controls.

2.05.05 Improved Flood Forecasting. This alternative envisions enlarging the scope of present Trinity River Basin flood forecast programs by installation of additional stream gaging instrumentation for more timely forecasting of floods and their extent, coupled with prompt evacuation and protective measures to achieve a higher degree of safety to lives and property. Because of the technical nature of the work involved and the interstate factors that must be considered, Federal agencies have in the past taken the lead in technique development and operation. Considering the size of the Basin, leadership for this alternative would probably rest with the Federal Government, but might be assumed by a State agency working closely with the National Weather Service.

This alternative would not significantly reduce presently experienced flood damages nor would it essentially alter the present course of steadily mounting flood damages resulting from continuing flood plain development. The primary benefits of this alternative would accrue to the social well being account in terms of increased protection to human lives and movable property in flood prone areas. This alternative would have no effect on the planning objectives of national economic development and environmental quality, or on the project purpose of flood control.

2.05.06 Temporary Evacuation and Flood Fighting. This alternative incorporates timely evacuation of humans, livestock, and portable property ahead of rising floodwaters and the raising of temporary sandbag dikes, levees, or other structures to control flooding.

In some situations, temporary evacuation in the face of an impending flood disaster may be the only prudent action to take, but the frequency, duration, and irregularity of flooding along the

Trinity River present conditions generally unadaptable to this alternative. The success of flood fighting depends on the height the floodwaters attain, their velocity, duration, and the amount of time that advance warning provides. Even if successful, flood fighting by its definition requires an individual response to each flooding event. Regardless of who pays the expense, it is by nature cost ineffective, since each flood fighting action is a temporary expedient that produces little of lasting value. The cost of evacuation is pure cost in all events, and if a flood fighting action is unsuccessful, the cost of the flood fighting plus the value of the damaged property is lost. This alternative, like the previous alternative, would do little to achieve planning objectives or project purposes.

2.05.07 Flood Proofing Structures. Flood proofing consists of modifying structures and building contents in a manner designed primarily to reduce or eliminate flood damages. Such adjustments can be undertaken on existing structures or incorporated during initial construction.

Since the flood proofing of nonfederally owned structures is not generally considered to be a Federal responsibility, the flood proofing of structures would depend primarily on each individual owner's awareness of flood hazards, his willingness to undertake flood proofing measures, and his ability to bear the expense.

Although flood proofing techniques and information on them have been available for some years, the use of structural flood proofing on habitable structures has not been sufficiently widespread in the Trinity River Basin to noticeably reduce the ever increasing rate of flood losses. There is, therefore, no reason to believe that future individual initiatives to accomplish this form of flood proofing will increase significantly.

This alternative would do very little to beneficially or detrimentally affect environmental quality. It would reduce flood damages to habitable structures. It would benefit the social well being account by contributing to public health and safety.

2.05.08 Weather Modification. This alternative contemplates the possibility of achieving a degree of weather modification that would permit sufficient control of precipitation amounts and patterns over the Trinity River Basin to effect flood control. Weather modification studies to date appear to have been designed to attain normalization of or increases in precipitation over a given geographic area. In case of flood control, normalization of precipitation patterns might be useful, but the basic flood problem on the Trinity River results primarily from occasional heavy rainfall flowing down a relatively small channel with a flat gradient.

Trinity River flood control achieved through controlled normalization of basin rainfall patterns and frequencies would eliminate flood hazards to large areas of land along the entire river length without the necessity of any structures or channel modification. This scheme would produce wide economic benefits by permitting flood plain development, particularly in metropolitan areas where flood plain land would become very desirable because of its location.

By hastening flood plain development, this alternative would produce significantly detrimental effects on the natural environment and existing ecosystems in the Trinity River flood plain.

Weather modification techniques remain in the relatively early experimental stages with many more years ahead to assure even their feasibility. They are considered technologically unattainable at this time.

2.05.09 Summary of Flood Damage Control Alternatives. A total of 15 various alternative means of reducing flood damages have been considered in the previous sections. Throughout these discussions, references have been made to the capability of alternatives to fulfill the project purpose of flood damage control and to their technological feasibilities. The ability of each alternative to meet these two criteria is considered fundamental. If a particular alternative cannot be accomplished because it is not attainable by present technology or by reasonably foreseeable technological development by the time it would be needed, rules of reasonableness suggest that it would be futile to consider it further. Likewise, if evaluation of a particular alternative indicates that it is incapable of fulfilling its intended purpose to any meaningful degree, rules of reasonableness suggest that it would serve no useful purpose to consider it further.

These two criteria, (1) in order to be considered a viable component action, a single purpose alternative must be technologically feasible and (2) in order to be considered a realistic component action, a single purpose alternative must fulfill to some meaningful degree its individual project planning purpose, are displayed as selection criteria 1 and 2 in Table 2-1. Table 2-1 lists the 15 flood damage control alternatives discussed and the ability of each to meet the two selection criteria.

2.06 Water Supply Alternatives. Subsequent to authorization of the Trinity River Project, several water needs and supply studies of both the Trinity River Basin and the State of Texas as a whole have been conducted. The most comprehensive of these studies is the overall appraisal of the water problems of Texas, with possible solutions, which was undertaken in the mid-1960's by the Texas Water Development

TABLE 2-1

SUMMARY OF FLOOD DAMAGE CONTROL ALTERNATIVES

	Alternative	Text Paragraph	Selection Criterion No. 1	Selection Criterion No. 2
1	Channel enlargement	2.04.01	+	+
2	Channel enlargement for reservoir regulation flows	2.04.02	+	+
3	Multiple tributary lakes	2.04.03	+	+
4	Leveed metropolitan floodways	2.04.04	+	+
5	Levee strengthening From Five Mile Creek to Cedar Creek	2.04.05	+	+
6	Levees from Cedar Creek to Wallisville Lake	2.04.06	+	+
7	Modification of Lake Livingston	2.04.07	+	0
8	Selective flood plain acquisition	2.05.01	+	+
9	Selected flood plain easement acquisition	2.05.02	+	+
10	Flood plain land use controls	2.05.03	+	+
11	Flood insurance	2.05.04	+	0
12	Improved flood forecasting	2.05.05	+	0
13	Temporary evacuation and flood fighting	2.05.06	+	0
14	Flood proofing structures	2.05.07	+	0
15	Weather modification	2.05.08	0	0

NOTE: A "+" indicates alternative satisfies the criterion.
A "0" indicates it does not.

Board. The report, The Texas Water Plan, published in November 1968, and subsequently rejected by referendum, states ". . . studies for the Texas Water Plan show conclusively that presently available water resources are grossly inadequate to meet Texas' future economically justified water needs. . Importation of water from out-of-state sources will be essential." The Texas Water Plan included consideration of the proposed Tennessee Colony Lake in reaching this conclusion.

2.06.01 Ground Water Supply. This alternative involves drilling a series of additional wells over the Trinity group, Woodbine, Carrizo-Wilcox, Queen City, Sparta, and Gulf Coast aquifers (Plate 10) and withdrawing water at the maximum sustained yield rate for each aquifer. The water obtained would be used to offset future municipal and industrial water deficits of the Basin.

The feasibility of this alternative is subject to several important considerations which are condensed below from The Texas Water Plan.

More ground water is presently being removed in many areas of the State than is being replaced by natural recharge. In effect, the resource is being mined. This situation is particularly pronounced with regard to the Gulf Coast aquifer around Houston. Sustained heavy pumpage in local areas has caused several serious problems, and it is probable that these problems will become more widespread in the future unless the aquifer is properly managed. Declining aquifer water levels have increased pumping lifts, caused the intrusion of saline waters into the aquifer in the Galveston, Baytown, and Texas City areas, and has, in part, contributed to land surface subsidence in the Baytown-Pasadena area and along the Houston Ship Channel.

Resistance to regulatory measures by ground water users has prevented an effective management program for many important aquifers. Without properly planned, postive management programs, aquifers may be overdeveloped or improperly developed, resulting in their premature depletion. The Trinity group aquifer that underlies the Dallas-Fort Worth Metroplex has already been intensively developed for municipal and industrial water supply. In these heavily pumped areas, significant reduction in artesian head has already occurred. Detailed studies of the aquifer have been initiated by State agencies to develop a mathematical model to predict the behavior of this aquifer under alternate management programs. Under present Texas statutes dealing with water law, potential developers of ground water have no legal protection with respect to continued availability and use of these supplies.

A ground water alternative for water supply would have only minor effects on all natural environmental considerations, except water tables, which would likely be adversely affected.

Although several thousand wells might be required, each well site might require only about a quarter acre, and these sites would be widely dispersed. The inundation of large tracts of river and stream bottomlands, the associated adverse environmental impacts, and detrimental effects on local social patterns would be avoided.

The total Trinity River Basin sustained yield ground water supply has been estimated at 326,000 acre-feet annually. From a 1960 base use rate of 116,000 acre-feet annually, ground water usage is projected to reach 184,000 acre-feet annually by the year 2020 and 316,000 acre-feet by 2085, or 97 percent of total estimated yield.

Table 2-2 recaps the upper Trinity River Basin water balances. It does not include the projected yield from Tennessee Colony Lake but does include projected ground water usage. It demonstrates that ground water usage alone could not supply water needs of the upper Trinity River Basin area since it would supply only about 5 percent of upper basin needs under 1985 conditions. Because it would not supply quantities needed, this alternative is not considered to be capable of fulfilling the purpose of water supply to a meaningful degree.

TABLE 2-2

UPPER TRINITY BASIN PROJECTED WATER BALANCES
(1,000 acre-feet/year)

Source	Year 1985	1990	2000	2020	2085
Upper basin lakes	1,139.4	1,131.9	1,117.1	1,173.6	1,171.0
Ground water	47.0	53.0	59.0	71.0	85.0
Usable return flows	29.4	44.9	61.4	78.0	143.9
Total supply	1,215.8	1,229.8	1,237.5	1,322.6	1,399.9
Total needs	922.0	1,094.0	1,399.0	2,001.0	5,560.0
Deficits	0.0	0.0	161.5	678.4	4,160.1

2.06.02 Alternative Lake Water Supply Sources. This alternative contemplates the development of alternate water supply sources by construction of additional dams on streams in the general vicinity of the Dallas-Fort Worth Metropolitan Area. Since the drought period of the early 1950's, several entities have conducted extensive and continuing studies of water availability and potential sites for developing surface water supplies in the upper Trinity River Basin and in adjacent basins to the east. Potentially viable in-State sites have been identified, their potential yields evaluated, and these data balanced against projected population and per capita consumption increases in the upper Trinity River Basin.

Although the Trinity River Basin is bounded on the north by the Red River Basin and on the west and south by the Brazos River Basin, imports from lakes in these basins are not generally considered to be potential water supply sources. Inflow from the Red River to Lake Texoma, which lies on the Texas-Oklahoma border about 70 miles north of Dallas, possesses a dissolved solid concentration ranging from 1,000 to 2,000 milligrams per liter (mg/l), most of which is chloride from upstream saline springs and seepage areas. Since 1943, the U.S. Public Health Service recommended limit of 250 mg/l chlorides has been exceeded about 65 percent of the time. Conventional municipal purification processes for drinking water have little effect on chloride content. The Brazos River also has a notable salinity condition and, in addition, its upper watershed lies in a significantly drier climate where annual rainfall ranges from 18 to 30 inches. Watersheds to the east of Dallas generally receive an annual average rainfall of over 40 inches and therefore produce significantly greater rainfall runoff per unit of land area and larger dependable water supply yields. Transportation of water from one basin to another is limited by State law (Texas Water Development Board, 1968) to that water which is surplus to the projected 50-year needs of the basin of origin. Authorization, funding, design, construction, and impoundment of water require periods of time approaching, and sometimes exceeding, a decade. Water supply lakes in lieu of Tennessee Colony Lake could provide water of better quality but would transfer many of the associated environmental impacts to other sites throughout the drainage basins and estuaries. Only detailed investigation and analysis could determine the significance of impacts at alternate reservoir sites.

This alternative could fulfill the purpose of water supply. It would also be anticipated that the national economic development objective and regional economic development account would also be fulfilled. Additional water supply would benefit the social well being account. The construction of alternate lakes would produce adverse effects on the environmental quality objective.

2.06.03 Mississippi River Water Importation. Because of the need for mutual agreement and cooperation between the two or more states involved, it would appear to be a prerequisite to interstate transfer of water that the state receiving additional water fully develop and prudently use its in-state water supply resources before seeking supplies from other states. This makes questionable the importation of Mississippi River water into the Trinity River Basin for the near future. Preliminary studies indicate that the transportation costs for transfer of Mississippi River water to the upper Trinity River Basin would be in the range of $0.31 to $0.46 per thousand gallons. This does not compare favorably with the projected cost of approximately $0.03 per thousand gallons for Tennessee Colony Lake water plus a pumping cost ranging from about $0.05 to $0.15 per thousand gallons, depending on the destination of the water. The above costs do not include treatment costs for municipal use, which would be approximately the same in either case.

Importation of surface water from the Mississippi River by pipeline would avoid many of the environmental impacts associated with land inundation by additional lakes in the Basin.

Importation from the Mississippi River would impose significant adverse economic effects on water users and subsequently on the region's social well being account, as well as its economic climate. Energy consumption for pumping would be large.

This alternative is technologically feasible but would not achieve the planning objective of national economic development. The water supply purpose could be accomplished with regard to water quantity but would be expensive. The social well being account would not be benefited through contributions to either real income of relevant groups or to public health, safety, and convenience. Recent concern has been expressed by the Environmental Protection Agency concerning the suitability of lower Mississippi River water for municipal water supply.

2.C6.04 Wastewater Reclamation and Reuse. This alternative includes the recapture and treatment of municipal and industrial wastewater for reuse to augment present and future municipal water supplies.

Some reclamation and reuse of municipal and industrial wastewater has been a reality throughout this country for many years. Gavis (1971) estimates that one-third of the nation's population utilizes water from streams in which one gallon in 30 is water that has previously been used upstream and returned to the streamflow. In more extreme cases, one gallon in five has been previously used. Wastewater discharged into streams eventually loses its original identity through dilution, blending, and natural recovery. It then becomes suitable for this indirect reuse after conventional purification in municipal treatment plants.

Although reclamation and direct reuse for potable water supply has been successfully inaugurated in a few other countries such as South Africa, this practice has been limited primarily to emergency situations in the United States. As more pristine supply sources are depleted in the United States, wastewater reuse can be expected to assume added importance.

There appears at present to be two primary deterrents to more extensive direct wastewater reclamation and reuse for municipal water supply in this country. The first concerns the cost of wastewater reclamation, related demand-generated developmental research on treatment processes, and long term health effects questions. To date, alternative sources of water supply have been more economical than reclamation and reuse, and therefore there has been a lag in demand-generated developmental research programs. It is quite probable, however, that demand for wastewater reclamation will increase as more pristine supply sources are depleted and as a result of the rise in the value of wastewater. This value increase will accrue as a result of the more extensive and costly treatment practices imposed by increasingly stringent effluent standards.

The second deterrent deals with the problem of public acceptance of the concept of wastewater reuse for potable water supplies. This lack of present public acceptance appears to stem from two factors: (1) current aesthetic concepts borne of a general lack of understanding of present technological capabilities and (2) the understandable skepticism on the part of some public officials who must concern themselves with broad questions of public welfare and health. However, as public health officials become assured that hazards can be minimized and as more economical supply sources are depleted, the question of official acceptance will be resolved, and present aesthetic opposition will diminish through public information dissemination. This alternative is not technologically achievable in sufficient quantities to be meaningful at this time. It would be expensive, energy consuming, and would expend natural resources in terms of chemicals and filter materials etc. for wastewater treatment. It could slow the rate of local natural resource damage such as inundation by water supply lakes.

2.06.05 Desalinization. This alternative consists of a program to desalt sea water from the Gulf of Mexico and pump it to the Dallas-Fort Worth Metroplex or to desalt water from Lake Texoma and route it via pipeline to Isle du Bois Creek where it would flow to Dallas via Aubrey Lake, Lake Lewisville, and the Elm Fork of the Trinity River.

According to the National Water Commission (1973), the existing world water desalting capacity in January 1971 totaled about 304 mgd. The United States and its territories had about 320 plants with a total capacity of about 55 mgd. The total average daily demand for water supply in Dallas and its connected cities in 1975 is estimated at about 240 mgd (URS/Forrest and Cotton, 1973). The world's largest operating plant is in Kuwait and has a capacity of 30 mgd. A contract has recently been awarded for a 48 mgd plant in Hong Kong. The largest desalting plant in the United States in 1973 was the 2.6 mgd plant in Key West, Florida (about one percent of the 1975 Dallas average daily demand). The largest brackish water desalting plant in the planning stages in the United States is the 100 mgd plant to be situated near Yuma, Arizona (U.S. News and World Report, 1973). A water desalting plant (or plants) capable of replacing the dependable yield of the proposed Tennessee Colony Lake would have to produce about 490 mgd.

Since 1952, the cost of desalting water has decreased from about $7 per 1,000 gallons to about $1 per 1,000 gallons for sea water conversion plants and to about 50 cents per 1,000 gallons for brackish water conversion plants. Currently, sea water is desalted almost exclusively by distillation, while lower salinity waters (up to about 10,000 mg/l) are amenable to desalting by one of the membrane processes. Over the longer term (15 to 20 years), further cost reductions may be accomplished through technological advances, but unless a basic technology breakthrough is achieved, any cost reductions will likely be limited to those achieved through gradual design improvements. The rapidly escalating costs of energy will severely handicap efforts to reduce costs, since all desalting techniques require relatively large quantities of energy. According to the National Water Commission (1973), desalting projects using energy from outside sources (not in combination with energy production) are becoming less and less attractive as the cost of energy increases. They can be economically attractive where they can utilize the waste heat from power production or a natural energy source such as geothermal heat.

Waste product disposal from desalting plants can present environmental problems. The volume of waste brine from a sea water conversion plant is typically about 50 percent of the volume treated. The effluent from a 10 mgd plant, for example, would contain about 2,000 tons of salt residue daily. The market for most of these salts is limited, so its recovery and commercial disposal is impractical in most instances. Desalting plants can also add to localized environmental problems by the discharge of waste heat either from production of the additional power necessary for their operation or from the heat in the plant effluent when the distillation process is used (National Water Commission, 1973).

For these reasons, desalinization of sea water or of brackish water from Lake Texoma was not considered technologically feasible within the time frame of project need.

2.06.06 Evapotranspiration Control. This alternative considers the possibility of suppressing evaporation from existing area lakes in order to increase dependable yields and of reducing transpiration by phreatophyte control.

Suppressing evaporation from existing lakes in the area would have the effect of increasing the amount of water available for water supply purposes. Achieving greater yields from existing lakes could be expected to reduce the unit cost of water and slow the rate of water resource development.

Because of its obvious advantages to areas with high net evaporation rates, evaporation suppression has been under study for a number of years. Monomolecular films of cetyl alcohol or alkoxyethanols have been shown to be effective under certain conditions in achieving limited degrees of evaporation suppression.

The feasibility of the use of monomolecular films has yet to be demonstrated on large lakes. Problems relating to dispersion on large surfaces and film rupture by wave action or by boating activity have not been overcome.

This element of the alternative for evapotranspiration control is not at present technologically feasible and would not achieve the water supply planning purpose.

Invader phreatophytes such as salt cedar (Tamarix pentandra) and mesquite (Prosopis juliflora) have imposed significant evapotranspiration loads on several stream valleys in New Mexico and western Texas but are not currently significant contributors to the evapotranspiration rate in the Trinity River Basin. Invader phreatophyte control would not fulfill the water supply planning purpose.

Two hydrophytes, water hyacinth (Eichhornia crassipes) and Hydrilla sp. are known invaders of Lake Livingston and are probably established in other reaches of the lower Trinity River as well. Evapotranspiration rates from water hyacinth may approach six to seven times the rate normal to terrestrial vegetation (Ryckman et al., 1974) and over three times the evaporation rate of a free water surface (Holm et al., 1971) Hydrilla sp., however, is a submerged weed which clogs waterways and lakes with a massive growth that impedes water flow and which has been reported to have reduced the channel capacity of a large irrigation canal as much as 80 percent within five years after completion of the canal (Holm et al., 1971).

While the complete eradication of these weeds from the Trinity River would not fulfill the water supply planning purpose, their presence constitutes a menace to the viability of the Trinity River that is of continuing concern to agencies responsible for the overall well being of this water system.

2.06.07 Weather Modification. This alternative suggests increasing the water supplied by areal runoff in the upper Trinity River Basin through weather modification such as cloud seeding to increase average annual rainfall. This alternative is not at present technically attainable with any measurable degree of reliability and is not likely to be for many years in the future. It would increase the risk to lives and safety and probably would increase flood damage if undertaken at this time. Social aspects concerning public policy and legal questions resulting from inadvertent damages remain to be resolved.

2.06.08 Home and Business Cisterns. An alternative of individual installation of cisterns for water supply in homes and commercial buildings which would constitute a series of small reservoirs is not technologically feasible because of possible health hazards, lack of sustained yield assurance, and problems concerning installation program enforcement.

2.06.09 Extend Present Water Supply by Conservation Programs. This alternative contemplates the institution of a gradualized water conservation program designed to reduce the per capita water consumption rate from its estimated present rate of 160 gallons per capita per day to about 125 gallons per capita per day by the year 2020.

In their recent regional water supply study, the North Central Texas Council of Governments (1974) presented data estimates for the 16-county North Central Texas Council of Governments Region. The following estimates are excerpted from this study.

Sources of year 2000 water supply	Yield (mgd)
Dependable ground water supplies	60
Existing surface water supplies (including return flow)	878
*Aubrey Lake (funded for construction)	63.4
Lakeview Lake (funded for construction)	12.1
Cooper Lake (under construction)	79
Total supply	1,092.5

*Net increase of Aubrey-Lewisville Lakes System.

Projected 16-county population and water usage

Year	*Water use (gpcd)	Population (million)
1970	160	2.5
1980	170	3.6
1990	180	5.0
2000	190	6.4
2010	200	7.6
2020	205	8.8

*For cities over 200,000 people.

By holding the year 1970 usage rate of 160 gpcd constant and multiplying it by the population estimates above, the following water requirements were found:

Year	Regional water requirement (mgd)
1970	400
1980	576
1990	800
2000	1,024
2010	1,216
2020	1,408

A lineal interpolation of the population growth from the years 2000 to 2010 indicates that the available 1,092.5 mgd water supply would serve the year 2003 population at a daily consumption rate of 160 gallons per person. After the year 2003, the per capita usage would have to decrease to about 125 gallons per day by 2020 if the supply of 1,092.5 mgd were not increased.

Therefore, if present supplies were developed and equitably distributed within the 16-county area by pipeline construction, if lakes presently under construction were completed, and if no further water supply development were undertaken, the present daily usage rate of 160 gallons per person could be maintained until about the year 2003. Decreased return flows resulting from constant usage rate would probably make the year 2003 somewhat uncertain, however. Thereafter, the daily consumption rate would have to be decreased gradually to a 125 gallon per capita per day rate by the year 2020. Further population growth after the year 2020 would require a decreasing per capita daily consumption rate. It should be noted, however, that based on historic trends, the per capita consumption rate of 160 gallons per day will not remain constant. Rather, North Central Texas Council of Governments (1974) projects the usage rate to have risen to 190 gpcd by the year 2000 and to 205 gpcd by 2020. Maintaining a constant usage rate of 160 gpcd, therefore, represents a 16 percent reduction from normally expected usage in the year 2000, and a usage rate of 125 gpcd in the year 2020 represents a 39 percent reduction from the expected usage rate of 205 gpcd.

There are many methods of water savings available, but in theory any effective water conservation program would have to be equitably shared among domestic, municipal, commercial, industrial, and agricultural users, would have to be enforceable, and would be long term. The following are some of the program elements that might be adopted to make such a program effective.

2.06.09.01 Pricing. Historically, pricing has proven to be a remarkably effective mechanism for the allocation of a scarce resource to its maximum utility for society. As regards water resources, pricing is a potentially powerful tool for the regulation of its consumption (use). Many theories and attendant variations have been propounded, but a basic thrust toward restructuring existing municipal water user rates so that a higher unit rate is charged for successive increments consumed would provide a financial penalty for excessive consumption. A further refinement might include the following two steps: (a) separating the charge for water from the service expense for supplying it and allocating the service expense on a marginal cost basis among various classes of subscribers and (b) in addition to increased successive increment costs, the basic water rate would be adjustable on a seasonal or periodic basis to restrict use during high demand and restricted supply periods. This second step would provide a method whereby all water resource users, including self suppliers from surface or ground water sources, could be allowed to pay for their use of resources. Self suppliers, including those operating under both appropriative and riparian rights, would be included in a metered permit program whereby their consumptive use could be monitored and coordinated into a sequential use program.

2.06.09.02 Public Information Programs. A public relations program could be conducted to encourage the wise use of water, pointing out to consumers the benefits to be realized through intelligent water use. This program would provide informative data on efficient agricultural irrigation methods, home owner information on both efficient and off-peak fixture usage, lawn sprinkling methods, planting guides for drought resistant varieties of landscape trees, grass, and shrubs, and opportunities for sequential reuse or recycling by industries.

2.06.09.03 Municipal Conservation Programs. Programs by municipalities designed to promote efficient use of water in public facilities, to repair leaking valves and detectable leaks, and to limit irrigation or sprinkling in public parks and golf courses to reuse water would aid in the reduction of potable water use, as well as set examples for the citizenry.

2.06.09.04 Plumbing and Appliance Codes. According to the National Water Commission (1973), recent studies have shown that appliances and fixtures now available can reduce total water use in the average household by as much as 35 percent, and savings for commercial and business establishments can be as high as 50 percent. Plumbing codes could be refined and appliance codes could be instituted on a national or state basis to effect the above water use reductions.

Plumbing codes could require the installation of flow regulating devices on showers, lavatory, and sink faucets. One relatively inexpensive shower regulating device, for example, claims to reduce the normal shower flow of 7 to 10 gpm to about 3 gpm (Water and Waste Engineering, 1974). Inasmuch as the average shower is estimated to require 35 to 40 gallons of water, this device could provide substantial water savings.

Plumbing codes could require the installation of toilet fixtures which employ 2 to 3 gallons of water per flush as opposed to the normal

5 to 6 gallons presently required. Since toilets are estimated to account for about 45 percent of all water used in the average household, this revision could effect substantial water savings (National Water Commission, 1973).

Plumbing codes could require the installation of water heaters close to sink faucets in order to reduce the time sink faucets are run before hot water is obtained.

Appliance codes could provide for water use efficiency ratings on appliances such as dishwashers and automatic clothes washers.

Appliance codes could set water efficiency performance standards for appliances and could ban garbage disposals that require water.

2.06.09.05 Other Programs. Other programs could include: (a) a concerted development program to achieve wastewater recycle to augment reservoir supplies, (b) a statute requiring the use of nonpotable water such as untreated water piped from Lake Texoma in a parallel distribution system so that it could be used in sanitary systems and for fire protection, and (c) the installation of a system for the sequential use of treated wastewater for industrial purposes and then for agricultural irrigation, lawn sprinkling of private and public areas, and for fire demand.

A program designed to maintain a reduced level of the per capita water usage corresponds to a do nothing approach to water resource development. From this standpoint, it would be beneficial to the natural environment aspects of the environmental quality account but would likely not enhance its cultural resources aspects. Since it would involve little or no further development, it is also considered technologically feasible.

Limiting per capita water usage on the scale of 60 to 84 percent of normal demand would be considered tantamount to water rationing. Rationing of water on a regional basis has historically been considered a last resort alternative, not only by policy makers who must respond to public sentiment, but also by the affected citizenry, even though these citizens normally can be expected to respond favorably in visibly extreme or emergency situations of relatively short duration. To embark on a water rationing program of indeterminate length when other alternatives are available could only be expected to produce severely detrimental impacts on the social well being account.

In addition to affecting the individual citizen, industry would be expected to share in such a water curtailment program. Industries already situated in the region would suffer a competitive handicap as the result of the increased capital outlays and operating costs that they would incur. Similarly, regional water rationing could only be viewed as an economic disincentive by local industries which plan expansion or outside industries interested in siting future plants in the region. This alternative would have an adverse effect on the regional development account.

On a national basis, water rationing in a dynamic and burgeoning region such as the North Central Texas Council of Governments 16-county planning region of north central Texas would do little to increase the nation's output of goods and services or to improve national efficiency. In some cases, it is entirely reasonable to postulate that such a program could have adverse psychological effects on industrial and agricultural interests in other regions of the country. Water rationing would not contribute to the national economic development account.

Water rationing as a result of the do nothing approach does not fulfill the basin planning objectives of water supply as earlier defined.

2.06.10 Summary of Water Supply Alternatives. A total of nine alternatives for water supply have been discussed previously. Table 2-3 lists these alternatives and the ability of each to meet the two selection criteria as previously defined.

TABLE 2-3

SUMMARY OF WATER SUPPLY ALTERNATIVES

Alternative	Text Paragraph	Selection Criterion No. 1	Selection Criterion No. 2
1 Ground water supply	2.06.01	+	0
2 Alternative lake water supply sources	2.06.02	+	+
3 Mississippi River water importation	2.06.03	+	+
4 Wastewater reclamation and reuse	2.06.04	0	0
5 Desalinization	2.06.05	0	+
6 Evapotranspiration control	2.06.06	0	0
7 Weather modification	2.06.07	0	0
8 Home and business cisterns	2.06.08	+	0
9 Extend present water supply by conservation programs	2.06.09	+	+

NOTE: A "+" indicates alternative satisfies the criterion.
A "0" indicates it does not.

2.07 Alternatives to Navigation. Alternatives to providing navigation capabilities on the Trinity River for the transport of freight in the region from Liberty upstream to Fort Worth include freight transport, by railraods, trucks, aircraft, and pipelines. All these modes of transport presently exist in the region, and none is Federally owned or operated, although each may receive a particular type of subsidy. Unless specifically directed otherwise by Congress, the construction, operation, or maintenance of these alternative modes of freight transport would not normally be undertaken by the Corps of Engineers. Therefore, the exercise of any of these alternative modes of freight transport requires only the election of a no action course in regard to the provision of navigation facilities on the Trinity River.

The selection of either the construction of navigation facilities or the no action alternative involves the consideration of one basic question: whether or not the severity of effects on the human environment and natural assemblages as they presently exist in and along the Trinity River, and are likely to exist in the future, constitutes an acceptable trade-off in relation to benefits to the national economic development, regional economic development, and social well being planning accounts.

Compared with a navigable waterway, the effects of no action regarding navigation on the human environment and on the existing terrestrial and aquatic assemblages would be more gradual and therefore less outwardly apparent. Whether the final or long term effects would vary significantly in either case is open to question, since the development of the resources in the Trinity River Basin for economic purposes is expected to continue on an individual enterprise basis as a function of both population pressure and economic feasibility. The basin future without the project is discussed in Section 1. Section 3 discusses the effects of the proposed multiple purpose channel. In essence, the existing environment of the Trinity River Basin would be expected to undergo widespread change over the long term whether or not navigation capability for the Trinity River is provided. Many of these changes will adversely affect natural assemblages. Theoretically, man has the capacity to control his environment. Therefore, the effects of the no action regarding navigation alternative on the human environment, adverse or beneficial, would result from man's own choices. The basic difference in effects resulting from the two alternative courses of action lies with the relative abruptness with which these forecasted changes take place. In addition, none of the four various modes of freight transport included in the no action regarding navigation alternative can be considered to exert a net beneficial effect on the natural environment or natural biological resources. Thus, this alternative to Trinity River navigation cannot be considered to benefit the environmental quality planning account.

The national economic development planning account considers the value of the nation's output of goods and services and the improvement of economic efficiency. The various modes of freight transport included in the no action regarding navigation alternative contribute to the nation's output of goods and services. Since they operate under a free enterprise system, they must, over the long term, be profitable in order to remain in business, and thus they contribute indirectly to national economic efficiency. The navigation feature of the Trinity River Project would also benefit the national economic development planning account by exhibiting a benefit-cost ratio of 1.2 to 1.0.

From a regional economic development viewpoint, each of the existing modes of freight transport which would be available under the no action regarding navigation alternative is efficient for its application, adds to the regional economic base, and contributes to the social well being of the region's citizenry. Likewise, each exerts its particular adverse social effects and detrimental environmental impacts on the region. In other regions of the United States, various combinations of these alternate freight conveyance modes, including waterway transport, coexist and compete. Often truck routes, railroads, and waterways roughly parallel each other and connect the same terminal points. Their coexistence and competition demonstrate that these various transport modes must possess advantages to the shipper that are peculiar to each. To conclude that a navigable waterway is redundant in regions where other modes of freight transport are available is to deny that the navigable waterway is capable of contributing to the regional economic development account by virtue of its peculiar advantages to shippers, a circumstance that is apparent in other regions of the country.

That contributions to the social well being planning account have been made by the truck, railroad, pipeline, and aircraft modes of freight transport is an intuitively acceptable premise to most people. For example, funds from the national gasoline tax have been used to construct a Federal system of interstate highways which in turn have increased truck transport efficiency. Although few people actually calculate the resulting individual monetary benefits derived from savings on gasoline, time, and reduced costs of goods in the market place, few would deny they exist. While the interstate highway funds were derived from a specific tax, in other instances public services such as national parks, public libraries, school systems, fire and police protection, and street lighting contribute to social well being, and indirectly to individual monetary benefits, but are supported by general tax revenues. Their existence demonstrates that public consensus holds them beneficial to social well being, even though direct, individual monetary benefits cannot be ascertained. In the same manner, lack of a means to demonstrate individual monetary benefit to citizens from navigation facilities does not refute the existence of such benefits. While freight transport modes such as trucks, railroads, aircraft, and pipelines must demonstrate their contribution to the social well being of people by operating efficiently over the long term to generate profits, a public facility supported by tax revenue can only demonstrate its contribution to the individual monetary return aspects of the social well being planning account by exhibiting a benefit-to-cost ratio greater than 1.0 to 1.0.

2.08 Recreation Alternatives. The 1965 Texas State Comprehensive Outdoor Recreation Plan (SCORP) indicated that a deficiency of land and water based recreation opportunities existed in the general area of the proposed project. There is a shortage of public picnicking and camping facilities and bicycle or walking paths. The lakes located in the region receive heavy boating, fishing, water skiing, and swimming use. This present heavy usage indicates the need for additional recreational water surface to accommodate the ever increasing requirements brought about by population increases, additional leisure time, and increasing affluence.

2.08.01 Additional Facilities at Existing Lakes. Under this alternative, recreation facilities such as roads, boat ramps, parking areas, sanitary facilities, picnicking and camping units, and trails would be provided in addition to those already existing and to those in various project master plans. As shown in Table 1-44, many existing public facilities administered by the Corps of Engineers are already receiving excessive use, and the natural environment has suffered as a consequence. If more facilities were to be provided, in addition to those planned for optimum development of existing projects, the environment would suffer from the increased traffic, the quality of the individual recreational experience could decline, and the recreational needs of this area would remain unmet.

Construction of recreation facilities currently on master plans but not yet in existence is contingent upon funding by the Federal Congress and cost sharing agreements with local interests under Public Law 89-72. To date, it has been difficult to find local sponsors willing or able to share the large capital outlays required to develop and maintain recreation areas. This alternative would contribute to the national economic development objective and the regional economic development accounts but would neither advance the environmental quality objective nor contribute significantly to the social well being account.

2.08.02 Developing Access to Existing Streams. This alternative contemplates public access to streams, streambeds, and stream pools for water associated and land based recreation. The lands acquired in these areas would be developed by providing access roads, picnic sites, and camping facilities. Developments of this type would probably be popular with local residents and possibly some transients. Lacking a focal point, such as a lake, facilities would be strung out and would differ markedly from the attractions associated with large bodies of water.

To accommodate large scale visitation, sizable land areas would be required. The severity of natural environmental effects would be somewhat proportional to the amount of recreation demand fulfilled. Demand for recreational activities associated with large water bodies, such as water skiing, pleasure boating, and fishing would be largely unsatisfied. There would be a detrimental social effect on landowners along the river in terms of privacy and degradation of natural resources. Land use changes would occur from agriculture to recreation. Recreational activities of this nature would tend to stimulate rural economic growth by attracting urban dwellers who would require goods and services in connection with these activities. Such recreational pursuits as canoeing would be enhanced. Operation and maintenance of these types of facilities would normally be funded and administered by state agencies.

This alternative would contribute little to the national economic development objective or to regional economic development considerations, would not advance the environmental quality objective, but would contribute to the social well being account.

2.08.03 Terrestrial Recreation Areas. This alternative would provide public land areas, not necessarily associated with water, for land oriented recreational activities, including bicycle trails, horse trails, off-road motor bike trails, nature study trails, primitive camping areas, picnicking areas, hunting areas, and outdoor games and sports areas.

The Corps of Engineers is limited by the Flood Control Act of 1944 and the Federal Water Project Recreation Act of 1965 to the development of recreational facilities at Federal water resource projects. Therefore, land oriented recreational facilities cannot be provided by the Corps of Engineers unless they are incrementally associated with a water resource development project. This does not preclude the possibility that other governmental agencies could accomplish this alternative, although funding and administration by local interests is a problem to both agencies and taxpayers. Recreation areas able to accommodate various recreation pursuits would necessarily need to be relatively near population centers in order to provide convenient accessibility. Because some recreational activities are not compatible, the separation of activities would likely require separate locations. Thus, hunting areas would be separated from picnicking and organized outdoor sports areas, and off-road motor biking would be provided on isolated areas such as a sand and gravel pit where the bike riders could do very little more to degrade the ecosystem or upset the natural and human environments with noise.

Viability of this alternative would partially depend on reversal of the historic concept of acquiring and developing relatively remote, inaccessible, and inexpensive land to a program of locating recreation areas where recreation needs are greatest. This reversal could probably be best accomplished by regional entities, such as the North Central Texas Council of Governments and Houston-Galveston Area Council. These agencies could be expected to be familiar with potential recreational areas and with recreational and environmental preservation needs and desires of constituents in their respective areas. Thus, each could consider with freedom from provincial and individual influence such potential areas as an Elm Fork flood plain corridor which includes land around North Lake; Greater Southwest International Airport; a Clear Fork of the Trinity River corridor from Loop 820 to and along the east shoreline of Lake Benbrook; selected desirable areas around or near Eagle Mountain Lake, Lake Ray Hubbard, and White Rock Lake; the reach of the West Fork between Dallas and Fort Worth; or the Village Creek valley corridor including selected areas along the west side of Lake Arlington.

The natural environment would be benefited to the extent that some greenway corridors and open spaces would be preserved that otherwise would ultimately be developed for residential and commercial uses or exploited for minerals. The condition of the natural environment within these areas would undergo significant modification with the degree of degradation dependent upon public sensitivity to natural values, visitation intensity, type of recreation use, degree of control, and extent of maintenance performed by the responsible agencies.

Life quality considerations such as leisure opportunities, desirable community growth, cultural opportunities, and aesthetic values could be enhanced with proper usage supervision to avoid urban jungle atmospheres.

This alternative would not contribute to the national economic development or environmental quality objectives but would benefit the regional economic development and social well being accounts.

2.08.04 Designation of Wild, Scenic, or Recreational River Areas. Under this alternative, the Wild and Scenic River Act of 1968 (Public Law 90-542) would form the basis for designation of the Trinity River as a wild river, scenic river, or to provide recreational river areas. The Trinity River does not fulfill the criteria necessary for designation as a wild river area because it is not ". . . generaly inaccessible except by trail, with watershed or shorelines essentially primitive and waters unpolluted." Likewise, the Trinity River does not meet the requirements to be classified as a scenic river area since its shoreline is not ". . .still largely primitive and largely undeveloped." Texas Parks and Wildlife Department (1973) found that only that reach of the Trinity River below Lake Livingston meets the requirements for consideration as a recreational river area by possessing characteristics of being ". . . readily accessible by road or railroad, that may have some development along its shorelines, and that may have undergone some impoundment or diversion in the past." Classification of this reach of the Trinity River as a recreational river area would provide a higher degree of protection to streamside vegetation and wildlife, as well as provide recreation areas for hikers, canoeists, and fishermen. There would, however, be adverse environment impacts commonly associated with human usage of recreational areas. There would be no large body of water associated with this type of development and little opportunity for visitors to participate in water based activities such as water skiing. Most of the areas that could qualify for this classification are on the more remotely located reaches of the river. This factor would probably reduce usage, and therefore the areas would be of marginal value in satisfying recreational needs.

By preserving some environmental resources, the planning objective of environmental quality would be partially fulfilled. The social well being account would also be benefited by the alternative's contribution to recreation opportunities.

2.08.05 Additional Recreation Lakes. This alternative consists of developing additional recreation lakes built on either the Trinity River or on tributaries throughout the Trinity River Basin or in adjacent basins within the recreation market area, possibly in conjunction with water supply, hydroelectric power generation, or power plant cooling water. Corps of Engineers studies have shown that single purpose recreation lakes are generally not economically justifiable. The reluctance of some local sponsors to participate in cost sharing with the Corps in the development of recreation sites at existing lakes, as required by the Federal Water Project Recreation Act of 1965, demonstrates the relatively low priority value placed on these types of facilities by local and state agencies.

Lakes constructed by state or local agencies have usually been built for specific purposes such as water supply and have provided limited public recreation facilities. Lakeshore land around these lakes generally remains in private ownership, and this restricts access by the general public. This type of development has evolved through the desire for economic gain by developers who profit from the sale of land at inflated values. Thus, while the public benefits to the extent defined by a state or local agency's primary project purpose, such as water supply, the recreational spin-off benefits or opportunities are sometimes limited to relatively small segments of the public.

Adverse effects on the natural environment resulting from indiscriminate land development motivated primarily by economic considerations abound around various lakes in the area. Some are more detrimental than others, but none of this development is required to observe the environmental considerations in its decision making processes that are required for Federal projects under the mandates of the National Environmental Policy Act of 1969, unless Federal funding is involved. By improving the region's economic base, this alternative would benefit to some measure the regional economic development account. To provide opportunities for people of the Trinity River Basin area to enjoy water oriented outdoor activities, while not necessarily preserving natural areas of significance for present and future generations would only slightly benefit the social well being and environmental quality accounts.

2.08.06 Summary of Recreation Alternatives. A total of five alternatives for recreation have been discussed in the previous sections. Table 2-4 lists these alternatives and the ability of each to meet the two selection criteria defined previously.

TABLE 2-4

SUMMARY OF RECREATION ALTERNATIVES

Alternative	Text Paragraph	Selection Criterion No. 1	Selection Criterion No. 2
1 Additional facilities at existing lakes	2.08.01	+	+
2 Developing access to existing streams	2.08.02	+	0
3 Terrestrial recreation areas	2.08.03	+	+
4 Designation of wild, scenic, or recreational river areas	2.08.04	+	+
5 Additional recreational lakes	2.08.05	+	+

NOTE: A "+' indicates alternative satisfies the criterion.
A "0" indicates it does not.

2.09 Hydroelectric Power Alternatives. Congress, through several acts of legislation, has directed consideration of hydroelectric power in Federal water resources development plans. The Corps of Engineers is responsible for insuring the maximum public benefits from each of its projects for all desirable purposes, including power generation. Hydroelectric power has become more economically competitive as a result of rising fossil fuel costs.

2.09.01 Alternative Fuel Sources. This alternative contemplates employing various fuels for the generation of electric power. According to Texas Transportation and Energy Report (1974a), over 99 percent of Texas' electrical power was being generated by natural gas in 1972. Because of possible future oil and natural gas deficits, utility companies are increasingly including lignite and coal in their plans for future power generating plants. These deposits in Texas are extensive and will probably be strip mined. Attendant impacts could include significant land disruption along with a greatly increased potential for air, water, and land pollution from burning coal and lignite.

Nuclear power plants are now coming into being as the demand for electrical power in Texas continues to double about every six years. While nuclear power generation offers great future promise as technology continues to be refined, controversy over site locations, safety, cooling requirements, and other factors has restrained development.

The uses of the above fuels to generate electricity are technologically feasible and would benefit the national economic development, regional development, and social well being accounts. The environmental quality account would not be benefited.

2.09.02 Geothermal Sources. Geothermal energy can be produced in areas where heat from magma or molten rock is shallow enough to be reached by drilling. Heated water or steam also may reach the surface naturally as geysers or hot springs. Geothermal power is already in limited use in various parts of the world, such as Larderello, Italy; Mamaskard, Iceland; Pathe, Mexico; Wairakei, New Zealand; and in northern California by Pacific Gas and Electric Company. The existence of a belt of heated water deposits in Texas has been well documented by oil well drilling (Dorfman and Kehle, 1974). This belt extends southward from Houston along the Texas coast. The best potential sites for exploratory drilling are being studied. Despite some optimistic outlooks, utilization of geothermal energy is in its infancy, and substantial technical problems remain to be solved, including the problems of corrosiveness of mineral laden hot water, possible land subsidence, and potential air, water, and land pollution. Thus, geothermal power in Texas is not likely to replace or be capable of augmenting either fossil fuels or nuclear energy on a significant scale in the near future.

2.09.03 Wind Driven Generators. This alternative envisions the use of a series of strategically sited windmills to generate electricity. Tapped on a large scale, wind power could theoretically produce enormous amounts of electrical energy, and because the concept is so simple, it has tantalized inventors for many years. Although a series of large windmills dotting the landscape may not be aesthetically attractive, the lack of other possible environmental detriments, together with a potentially limitless source of free power, is appealing. Although the windmill has been used to generate small amounts of electricity since around 1890, the potential of wind power on a large scale has received only passing attention in searches for new energy sources because of economic considerations and technical problems. National energy deficit concerns have very recently spurred renewed developmental efforts. This alternative is not considered technologically feasible within the time frame of the Trinity River Project.

2.09.04 Installations at Other Damsites. This alternative would include the possible installation of hydroelectric facilities at other existing damsites that could serve the same energy network as the proposed facilities or the installation of facilities to utilize the stored water in lakes for the generation of electrical power during peak demand periods and to pump water back into an existing lake during off-peak electrical demand periods.

Policies of the Texas Water Rights Commission with respect to dedication of water, including Federal lakes, are governed by priorities of use established by Texas law, as follows:

Use	Priority
Domestic and municipal	1
Industrial	2
Irrigation	3
Mining	4
Nydroelectric power	5
Navigation	6
Recreation and pleasure	7

All water stored in Federal lakes in the Trinity River Basin has been allocated to water supply for domestic, municipal, or industrial uses, each of which use ranks higher in priority than hydroelectric power use. As may also be noted from Section 1, which lists lakes, their owners, and the purposes for which water is stored, the entities controlling these lakes have committed the stored water to usages bearing higher priorities than hydroelectric power usage. Therefore, there is no water available in existing Basin lakes for the generation of hydroelectric power at other damsites.

2.09.05 Magnetohydrodynamic Generators. Magnetohydrodynamic (MHD) electric power generation is accomplished by substituting a hot, flowing ionized gas for the rotating copper coils in an electric generator. As pointed out by Weaver (1972), the concept is simple, and calculated efficiencies are high compared to a conventional fossil fueled generating plant. The technological development of MHD generation has not yet advanced sufficiently to permit its practical application, and therefore MHD is not considered technologically feasible within the time frame of the Trinity River Project.

2.09.06 Solar Power. The sun is the greatest source of available energy on the earth's surface. Solar radiation transmits 100,000 times as much energy to the earth as can be generated by all the world's electrical production capabilities (Weaver, 1972). Weaver reports that only 65 percent of the energy received is absorbed, and only a minute portion is directly utilized by man. Fossil fuels are, simply stated, stored solar energy which has accumulated for millions of years, so that solar energy is currently used indirectly.

From the environmental viewpoint, the use of solar power is as clean or cleaner than any other source of energy. The principal reason it has not been used more extensively is economics. Other sources of energy have proven cheaper to use and more convenient to adapt to current needs. As fossil fuels are depleted and their value rises as a consequence, and as its gathering becomes more efficient, solar energy will be used more extensively. This alternative is not considered technologically feasible within the time frame of need for the proposed Trinity River Project.

2.09.07 Summary of Hydroelectric Power Alternatives. A total of six alternatives to hydroelectric power generation have been discussed in the previous sections. Table 2-5 lists these alternatives and the ability of each to meet the two selection criteria defined previously.

TABLE 2-5

SUMMARY OF HYDROELECTRIC POWER ALTERNATIVES

	Alternative	Text Paragraph	Selection Criterion No. 1	Selection Criterion No. 2
1	Alternative fuel sources	2.09.01	+	+
2	Geothermal sources	2.09.02	0	0
3	Wind driven generators	2.09.03	+	0
4	Installations at other damsites	2.09.04	+	0
5	Magnetohydrodynamic generators	2.09.05	0	0
6	Solar power	2.09.06	0	0

NOTE: A "+" indicates alternative satisfies the criterion.
A "0" indicates it does not.

2.10 No Action. The no action alternative refers only to foregoing the proposed Trinity River Project and any of its presently contemplated alternative courses of action. If adopted now, it does not preclude the possibility that changed conditions in the future might precipitate later authorization of a similar action. Additionally, adoption of a no action alternative with regard to the Trinity River Project does not signify that the normal course of events in the project area will be halted. Change, with its good or bad effects on the human environment, on remnants of the natural environment, and on ecosystem vestiges will take place, and it is also entirely possible that another governmental agency, either Federal, State, or local, might undertake some portion of the project.

Studies by the Texas Water Development Board (1968), URS/Forrest and Cotton, Inc. (1973), and the Corps of Engineers generally concur that the upper Trinity River Basin faces a water supply deficit by the mid-1990's. There can therefore be little doubt that the no action alternative would encourage State or local entities to construct water supply lakes that would take the place of Tennessee Colony Lake. These entities could include various river authorities and municipal utility districts. As pointed out by URS/Forrest and Cotton, Inc. (1973), ". . . the cost of water in a Federal multi-purpose project in (sic) normally less expensive to the local interest than a non-Federal project. . . ." Thus water supply provided for future Trinity River Basin needs could be expected to be more costly to local interests if supplied from single purpose lakes constructed by non-Federal entities. These costs would be passed on to consumers.

Past actions indicate that, if flood prone land is in some way attractive, man will attempt to occupy or utilize it. The no action alternative, in the absence of coordinated and comprehensive flood control planning, would probably result in a continuance of fragmented and uncoordinated flood control activities, principally levee construction and drainage activities. If land values continue to inflate along with agricultural commodity prices, this process may be expected to accelerate. As this land conversion process accelerates, additional acreages of bottomland hardwood forest, millions of trees, unique wetland wildlife habitat, and valuable remnant ecosystems may disappear. The no action alternative could possibly be economically beneficial to some private individuals and groups. Lacking either a comprehensive plan or direction, coordination of individual activities would be unnecessary. Each affected individual or group would be relieved of the concern for overall social benefits and would be free to proceed with flood control measures dictated primarily by economic self interest. One owner of land on the river, for example, might levee his holdings without regard to hydraulic considerations that would result in higher flood stages on neighboring land upstream or across the river.

Developers would be free to continue subdividing flood prone river bottomland and reselling the sites to the uninformed.

The demand for water based recreation is evidenced by the increase in visitation to Corps of Engineers lakes. During the past decade, the rate of increase has averaged 10 percent per year.

The Corps as a single agency is the largest supplier of water oriented outdoor recreation facilities in the Trinity River Project market area, with 10 lakes totaling over 213,000 surface acres of water. Most of the existing facilities at these lakes are approaching or exceeding optimum visitation.

Several other Federal, State, county, and municipal agencies have also provided lakes which are used to some extent for outdoor recreation. As of April, 1975, the Soil Conservation Service had developed 822 of their planned 1,109 small watershed impoundments totaling about 20,000 surface water acres throughout the Trinity River Basin. In addition, municipal water supply lakes constitute about 309,000 acres. However, lakes constructed by agencies other than the Corps of Engineers have made only limited provision for public recreational development. These lakes have been built for a specific purpose such as water supply, flood control, power, or combinations thereof. Private development around these lakeshores results in exclusive use of the shoreline and lake waters by adjoining landowners and quite limited public use of the water for recreation because of limited points of access. Increased usage at existing recreational facilities could adversely affect the remaining natural resources and intensify water, noise, air, and solid waste pollution at these sites.

As related in Section 1, navigation of the Trinity River has been regarded by some as advantageous since early pioneer days. The first Trinity River navigation project to Dallas was authorized by Congress in 1902. Although the project was later abandoned, some of the economic advantages attributed to navigation 70 years ago remain today. The no action alternative would forego the economic benefits of navigation that could accrue to the area.

The incremental addition of hydroelectric power could become part of the project provided it is justified economically and authorized by Congress. The hydroelectric power benefits would be foregone with the no action alternative.

The no action alternative remands the solution of the water resource problems of the Trinity River Basin, as stated at the beginning of this section, to other Federal, State, or local entities.

2.11 <u>Alternatives that Address Multiple Project Purposes</u>.

2.11.01 <u>General</u>. When considering the formulation of alternative plans that involve a wide spectrum of possible alternative actions that address the five project purposes in different ways, a large number of combinations could result. However, it is crucial to the evaluation and decision making processes that alternative plans to be considered are reduced to a manageable number.

From the preceding discussion of single purpose alternatives, it may be observed that, although several of these single purpose alternatives may represent attractive concepts to various interests, they are not applicable to the proposed project either because they are technologically infeasible within the project time frame or because they fail to fulfill, to any meaningful degree, their respective project planning purpose. Table 2-6 displays a flow chart demonstrating the alternative plan selection process used. It includes the various single purpose alternatives previously discussed.

2.11.02 Alternative Plan Formulation. Requisites to both alternative plan formulation and to project formulation are the identification of existing and future problems and needs of the project area and the evaluation of project area resource capabilities. These requisites have been addressed in Section 1.

It is the intent of the Water Resources Council (1973) that the overall purpose of water and related land resource planning be to promote the quality of life by reflecting society's preferences for the attainment of two objectives: (1) to enhance national economic development and (2) to enhance the quality of the environment. Formulated plans . . ."will be directed to the improvement of the quality of life by meeting current and projected needs and problems as identified by the desires of people in such a manner that improved contributions are made to society's preference for national economic development and environmental quality."

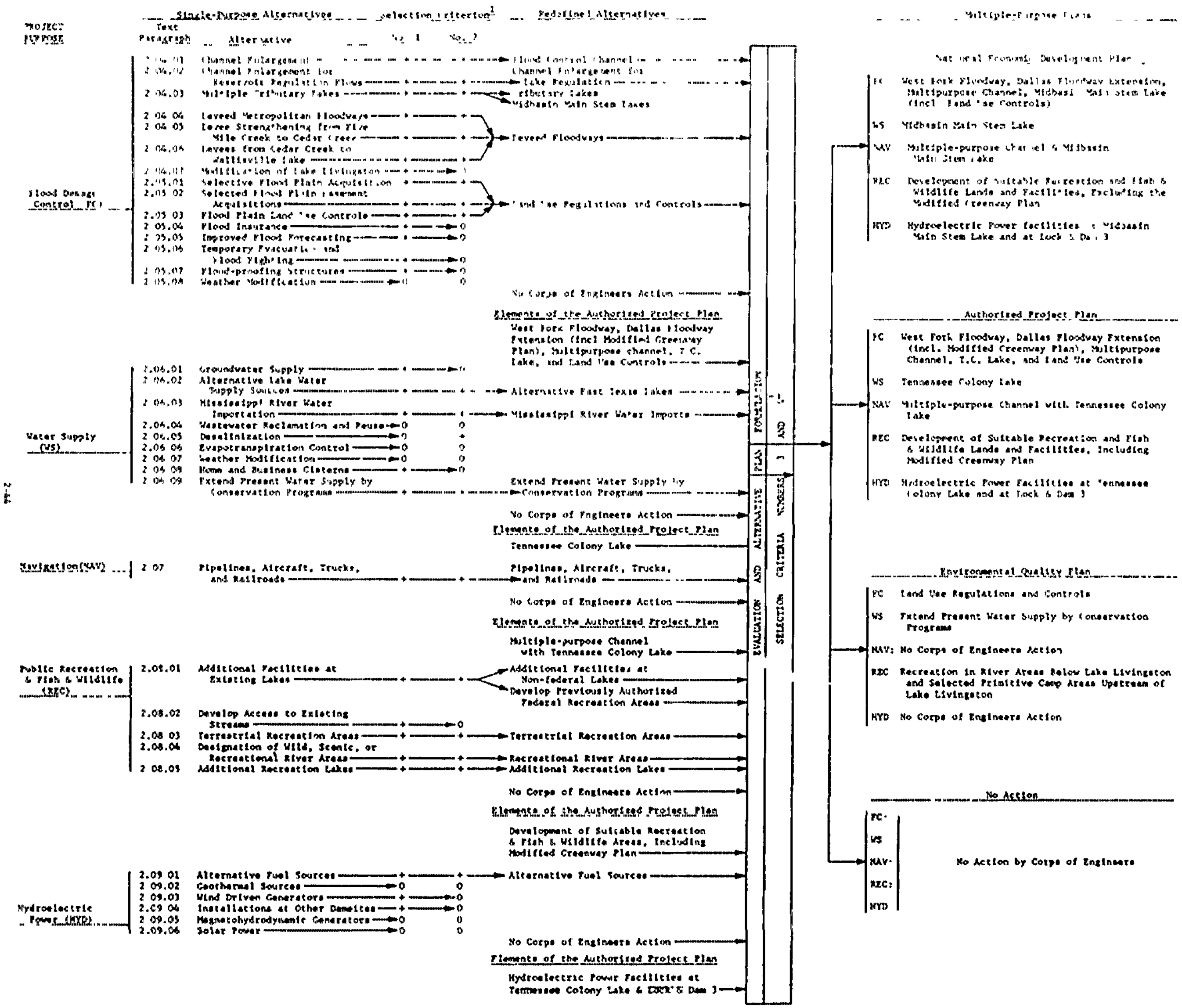
Two alternative plans, each designed to maximize or emphasize one of the considerations set forth above, were formulated: (1) the National Economic Development Alternative Plan and (2) the Environmental Quality Alternative Plan. Social well being is, for the purposes of alternative plan formulation, a fundamental concept embodied in both of these planning objectives. It must therefore be recognized and accounted for in both the formulation of alternative plans that maximize or emphasize the planning objectives and in their subsequent evaluation.

The mechanics of the alternative plan formulation process are displayed in Table 2-6. The single purpose project alternatives are among the Trinity River Project water resources planning alternatives considered (U.S. Army Corps of Engineers, 1974a). From these previous discussions, alternatives meeting selection criterion 1 and 2 were reconsidered and redefined by an interdisciplinary environmental team in order to include both the single purpose elements of the proposed project and the no action alternative, to combine closely associated single purpose alternatives or to separate others into pertinent facets, and to reflect the interdependencies among single purpose alternatives inherent in a multiple purpose project. The alternative plan formulation process was in part accomplished by dividing the project area into subregions in order to recognize the several diverse aspects inherent to an area the size of the proposed project area. The following six subregions were considered.

2.11.02.01 Subregion I. Subregion I includes the portion of the Trinity River Basin planning area beginning at Riverside Drive in Fort Worth and extending downstream to Five Mile Creek on the southern outskirts of Dallas. This subregion was selected on the basis of its primarily metropolitan character. Portions of this subregion are shown in Photographs 17 through 22, Appendix A.

PLATE 2-6

MULTIPLE-PURPOSE ALTERNATIVE PLAN FORMULATION PROCESS DIAGRAM



[1] Selection Criteria

1. In order to be considered a viable component action, a single-purpose alternative must be considered technologically feasible (receive a + in the Selection Criterion No. 1 column)

2. In order to be considered a realistic component action, a single-purpose alternative must fulfill to some meaningful degree its individual project planning purpose (receive a + in the Selection Criterion No. 2 column).

3. All single-purpose alternatives selected as component actions of a multiple-purpose alternative plan must be mutually compatible

4. Each formulated multiple-purpose plan must address the maximum number of basin planning purposes consistent with the previous three criteria.

Note: Hydroelectric power facilities are evaluated and proposed as a part of preconstruction planning activities on the Authorized Project. Construction of this feature would be contingent upon Congressional authorization.

2.11.02.02 Subregion II. Subregion II includes that portion of the Trinity River Basin planning area beginning at Five Mile Creek and extending downstream to the vicinity of river mile 400, near Trinidad. This subregion is basically an agricultural area that extends across the Black Prairie physiographic region into the East Texas Timber Belt, as shown on Plate 6. Soils in this subregion are predominately Texas Blackland Prairie soils, as shown on Plate 12. The flood plain is characterized as mainly row crop agricultural land protected by levees erected by local interests, although many sand and gravel operations are evident. Photographs 15 and 16 show portions of this subregion.

2.11.02.03 Subregion III. Subregion III includes that portion of the Trinity River Basin planning area beginning about river mile 400 and extending downstream to the vicinity of river mile 335 near Catfish Creek. This subregion is characterized by a land use transition, as shown on Plate 13, wherein agricultural cropland dominance gradually shifts to a mixture of forest and rangeland or pastureland dominance. Photographs 13 and 14 show portions of this subregion.

2.11.02.04 Subregion IV. Subregion IV includes that portion of the Trinity River Basin planning area beginning about river mile 335 and extending downstream to the headwaters of Lake Livingston. This subregion is characterized as mainly wooded land and pasture or rangeland with agricultural cropland (mostly within the Texas Department of Corrections facilities) comprising a relatively small percentage, as shown on Plate 13. Photograph 9 shows portions of the Eastham and Ferguson Prison Farms.

2.11.02.05 Subregion V. Subregion V includes that portion of the Trinity River Basin planning area beginning at the Lake Livingston Dam and extending downstream to Wallisville Dam. This subregion is characterized as predominately forest land with relatively high annual precipitation rates and flat terrain. The flood plain is typified by large wetland areas and extensive second home or vacation home developments. Photographs 2 through 7 show a variety of scenes in this subregion.

2.11.02.06 Subregion VI. Subregion VI includes that portion of the Trinity River Basin planning area beginning at the Wallisville Dam and extending through the Bay System to the Houston Ship Channel. This subregion is characterized as an estuarine area, shown in part on Photograph 1, and the open bay areas of the Galveston Bay complex.

The formulation of each of the alternative plans was achieved through the joint efforts of an interdisciplinary environmental team which arrived at its consensus by drawing on its individual and combined knowledge of the area, its problems and needs, and its resources and attributes. Selection of any particular reconsidered and redefined alternative as a component of any one alternative plan did not preclude its selection as a component of the second alternative plan. It was also found necessary in some instances to select a blend of more than one single purpose alternative to fulfill a single project purpose in order to recognize the underlying social well being concept inherent in each planning objective. In addition, each alternative plan formulated was subject to selection criterion 3 and 4, which are displayed in Table 2-6.

2.11.03 Formulated Multiple-Purpose Plans. The Authorized Project Plan is abstracted below with quantification and evaluation presented in Section 3. The National Economic Development Plan and the Environmental Quality Plan, outlined in Table 2-6, are also described below. No Action was defined in Paragraph 2.10.

The Authorized Project Plan includes four basic features of the originally authorized Trinity River Project: (1) The West Fork Floodway and (2) the Dallas Floodway Extension for the purposes of flood control and recreation and fish and wildlife; (3) Tennessee Colony Lake for the purposes of flood control, water supply, recreation and fish and wildlife, navigation, and hydroelectric power; and (4) the Multiple-purpose Channel for flood control, navigation, recreation and fish and wildlife, and hydroelectric power. These four features have undergone numerous design modifications as preconstruction planning has progressed since its initial funding in fiscal year 1970. One of these modifications (hydroelectric power) will require Congressional approval. Preconstruction modifications are described in the first part of Section 3.

The National Economic Development Plan includes construction of the West Fork Floodway, the Dallas Floodway Extension, a midbasin main stem lake, and the Multiple-purpose Channel. Although these would be the same elements as the Authorized Project Plan, the design of these elements would emphasize hydraulic and economic efficiency.

For the West Fork Floodway this emphasis would delete the modified greenway plan and align the Multiple-purpose Channel along the existing river. All obstructions, including vegetation such as trees and other woody shrubs, would be removed to promote hydraulic efficiency and permit the narrowest possible leveed floodway capable of confining a Standard Project Flood. Cutoff segments of the existing river would be used for excavated material disposal and reserved for future use as maintenance dredge material disposal sites. The Dallas Floodway Extension would be designed in a similar manner.

The Multiple-purpose Channel would be constructed along the most economical alignment, utilizing the existing river channel wherever possible, conventional excavation and disposal techniques, and two-stage construction. River cutoffs would be used for excess excavation and maintenance dredge material disposal areas. No reforestation work would be undertaken.

The Tennessee Colony Lake Damsite would be reevaluated to site the dam at its most economically efficient location, multi-level intake structures (selective withdrawal capability) for downstream water quality at Tennessee Colony Dam would be deleted, and ring levees for control of dredge material in the midbasin lake and Lake Livingston would be foregone.

Modifications dealing with the recreation aspects of this Plan, such as the modified greenway plan, that are included in the Authorized Project Plan would be omitted in the interests of economy. Additionally, physical facilities provided at remaining recreation sites would be restricted to the minimum necessary, thereby maximizing the benefit-cost ratio.

The Environmental Quality Plan proposes essentially nonstructural methods to achieve water resource planning objectives. Flood damage control would be provided to areas within the 100-year frequency flood plain by land use regulations and controls. The zoning facet of a land use regulations and controls plan would employ the Flood Disaster Protection Act of 1973, as previously described, as its primary vehicle. Since this Act is primarily structured to provide economic incentives designed to minimize structural flood damages over the long term in the flood plain, it would do little in itself to beneficially affect the existing natural assemblages in the flood plain. Mineral exploitation, logging, clearing for grazing or row crops, and other nonstructural land uses could, and likely would, continue.

In order to both reduce flood damages and to beneficially affect the natural assemblages in the flood plain, ecologically viable acreages would be acquired in fee simple. These include: about 6,000 acres in several parcels between Riverside Drive and Five Mile Creek, about 2,500 acres near Trinidad, about 10,000 acres in the vicinity of Richland and Tehuacana Creeks, about 13,000 acres in various parcels between the Tennessee Colony Damsite and Lake Livingston, and about 5,000 acres near Liberty. Flood plain easements would be acquired in those reaches of the flood plain that would neither be zoned in consonance with the Flood Disaster Protection Act of 1973 nor acquired in fee simple.

The water supply purpose would be partly acheived by use of the water conservation program previously described, and no action would be taken on the Multiple-purpose Channel and hydroelectric facilities. Only those recreation facilities that prove environmentally compatible and that provide minimal opportunity for recreationists to inflict adverse environmental impacts on the area would be provided. These would consist of primitive campsite acreages strategically located at convenient canoeing distances along the Trinity River. Land access would be limited to those sites placed near existing highway bridges crossing the Trinity River or at other existing public access points. Additional recreation could be permitted by providing public access for fishing at selected points.

2.11.04 Evaluation of Multiple-Purpose Plans. The formulated Multiple-purpose Plans require systematic evaluation in order to develop readily comparable information and in order to indicate options so that decisions concerning alternate courses of action can be made with full awareness of potential implications.

While each formulated Multiple-purpose Plan maximizes or emphasizes its respective planning objective, it has implications with respect to other planning objectives, as well as to social well being. Therefore, each formulated Multiple-purpose Plan is evaluated in terms of the four accounts set forth by the Water Resource Council Guidelines of 1973. These accounts are described in the following paragraphs.

2.11.04.01 The National Economic Development Account (NED). The NED account reflects user benefits and is considered primarily in terms of relative benefit-cost ratios.

2.11.04.02 The Environmental Quality Account (EQ). The EQ account considers effects on the natural environment, on ecological systems, and on other aspects of our natural heritage. It is evaluated primarily in nonmonetary terms.

2.11.04.03 The Regional Development Account (RD). The RD account considers effects on the regional economic base, income and population distribution, and secondary effects of a regional nature. It is evaluated primarily in nonmonetary terms, but quantitative data are presented where applicable.

2.11.04.04 The Social Well-being Account (SWB). The SWB account considers effects on the broad spectrum of social welfare including health and safety, recreation opportunities, and other cultural and quality-of-life considerations. It is evaluated primarily in nonmonetary terms.

It should be noted that interrelationships and interdependencies exist among these four evaluation accounts. Therefore, the accounts may evaluate different facets of the same impact by differing criteria, depending on the effect recipient. As a result, they cannot be mutually exclusive.

Evaluations of the formulated Multiple-purpose plans are displayed in Table 2-7

TABLE 2-7

COMPARATIVE EVALUATION OF MULTIPLE-PURPOSE PLANS

Evaluation Account	Multiple-purpose Alternatives: Authorized Project Plan	National Economic Development Plan	Environmental Quality Plan	No Action Plan
NED ACCOUNT				
Flood Damage Control	The B/C* ratio, expressed here as benefits to allocated costs, for the Multiple-purpose Channel, including the West Fork Floodway and the Dallas Floodway Extension segments, is 1.8 to 1. The benefit to allocated cost ratio for Tennessee Colony Lake is 2.9 to 1.	Channel realignments and levee relocations, both designed to reduce costs and promote hydraulic efficiency, would not appreciably reduce flood damage losses but would reduce both construction and operating costs. These could be expected to produce a higher benefit to allocated cost ratio than shown for the Authorized Project Plan.	Benefit-cost ratio for various types of land use regulation are: (a) 1.3 to 1 for fee title acquisition and evacuation, (b) 1.1 to 1 for restrictive easement acquisition, and (c) 39 to 1 for flood plain zoning. The actual B/C ratio accruing from this land use regulation alternative plan would vary, depending on the final blend of the three types of land use regulation adopted and the operational efficiency of responsible agencies.	Benefit-cost ratio indeterminate. Average annual flood damage losses would continue to increase as development of flood plain progresses. Losses would be tempered by individual structural flood control activities. Flood Disaster Protection Act of 1973 would indemnify for losses but not reduce the rate of loss substantially. The Act would reduce future increases in average flood damage losses over the long term.
Water Supply	The benefit to allocated cost ratio for Tennessee Colony Lake water supply is 4.0 to 1.	Same as the Authorized Project Plan.	Since water conservation programs would be undertaken by other Federal, State, and/or local agencies, the B/C ratio would depend on the programs undertaken and the efficiency of the agency involved. However, since rationing of any resource is seldom undertaken for purposes of cost effectiveness or can be efficiently carried out in a free economy, especially in a localized situation, it is considered doubtful that this alternative would exhibit a favorable benefit-cost ratio.	If projected water needs are to be fulfilled, no action by the Corps of Engineers would require that other entities develop sources. Whether or not other entities would operate efficiently is indeterminate, but it would be forecast that they would not operate at a loss and therefore contribute to National efficiency.
Navigation	The benefit to allocated cost ratio for the Multiple-purpose Channel is 1.2 to 1. The benefit to allocated cost ratio for Tennessee Colony Lake is 1.4 to 1.	Cost savings measures such as standard excavation material disposal methods, channel realignment, deletion of the 6 on 1 waterline slope, and two stage construction would produce a higher benefit cost ratio than that exhibited for the Authorized Project Plan.	Same as the No Action Plan.	No Corps of Engineers action would remand freight transport to existing Basin modes. Existing modes contribute to National economic development by not operating at an overall loss.
Recreation and Fish and Wildlife	The benefit to allocated cost ratio for Recreation and Fish and Wildlife is 4.7 to 1.	Costs to provide physical facilities at recreation areas would be minimized, thereby maximizing the benefit-cost ratio above the 4.7 to 1 shown for the Authorized Project Plan.	Provision of primitive campsites and other minimal and rustic facilities, together with minimal-sized land acquisitions, should provide the maximum number of visitations per unit of cost. This would maximize the benefit-cost ratio while minimizing environmental damage.	No action by the Corps of Engineers would leave the development of new recreation areas or facilities to other governmental agencies or to private enterprise. B/C ratios cannot be forecast.
Hydroelectric Power	The benefit to allocated cost ratio for hydroelectric power at Tennessee Colony Lake and Lock and Dam 3 is 2.2 to 1.	Same as the Authorized Project Plan.	Same as the No Action Plan.	Electric power would be provided by existing utility companies who now contribute to National economic development.

*Benefit-cost

(Continued)

Table 2-7 (continued)

Evaluation Account	Authorized Project Plan	National Economic Development Plan	Environmental Quality Plan	No Action Plan
	Multiple-purpose Alternatives			
EQ ACCOUNT				
Flood Damage Control	Channel modification would be expected to produce severe disruption of aquatic and near-bank habitat which would imperil the existence of any aquatic species living in these areas. Water table changes would alter terrestrial vegetation patterns. Large-scale excavation would cause permanent changes in physical and biological characteristics of aquatic habitat. Existing river and related natural resources would be disrupted. Damage to man-made resources not affected by channel construction would be greatly reduced. Channel excavation would cause considerable short term water pollution in form of turbidity from erosion of unvegetated excavation areas. Potential for release of toxic materials from existing sediments would exist. Construction and operation activities would add to air, noise, and solid waste pollution within the project area.	Channel realignment and other vegetative clearing for increased hydraulic efficiency would adversely affect the natural environment. Limiting revegetation to seeding of grasses for erosion control and omission of reforestation in the interest of cost reduction would also adversely affect both aquatic and terrestrial ecosystems. These effects are in addition to the effects described for the Authorized Project Plan.	Achieving flood damage reduction by the institution of land use regulations would be less damaging to natural resources than structural methods. It may be less effective in many areas in reducing flood damages. For those areas zoned, development would be, in general terms, selectively controlled--an improvement over uncontrolled development that may occur with no-action. Although all development may not be prevented from encroaching on wildlife habitats, this alternative would be desirable in that it would reduce the rate of this encroachment. Selective control of development could prevent activities in the river corridor that contribute heavily to pollution or conflict with the natural environment. In those selected areas which would be acquired in fee simple, plants and animals which have experienced population reductions because of habitat alteration would derive relief from encroaching development in their flood plain habitats. Existing natural conditions could be preserved. In those areas where restrictive easements would be acquired, the natural environment would not be appreciably benefited, since most of the existing land use activities would continue. The present rate of degradation would be slowed, however.	No action by the Corps of Engineers would benefit the remaining natural assemblages in the Trinity River flood plain by retarding the rate of land development and conversion from its existing state.
Water Supply	The conservation pool of Tennessee Colony Lake for water supply and sediment storage would permanently affect the existing natural assemblages on about 101,500 acres, of which about 44,000 acres are wooded, by inundation and by the dam and associated structures. These 44,000 wooded acres are predominately bottomland hardwood forest. Most have been selectively logged in the past and are presently grazed by domestic livestock. Nevertheless, their inundation represents a significant loss in terms of both existing vegetation and terrestrial fauna habitat. Secondary peripheral development would adversely affect adjacent natural habitat and further decrease faunal populations by reducing migration opportunities and habitat carrying capacities. Aquatic habitat would increase.	Rositing of Tennessee Colony Lake to promote cost efficiency could adversely affect the Catfish Creek watershed and the Gus Engeling Wildlife area. Deletion of multilevel intake capability for the Tennessee Colony Dam outlet works structure would adversely affect downstream water quality potential and aquatic biota. These effects are in addition to the effects described for the Authorized Project Plan.	Minimal adverse effects on natural environment because of little structural modification of land. Secondary effects on the natural environment resulting from probable reduced immigration and economic disincentives would reduce rate of degradation of the natural environment peripheral to population centers.	No action by the Corps of Engineers on Tennessee Colony Lake for water supply will not reduce the projected demand for water. Rather, other entities responsible for providing water would develop water supply lakes, probably in the same general area. Adverse environmental impacts associated with land inundation and induced peripheral development would take place. Their severity would depend on the actual sites selected, present land uses, and present site value as habitat areas or existing ecosystems. There could be no assurance that adverse environmental effects would be less severe than at the Tennessee Colony Lake site until the actual sites were selected and existing ecosystems comparatively evaluated. If these alternative sites

(Continued)

TABLE 2-7 (continued)

Evaluation Account	Multiple-purpose Alternatives: Authorized Project Plan	National Economic Development Plan	Environmental Quality Plan	No Action Plan
Water Supply				were to be developed by non-Federal agencies without Federal financial participation, there could be no assurance that such evaluation would be made, since the mandates of NEPA would probably not pertain.
Navigation	With navigation, the possibility of species introduction and increased water pollution by cargo spillage would exist. Migratory pathways for native aquatic species would be re-opened. Maintenance dredging would adversely impact adjacent land areas and navigation traffic would agitate channel water and disrupt channel bottoms and banks. The ecosystem of Trinity Bay would be adversely affected by channel construction, maintenance, and traffic. Other environmental impacts for the navigation aspects would be essentially the same as those described in flood damage control above.	Channel straightening and disposal of material and maintenance dredge material in cutoff river segments would result in severely adverse effects on natural assemblages of these areas and would preclude the provision for maintenance of natural streamflow through these segments.	Same as the No Action Plan.	No action by the Corps of Engineers would remand freight transport to present modes. This would remove adverse environmental effects on natural assemblages along and in the Trinity River resulting from the construction and operation of navigation facilities. Adverse effects on the biosphere from existing transport modes would increase in proportion to population and its associated activities in the Basin.
Recreation and Fish and Wildlife	Recreation land acquisition would total 31,384 acres, of which 9,600 acres would be acquired as separable lands for public use and access and 21,784 acres from joint project purpose lands. About 16,000 acres of the joint project purpose lands would form the Modified Greenway Plan parkway in the metropolitan area. All water surfaces in Tennessee Colony Lake and downstream could be used for recreation. The development of these recreation areas or recreation facilities could help to concentrate human activities in areas provided and relieve to a small extent the encroachment on other natural areas. Recreation activities in the areas provided would adversely affect ecosystems in those areas. Increased public usage of these areas would cause some degradation to adjacent areas. Current levels of local pollution such as solid waste and noise would increase.	Optimum annual visitation capabilities of existing Corps of Engineers recreation areas with full facility development is about 40.3 million user-days as shown in Table 1-64. The recreation user-days projected by the Corps of Engineers (1974b) for the year 2020 total over 275 million. Thus, minimal development of facilities would leave a substantial unfulfilled demand. Resultant overusage would impose adverse environmental effects on recreation areas and on other public and private areas, such as wildlife reserves.	By restricting recreation facilities to those serving recreationists interested in river fishing and canoeing in placid waters at remote locations where scenic and naturalist interests would predominate, the demand for usage of these facilities would be substantially reduced. Additionally, a substantial portion of each recreationist's time would be spent on water rather than on land. These two factors would combine to minimize adverse environmental impacts caused by recreation activities. Terrestrial recreation would be limited to primitive camping at designated primitive campsites.	Latent recreation demands would increase, and recreation that does take place would be more concentrated thus exerting more adverse environmental impacts.

(Continued)

Table 2-7 (continued)

Evaluation Account	Authorized Project Plan	National Economic Development Plan	Environmental Quality Plan	No Action Plan
	Multiple-purpose Alternatives			
Hydroelectric Power	Facilities installation would not impose significant additional environmental impacts beyond those associated with dam construction except for periodic surges of water for power generation, which would adversely affect downstream biota and could cause bank erosion and scouring.	Deletion of multilevel hydropower intake structures in the interest of cost efficiency would adversely affect the downstream water quality potential.	Same as the No Action Plan	Electrical power generation would continue by existing utility companies. Existing environmental effects would continue and increase as a function of increased power production.
REGIONAL ECONOMIC DEVELOPMENT ACCOUNT				
Flood Damage Control	In the Dallas-Fort Worth area the Multiple-purpose Channel and levees would provide protection from floods of up to the Standard Project Flood while requiring a minimum of land for project construction, thus stimulating and allowing maximum development and business and industrial activity in the flood plain. Increased property values would increase tax revenues, although some land would be acquired for the project. Existing and potential agricultural activity in flood plain might be replaced by other development. Existing facilities that contribute to national security would be protected from flooding, minimizing risk of slowdown in defense and other essential national production outputs during critical periods of national emergency. In the remaining downstream rural subregions it would provide protection from flooding ranging from 60 to 100 year frequencies. Regional economic stimulation from project construction and operation would also occur. Maximum amount of land in flood plain could be used for agricultural production, resulting in increased regional income. Increased property values would increase tax revenues. The flood protection provided would insure continued agricultural production in times of national need.	Reduction in the overall widths of the West Fork Floodway and Dallas Floodway Extension by deletion of the Modified Greenway Plan and design modifications for hydraulic efficiency would benefit the regional development account by making additional developable land available in these flood plain areas. These effects are in addition to the effects described for the Authorized Project Plan.	Flood damage control by land use regulation would produce varying effects depending on the blend of zoning, easements, and acquisition employed. In general, land use regulation in the metropolitan flood plain would exert a beneficial effect on business and industrial activity by preventing future flood damages. It would help achieve a more balanced regional economic growth in a highly urbanized region. Near status quo would be achieved in terms of tax revenue production. Public services and facilities may be more conveniently operated and maintained. Some decrease in property values would occur within flood plain limits. Limited agricultural activity could be encouraged in flood-prone areas. Existing facilities would receive no protection from flooding. In rural subregions land use regulation would be expected to produce a generally adverse effect on local and regional economic development. Loss of tax revenues in flood plain areas would occur. Limited agricultural activity in the flood plain could be encouraged by arranging a lease-back program for interested parties.	No action by the Corps of Engineers would neither deter the current rate of development in the Trinity River flood plain nor contribute to the regional economic development account.

(Continued)

TABLE 2-7 (continued)

Evaluation Account	Multiple-purpose Alternatives: Authorized Project Plan	National Economic Development Plan	Environmental Quality Plan	No Action Plan
Water Supply	Construction of Tennessee Colony Lake for water supply would induce peripheral development and thus enhance regional economic development prospects in the surrounding area. It would also indirectly contribute to a minor degree to the regional economic development by increasing the total water supply of the area.	Same as the Authorized Project Plan.	Curbing water usage on a regional basis would constitute a progressively noticeable economic disincentive for industry and thus be detrimental to the regional economic development account.	No action by the Corps of Engineers would not benefit the regional economic development account. Local entities responsible for supplying water would likely secure future supplies by construction of single purpose water supply lakes. This would be more expensive in terms of unit raw water cost. This alternative is considered slightly detrimental to the regional economic development account.
Navigation	From a regional economic base viewpoint, a navigation channel to Dallas-Fort Worth would provide an efficient means of commodity transport, particularly bulk commodities. In terms of bulk commodity transport, this mode would offer maximum economic efficiency. Waterborne commerce requires relatively long transit times. It would stimulate the economy of the entire region, distributing wages and income from project construction, operation and induced business and industrial activity along the watercourse. Increase in tax revenues from increased property values and general economic stimulation would increase government capabilities to provide services and facilities. Better land use patterns could be encouraged. There would be minor disruptions in existing agricultural activities. It would facilitate and be easily adaptable to defense-related production and transport during time of national emergency.	Same as the Authorized Project Plan.	No action by the Corps of Engineers would neither significantly benefit nor hinder the existing rate of regional economic development and thus have little effect on the regional economic development account.	Same as the Environmental Quality Plan.
Public Recreation and Fish and Wildlife	Peripheral development of commercial enterprises to cater to recreational activities at Tennessee Colony Lake would contribute to regional economic development of that area. The Modified Greenway Plan in the metropolitan area would induce minor regional economic development when compared to other factors contributing to economic development in the metroplex. Flood protection afforded to land along the Trinity River downstream from Lake Livingston Dam would greatly benefit its regional economic development potential for residential construction and agricultural activities.	From a regional cost viewpoint, 50 percent Federal participation in the provision of local recreation facilities would appear advantageous. Minimal facilities provision might stimulate regional businesses to provide neglected facilities and thereby enhance regional economic development.	Providing public recreation facilities for the segment of recreationists interested in canoeing, primitive camping, and river fishing would be expected to retard regional economic development by failing to satisfy increasing latent recreation demands. It would also impose unquantifiable costs on the region's natural environment. These costs would result from overusage of existing recreation facilities and by intrusive entries to other public areas, such as wildlife refuges, for recreational activities.	No Corps of Engineers action on development of public recreation facilities would neither significantly benefit nor detract from the regional economic development account.

(Continued)

TABLE 2-7 (continued)

Evaluation Account	Authorized Project Plan	National Economic Development Plan	Environmental Quality Plan	No Action Plan
	Multiple-purpose Alternatives			
Hydroelectric Power	The installation of hydroelectric facilities at Tennessee Colony Dam and at Lock and Dam 3 would contribute slightly to economic development near the sites and to regional economic development by providing economical electrical peaking power in small amounts.	Same as the Authorized Project Plan.	Same as the No Action Plan.	No action by the Corps of Engineers regarding hydroelectric generating facilities would have relatively little effect, either beneficially or detrimentally, on the regional economic development account.
SOCIAL WELL-BEING ACCOUNT				
Flood Damage Control	In the Dallas-Fort Worth area, construction activity would initially produce adverse aesthetic effects, a cause for anxiety by those concerned over man's general encroachment into flood plains. Over the longer term, the flood protection accorded would provide a sense of security concerning flood hazards and livelihood opportunities. The resulting increase in developable flood plain land might cause greater population densities within the urban area. In the rural areas, a sense of security concerning flood protection would result. Overall benefits to agricultural production and associated livelihood prospects would result in the flood plain. Population densities would increase in the flood plain, particularly below Lake Livingston where flood protection would enhance land development opportunities. Relocations of families within the construction and fee acquisition areas would occur with associated adverse effects on family living patterns and community cohesion. Utility and road relocations might affect community cohesion and alter family living patterns outside the construction area.	Same as the Authorized Project Plan.	Land use regulation for flood damage control in the Dallas-Fort Worth area would limit future development in the floodprone areas but would enhance metropolitan recreational opportunity potential. It would also have a beneficial aesthetic effect for those concerned with natural surroundings. A certain degree of flood anxiety would remain, but possible undesirable population concentrations in the flood plain would be slowed if not checked. Some relocations with attendant living pattern disruptions would occur. In the rural flood plain areas, nature-oriented recreation potential would be enhanced, some relocations would occur, and industrial developments, and thus some livelihood opportunities, would be precluded. A certain degree of flood anxiety would remain.	No action by the Corps of Engineers would remand flood control activities to State and local agencies or to private enterprise, and thus solution to the existing detrimental aspects of the social well-being account related to flood damage losses and anxiety factors would be remanded to others.
Water Supply	Rural lake setting of Tennessee Colony Lake within commuting distance of the Dallas-Fort Worth area would possess water-oriented recreation potential, would encourage vacation type development, but would require the displacement of about 325 families. Life patterns and existing community cohesion would be modified or affected for local	Same as the Authorized Project Plan.	Curtailment or rationing the use of water on a regional basis would produce adverse physical and psychological effects on residents and businesses in the region and thus be detrimental to the social well-being account.	With no action by the Corps of Engineers, responsible local utilities would develop water supplies from other sources. This would produce a minor adverse effect on the social well-being account as a result of higher water costs.

(Continued)

TABLE 2-7 (continued)

Evaluation Account	Multiple-purpose Alternatives: Authorized Project Plan	National Economic Development Plan	Environmental Quality Plan	No Action Plan
Water Supply	residents. Any existing anxiety concerning the adequacy of water supply through the 1990's would be reduced for some, but questions concerning quality may induce anxiety in others.			
Navigation	The navigation channel would induce land use changes on many oxbows. Increased surface area and added diversity of aquatic resources would attract recreationists. Navigation facilities would permit access by pleasure craft to all areas of river-channel-Gulf system, including many of the numerous oxbow cutoffs that would be created. Some may regard construction of a navigation channel as improving or degrading to aesthetic values, depending on personal values and interests. Some displacements would be required; community cohesion of present residential communities would be disrupted to some extent.	Same as the Authorized Project Plan.	Same as the No Action Plan.	No action by the Corps of Engineers with regard to navigation would produce no overt detrimental effects on the social well-being account. Similarly, little overt beneficial effect would be discernable.
Public Recreation and Fish and Wildlife	Project recreation facilities would help to fulfill growing demand for recreation areas in the Trinity River Basin. This would contribute to aesthetic considerations in localized areas, most prominently around Tennessee Colony Lake and the Dallas-Fort Worth mid-cities area. Development of the Modified Greenway Plan would benefit the social well-being account by providing recreation areas and facilities in the center of metropolitan area where population concentration, and thus the need for recreation areas, is greatest. It would contribute to the enhancement of the aesthetic aspects of the Dallas-Fort Worth metropolitan floodway.	Social well-being is often considered to be a direct function of the quality of the total environment. Omission of those programs designed to benefit environmental considerations would therefore adversely affect social well-being. The Modified Greenway Plan would be deleted in the interest of cost efficiency. Its beneficial effects and attributes described in the evaluation for the Authorized Project Plan would be foregone.	Restricting public recreation facilities to provide for low density, river corridor activities would satisfy only a small segment of the public recreation needs. This would not contribute significantly to the social well-being of the broad public spectrum.	No action by the Corps of Engineers would leave a large portion of the existing and future recreation demand unfulfilled. Latent demand for recreation would increase correspondingly.
Hydroelectric Power	Hydroelectric power generation presents a method of electric power generation that does not deplete fossil fuels or contribute to health hazards. It would be, in a broad sense, socially beneficial. Increased electric power availability contributes to a higher standard of living.	Same as the Authorized Project Plan.	Same as the No Action Plan.	In the absence of action by the Corps of Engineers, responsible utility companies would provide electrical power to meet demand, if possible. No action would have little, if any, noticeable effect on the social well-being account.

2.12 Summary of Multiple-Purpose Plan Considerations. As indicated by the Section 1 forecasts concerning the Basin future without the project, the various problems of water supply, flood damage losses, increasing recreation demand, and the accelerating rate of extirpation of wildlife habitat and other natural assemblages will continue, mainly because of increasing population pressures. Fragmented efforts to alleviate these problems may be anticipated in the absence of an organized, comprehensive plan. Some of these efforts, particularly flood damage reduction efforts, may create more adverse long-term environmental effects than some course of comprehensive action that includes conscious consideration of and sensitivity to effects on natural resources. In view of these problems, the No Action Plan apparently possesses few merits.

The fundamental difference between the Authorized Project Plan and the National Economic Development Plan concerns deletion of the numerous features and actions that have been included in the Authorized Project Plan to reduce adverse project effects on natural resources and assemblages. These deletions would be effected in order to reduce costs and thereby produce a more favorable benefit-cost ratio. In this manner, National economic efficiency would be maximized, but this maximization would require a corresponding trade-off of natural environmental considerations.

Other elements of the Authorized Project Plan and the National Economic Development Plan are essentially the same. Just as all human development activity has historically exacted its toll on the natural environment, either of these plans would produce adverse environmental effects. So long as this Nation is dedicated to economic development at all levels, ranging from the private citizen to the Federal Government, and so long as population growth and life quality pressures dictate, this process is forecast to continue. Recognizing this, Congress has set forth the process by which evaluation and display of all effects, including environmental impacts, can be brought forth for review and consideration during its decision-making process, so that social and economic benefit of an action can be weighed and balanced against these environmental costs.

The Environmental Quality Plan represents an essentially non-structural approach directed toward accomplishing purposes of the authorized project by legislation and institutional regulation. It would tend to discourage development and encourage preservation of the remaining natural areas in the flood plain. Impacts on natural assemblages would be less severe over the shorter term but, since regulatory plans are always subject to change, the long-term decline in species diversity and continued reductions of the natural environment and ecosystems in the region would still be expected to occur as human population pressures increase. Trade-offs would still be required, but relatively greater sacrifices would be imposed on the

National economic development, regional development, and social well-being accounts in the interest of preservation of natural assemblages. That these sacrifices would result in proven worth in terms of long-term survival of natural assemblages and species diversity in the region is questionable when viewed against the perspective of historical development trends.

SECTION 3 - AUTHORIZED PROJECT PLAN

3.01 Proposed Changes to the Authorized Project. Preconstruction planning studies on the Trinity River Project indicated that several changes should be made to the project that was authorized in 1965 and modified by the navigation reevaluation study requested by Congress (U.S. Army Corps, 1968). These proposed changes are summarized below.

3.01.01 Water Conveyance Facilities (84-inch pipeline). These facilities were authorized for water quality (dilution of Dallas-Fort Worth sewage effluents) and upper Basin water supply purposes. Current Federal policy as stated in Public Law 92-500, Section 102(b)(1), disfavors dilution as a means of improving water quality and, instead, seeks improvement by source treatment of pollutants. Federal policy defines water supply development costs as a local responsibility. A proposed change to the Trinity River Project to withdraw Federal participation in the construction of water conveyance facilities is included as a part of preconstruction planning activities. Construction of this feature in the future would be a non-Federal responsibility.

3.01.02. Channel Alignment. Several interrelated planning and design efforts resulted in significant proposed channel alignment changes. A conceptual plan for open space within the proposed floodways in the Dallas-Fort Worth metropolitan area by Texas Tech University (1972) recommended alignment changes to minimize construction damage to forested areas and unnecessary destruction of the streambank regimen. A channel departure leaving about 54 miles of river between Lock 5A and Lock and Dam 3 unchannelized is now proposed. This includes structural provisions for maintaining, as much as practicable, the existing within-banks flow conditions for this reach of the river.

3.01.03 Channel Dimensions. The Trinity River Project was authorized with a 150-foot bottom width. The navigation reevaluation study recommended a 200-foot bottom width with later widening to 250 feet; current studies recommend use of single-stage construction for the Multiple-purpose Channel rather than a subsequent 50-foot widening of the channel as previously proposed. In most areas, a 1 on 6 slope is proposed on both sides of the channel three feet above and three feet below the normal pool elevation to reduce erosion from wave wash (Plate 27).

3.01.04 Tennessee Colony Lake. The dam for this lake was located at river mile 339.2 in the authorizing document. Further studies have indicated that the dam should be relocated upstream to river mile 341.7. Cooperative studies with the Federal Power Commission indicated that hydroelectric power development would be feasible for this proposed lake, and a 16,000 kw hydroelectric power facility would be recommended as an additional project purpose, subject to Congressional authorization.

3.01.05 Navigation Locks. The navigation reevaluation study recommended deletion of Lock and Dams 2, 8, and 15 (U.S. Army Corps of Engineers, 1968). Subsequent studies have recommended deletion of Lock and Dams 11 and 14. Locations and lifts of adjacent locks have been adjusted accordingly.

3.01.06 Construction Excavation. Total construction excavation for the project would be in excess of 700 million cubic yards. For Multiple-purpose Channel construction, the use of waste disposal methods that minimize environmental impacts, rather than the side channel depositions previously proposed in the survey document, is recommended. Excavated materials would be shaped into various forms to blend with surrounding terrain. All exposed areas of excavation and fill would be covered by a layer of topsoil and revegetated with native plants. Materials would be deposited behind existing tree lines adjacent to the channel. Existing agricultural levees would be strengthened to provide a higher degree of flood protection but would be shaped to resemble natural terrain by varying widths, heights, and slopes. In open spaces, such as crop or pasture lands, low areas would be filled to surrounding elevations or filled to low slope drainage configurations. Depleted sand and gravel pits would be filled, contoured, and planted to resemble natural landscape. Wooded areas would be used for disposal of waste excavation only where no open areas are available.

3.01.07 Clearing and Replanting Vegetation. The total estimated amounts of forest clearing and revegetation of all denuded lands are shown in Table 3-1. Clearing for Multiple-purpose Channel excavation outside the natural river channel would include the channel itself and a strip which would average about 25 feet wide on each side of the channel. This would leave a 25-foot wide strip of vegetation where it exists on each side of the channel between the right-of-way line and the cleared area, except for haul road openings to excavation deposition areas. This would provide a sound and visual barrier and aid natural revegetation of adjacent areas. Wherever the Multiple-purpose Channel alignment coincides with the natural river channel alignment, minor alignment adjustments would be made to prevent damage to the existing vegetation on one side of the river channel. This would enable a portion of its original value to aquatic and terrestrial biota to be retained. Short term easements

TABLE 3-1

PROJECT CLEARING & REPLANTING

Reach	Clearing Forest: Lock & Dam (Ac)	Clearing Forest: Access Roads (Ac)	Clearing Forest: Channel Areas (Ac)	Clearing Forest: Waste Excavation Areas (Ac)	Replanting Vegetation: Turfing Channel Areas (Ac)	Replanting Vegetation: Reforestation of Channel Areas (Ac)	Replanting Vegetation: Turfing Exposed Areas (Ac)	Replanting Vegetation: Reforestation of Waste Areas (Ac)
Wallisville Dam to Lock 3	--	--	1,370	6,090	270	60	6,490	6,090
Lock 3, and Channel to Lock 4	23	83	671	1,435	370	100	1,939	1,435
Lock 4, and Channel to Lock 5A	--	15	295	389	225	48	1,254	389
Lock 5A, and Channel to Lock 5B	2	21	20	--	89	--	--	--
Lock 5B, and Channel to Lock 6	2	--	260	980	160	26	2,450	980
Lock 6, and Channel to Lock 7	16	67	1,600	1,003	1,170	300	5,576	1,003
Lock 7, and Channel to Lock 9	43	79	304	412	582	158	2,288	412
Lock 9, and Channel to Lock 10A	25	72	354	843	310	67	1,793	843
Lock 10A, and Channel to Lock 10B	13	122	174	--	53	--	--	--
Lock 10B, and Tennessee Colony Lake to Lock 12	961	83	2,616	2,264	--	--	420	--
Lock 12, and Channel to Lock 13	90	--	326	--	232	53	1,211	--
Lock 13, and Channel to Lock 16	10	--	585	281	258	58	1,315	281
Lock 16, and Channel to Lock 17	150	--	359	--	182	57	937	--
Lock 17, and Channel to Lock 18	--	6	1,950	237	289	65	1,859	237
Lock 18, and Channel to Lock 19	4	2	16	--	110	14	300	--
Lock 19, and Channel to Lock 20	4	7	618	--	205	52	1,233	--
Lock 20, and Channel to Lock 21	3	22	680	--	130	30	850	--
Lock 21, and Channel to FW Port	3	2	662	21	62	13	576	21
FW Port to Floodway at Riverside Dr.	--	--	702	45	99	23	776	45
TOTALS	1,349	581	13,562	14,000	4,796	1,124	31,267	11,736

Note: Clearing for the Tennessee Colony Lake area does not include selected or partial clearing for recreational areas, fish and wildlife purposes, or water quality.

would be acquired from landowners for disposal of excess construction excavation material outside of the proposed channel right-of-way. Forested areas would be cleared before deposition of construction excavation material, and these areas would be replanted with trees after placement of the excavation material, if agreeable to the landowner. Long term easements would be retained by the Federal Government on portions of these lands for disposal of hydraulic dredged materials from channel maintenance activities. Part of the construction excavation would be shaped into ring levees of from 5 to 50 acres to contain periodic hydraulic maintenance dredging materials. These ring levees would be spaced at intervals of about one area per mile of channel wherever needed. In the Dallas-Fort Worth metropolitan area, where depositions would reduce the flood control capability of the floodways, no ring levees would be constructed and dredged materials would be either barged to downstream disposal areas or deposited outside the levees in abandoned gravel pits. The Multiple-purpose Channel would be deepest in relation to the adjacent flood plain land in the upstream end of each lock pool. This depth would provide more than adequate capacity for floodwaters, and the upper slopes of the channel bank above the floodwater line would be replanted with trees. Topsoil in the construction areas would be salvaged and stockpiled wherever possible and would be spread over exposed cut and fill areas upon completion of construction. All areas would then be replanted with native grasses, including those areas to be reforested.

3.01.08 Lake Area Clearing. Clearing activities within the Tennessee Colony Lake area would be held to a minimum between the conservation pool shoreline and the real estate acquisition line outside the flood control pool level. Preservation of suitable forested lands in this area would be maximized in order to prevent unnecessary damage to wildlife habitat, set aside acreages for wildlife refuges, and increase the visual attractiveness of the peripheral lakeshore areas. Recreation areas that are densely vegetated would be partially cleared for better control of the more noxious insects, wildlife, and vegetation, such as mosquitoes, ticks, skunks, poisonous snakes, poison ivy, etc. Within the conservation pool of the lake, where most existing vegetation would be killed by inundation, the type and amount of clearing would be limited to those areas where a technical rationale for clearing exists. A strip about 1,000 feet wide would be totally cleared and grubbed through the lake for the navigation channel. Selected lanes about 200 feet wide for recreational boat travel would be cleared of trees between recreation areas and the open water areas of the lake. Water areas in the conservation pool adjacent to recreation areas would be cleared for boaters. Areas designated as "seining areas" by the Texas Parks and Wildlife Department for sampling and/or "rough fish" control purposes would be totally cleared. Other areas within the conservation pool might not be cleared of forest, depending on future coordination with State agencies. This coordination may result in some clearing to improve water quality and control aquatic weeds (such as water hyacinth) while some areas may be left uncleared in order to provide fish and wildlife habitat.

3.01.09 Disposal of Timber from Clearing. Some of the timber that would be cleared within the construction area is suitable for use as lumber, pulpwood, post, ties, saw logs, cordwood, etc. Careful delineation of areas to be cleared or left wooded would be accomplished by the Government prior to commencement of clearing operations, and no clearing would be done unnecessarily. In the interest of conservation, clearing contractors and others would be encouraged to make all reasonable efforts to utilize cleared timber for the above purposes. In some areas the public would be permitted to transplant trees to their private property. All cleared timber not utilized for a particular purpose would be burned. Burning operations by the contractor would be subject to all public laws governing such operations, including air and water pollution laws.

3.01.10 Measures for Wildlife Conservation. "Wildlife" and "wildlife resources" are defined by the Fish and Wildlife Coordination Act (16 U.S.C. sec 666b) as ". . . birds, fishes, mammals, and all other classes of wild animals and all types of aquatic and land vegetation upon which wildlife is dependent." Title 1 of the National Environmental Policy Act of 1969 describes the intent to ". . . preserve important historic, cultural, and natural aspects of our national heritage, and maintain wherever possible, an environment which supports diversity and variety of individual choice."

Construction and operation of the project would result in the elimination of about 70,000 acres of forest and woodlands: 45,000 acres due to inundation by the conservation pool of Tennessee Colony Lake and 25,000 acres due to the construction, operation, and maintenance of the Multiple-purpose Channel. Most of this acreage is within the flood plain of the Trinity River and is classified as "bottomland hardwood forest" and/or "forested wetlands." It is generally considered to be the westernmost extension of this type of wildlife habitat in the southeastern United States (Nixon and Willett, 1974).

The preservation of sizable areas of fast disappearing forest and wetlands in the Trinity Basin is of significant biological importance in terms of faunal and floral "gene pools," long term maintenance of viable ecosystems, conservation of the broad spectrum of wildlife species, and basic biological research and study areas. Forests and wetlands are also doubly important from the viewpoint of the time needed for reestablishment of these natural resources. While natural grasslands can usually be reestablished from grazing or cropland in five to ten years, it would require 30 to 50 years to reestablish a somewhat natural East Texas forest or woodland (Gehlback, 1974). The draining of wetlands is normally followed by more intensive land use, so that, if it were subsequently desired to reestablish a natural wetland ecosystem, it would be difficult, expensive, and time consuming.

About 25,000 acres of forested perimeter lands upstream of the conservation pool level but within the real estate acquisition limits of the proposed Tennessee Colony Lake are recommended as wildlife habitat protection lands, since these areas would be acquired for flood control purposes and codesignated for flood control and habitat protection purposes. It is proposed that public management of these lake perimeter lands be carried out by the Texas Parks and Wildlife Department for wildlife conservation.

In the Trinity River flood plain downstream from the proposed Tennessee Colony Lake, the remaining forest and wetlands are in the most frequently flooded areas and for this reason have not been encroached upon by more intensive land uses. It is proposed that about 45,000 acres of bottomland be acquired in fee title for increased reservoir regulation flow capacity. Management of these 45,000 acres and the 25,000 acres of Tennessee Colony Lake perimeter lands by the Texas Parks and Wildlife Department for wildlife conservation is recommended.

Approximately 31,000 acres of lands to be acquired for Tennessee Colony Lake flood control and water supply purposes in the Chambers, Richland, and Tehuacana Creek areas would be designated as a National Wildlife Refuge to be administered by the U.S. Fish and Wildlife Service. The above recommendations are subject to formal coordination with the U.S. Fish and Wildlife Service, the Texas Parks and Wildlife Department, and the Trinity River Authority.

3.01.11 Greenway Plan. The adoption of a greenway plan for the Dallas-Fort Worth area urban floodways, similar to that proposed by the 1972 report by Mertes et al., "Trinity River Greenway - a Prototype," is recommended. This report envisons a "parkway" within the metropolitan area flood plain for public use with public ownership and management by local interests. This would be a zone extending 500 to 1000 feet from the center of the natural river channel with provisions to preserve the existing vegetation. The greenway plan would include the parkway plus land use planning and zoning of adjacent areas within and outside the flood plain. This plan would also include the assignment of recreation benefits to the West Fork Floodway and Dallas

Floodway Extension and the resultant allocation of floodway construction costs to that purpose on the basis of the separable recreation costs. Public Law 89-72 cost sharing principles would apply to these separable recreation facilities. In accordance with the report recommendations, planning for the interrelated flood control, recreational, environmental, commercial, and navigational aspects of the greenway would be accomplished jointly by appropriate county, State, and Federal agencies.

3.01.12 Land Use Regulations. The adoption of appropriate land use regulations by non-Federal interests is recommended for areas within the 100 year flood plain which do not receive 100 year frequency flood protection with the project. This procedure would not prevent flood damages to existing structures, but should prevent flood plain development of structures which could be damaged by floods.

3.02 Project Purposes. The Authorized Project Plan currently consists of four physically interrelated features as shown in red on Plate 1, Appendix A. These are: the Dallas Floodway Extension and the West Fork Floodway for flood control in the Dallas-Fort Worth metropolitan area; Tennessee Colony Lake for middle and lower basin flood control, water supply, navigation, and electric power; and the Multiple-Purpose Channel for flood control from Fort Worth to Trinity Bay and navigation from Fort Worth to the Houston Ship Channel. Other purposes of the Authorized Project Plan are recreation and fish and wildlife conservation. It would also provide river bank stabilization and economic redevelopment benefits.

3.03 Other Related Projects. Table 3-2 includes a listing of the lakes shown on Plate 1 and indicates their owners, capabilities, and purposes. Table 3-3 lists the flood protection and navigation projects shown on Plate 1, together with their locations and current status. The estimated land acquisition quantities for the Authorized Project Plan are shown in Table 3-4.

3.04 Pertinent Data for the Authorized Project Plan. The various physical features of the project are described below.

Tennessee Colony Lake
(See Plate 4, Appendix A)

Generalized dam and structures dimensions:	
Length of dam, earth fill	39,000 feet
Maximum dam height	117 feet
Width at top of dam	30 feet
Side slopes, top 20 feet	3:1

Generalized dam and structures dimensions (continued):

Side slopes, 20 feet-71 feet from top	10:1
Side slopes, 71 feet from top to toe of slope	3:1
Concrete spillway, ogee weir, net length	400 feet
Spillway tainter gates	10 - 40'x35'
Flood control outlet works	8 - 10'x20' sluices
Hydroelectric power capability	16,000 kw

Hydrologic data:

Drainage area	12,302 sq mi
Average annual areal runoff (1985 conditions)	1,957,155 ac ft (2,702 cfs)
Maximum discharge (spillway design flood)	620,700 cfs
Initial yield (dependable water supply upon filling of lake)	748 cfs
Ultimate yield (dependable water supply after 100 years of sedimentation)	712 cfs

Description	Elevation	Acres	Cumulative acre-feet	Incremental acre-feet	Shoreline miles
Top of dam	319.0				
Maximum water surface	308.1	187,500	6,767,500	2,696,200	475
Flood control pool	292.0	147,200	4,071,300	1,983,400	400
Water supply pool*	275.0	98,300	2,020,100	1,841,500	325
Sediment storage				246,400**	

*The water supply pool is the normal volume of the lake and is also called the conservation pool; Tennessee Colony Lake would rank 3rd in surface area among Texas lakes, with Toledo Bend (181,[illegible]00 acres) and Sam Rayburn (113,400 acres) ranking one and two, respectively.

**Sedimentation in water supply pool, 178,600 acre-feet; flood control pool, 67,800 acre-feet.

<u>Multiple Purpose Channel</u>

(see Plates 3, 5, 27, and 28.1 through 28.10, Appendix A)

Channel bottom width:

Upstream of Lock 18	200 feet
Downstream of Lock 18	250 feet

Channel side slopes — 3:1 or flatter

Channel water depth	12 feet minimum

Design channel flow capacity:
Varies - 15,000 cfs (upstream end) to 45,000 cfs (downstream end)

Generalized excavation and right-of-way dimensions:

	Minimum	Maximum
Approximate depth below existing flood plain	23 feet	65 feet
Approximate channel width at top of slope	374 feet	676 feet
Approximate right-of-way for channel	474 feet	776 feet

Locks and dams	Channel mile	Pool elevation (feet above mean sea level) Downstream Pool	Pool elevation (feet above mean sea level) Upstream Pool	Spillway tainter gates Number	Spillway tainter gates Size (feet)
3	60.5	1-4	36	6	40 x 34.5
4	75.8	36	72	6	40 x 36
5A	97.1	72	100-101	-	-
5B	99.2	101	121-131	-	-
(Livingston Dam)	99.2	-	-	12	40 x 35
6	147.9	121-131	138	5	40 x 44
7	197.5	138	178	5	40 x 44
9	216.4	178	210	6	40 x 46
10A	234.0	210	237	-	-
10B	235.[illegible]	237	265-292	-	-
(Tennessee Colony Dam)	236.0	-	-	10	40 x 35
12	280.5	265-292	292	5	40 x 28
13	292.6	292	320	6	40 x 32
16	306.6	320	348	5	40 x 27
17	317.3	348	372	5	40 x 30
18	331.3	372	396	5	40 x 34.5
19	342.5	396	424	6	40 x 24
20	352.1	424	452	6	40 x 28
21	360.0	452	480	6	40 x 31

Lock sizes: Locks 3 through 18 - 84 feet x 600 feet
Locks 19 through 21 -84 feet x 400 feet

Metropolitan Area Channelizations
(see Plates 2.1 through 2.4, Appendix A)

Length of levees - 70 miles

River or tributary	Connecting river mile	Length of proposed channel (miles)
Trinity River	487 to 498	9.1
Five Mile Creek and two tributaries	487	5.4
Elam Creek	489	0.4
Honey Springs Branch	492	1.5
White Rock Creek	493	4.2
West Fork	506 to 552	30.9
Delaware Creek and West Irving Creek	508	2.5
Mountain Creek	508	3.8
Bear and Estelle Creeks	517	2.9
Hurricane Creek	529	0.7
Sulphur Branch Creek	531	1.4
Walker Branch Creek and one tributary	536	2.2
Big Fossil Creek	543	0.9
Little Fossil Creek	544	0.9
White Lake outfall channel	545	0.7

Transportation and Utilities Relocations 1/

Highways	38 each
Railroads	13 each
Gas and oil pipelines	145 each
Water and sewer pipes	13 each
Power lines	44 each
Telephone lines	18 each

1/ These are total figures for all four features of the multiple purpose project; the majority are related to the navigation and flood control channel. For the location of each existing structure, see Plates 31.1 through 31.4, Appendix A.

3.05 Authorized Project Plan Operations.

3.05.01 Flood Control Operations. In the Dallas-Fort Worth metropolitan area, the Dallas Floodway Extension and the West Fork Floodway would connect to the existing floodways in the two cities and would complete the long range plan to provide flood protection to the entire metropolitan area from the west side of Fort Worth downstream to the southeastern edge of Dallas. The degree of flood protection provided would accommodate a Standard Project Flood (SPF). SPF's would be expected to occur less frequently than once every 500 years, but could occur any year. In the Dallas-Fort Worth area, the SPF flows would vary from about 95,000 cfs to about 230,000 cfs. Relatively minor flood flows of up to 15,000 cfs in the Fort Worth area, increasing up to 25,000 cfs in the Dallas area, would be contained within the Multiple-purpose Channel located in the leveed flood plain. These flows would be passed from pool to pool of the Multiple-purpose Channel by operation of the five or six tainter gates located beside each navigation lock. When flows exceed the capacity of the channel, they would spread into the surrounding floodway and be contained by the levee systems. A flood flow of sufficient volume to overflow the channel banks in the metropolitan area could be expected to occur about once every 14 years, but could happen several years in a row, or several times in a year. A system of appurtenances (chutes, sumps, pumps, etc.) would provide drainage for local areas immediately outside the levee systems. The sumps would be designed to catch local runoff water until floodwaters inside the levees recede. Gates would then be operated to allow water in the sumps to drain by gravity into the channel. Eighteen sump areas ranging in size from about 10 acres to about 160 acres would be located in the metropolitan areas as shown on plates 2.1 through 2.4, and would be designed to accommodate the local area runoff from storm frequencies of up to 100-year occurrence. Since these sumps would occasionally be full of water, these areas could not be used for other purposes, except possibly some recreational activities.

TABLE 3-2

TRINITY RIVER BASIN WATER RESOURCE DEVELOPMENT PROJECTS - LAKES

Name	Owner	Location: Stream	Location: Mile	Total drainage area above (sq. mi.)	Total storage capacity in Year 2085 (acre-feet)	Dependable Yield in Year 2085 MGD (1)	Purpose (2)
		EXISTING UNDER CONSTRUCTION AND AUTHORIZED LAKES					
	FEDERAL						
Benbrook	Corps of Engineers	Clear Fork	15.0	429	72,500	6.5	FC-Con-Nav-R-F&W
Lavon, enlarged	Corps of Engineers	East Fork	55.9	770	380,000	92.0	FC-Con-R-F&W
Navarro Mills	Corps of Engineers	Richland Creek	63.9	320	44,900	10.3	FC-Con-R-F&W
Bardwell	Corps of Engineers	Waxahachie Creek	5.0	178	39,500	8.4	FC-Con-R-R&W
1,109 Small detention res (3)	Soil Conservation Serv.	(headwater & Tributary areas throughout basin)		2,819	775,705	0	FC-Con-R
Wallisville	Corps of Engineers	Trinity River	3.9	17,760	55,700	(9)	Con-Nav-S-R-F&W
Lakeview	Corps of Engineers	Mountain Creek	11.2	232	266,000	14.2	FC-Con-R-F&W
Grapevine-Roanoke System	Corps of Engineers	Denton Creek	11.7 & 32.0	604	353,100	34.9 (11)	FC-Con-Nav-R-F&W
Lewisville-Aubrey System	Corps of Engineers	Elm Fork	30.0 & 60.0	682	1,174,800	146.7 (12)	FC-Con-R-F&W-Q
Tennessee Colony	Corps of Engineers	Trinity River	341.7	12,302	1,841,500	460.2	FC-Con-R-F&W-Q-Nav
Cooper (10)		Sulphur River				78.1 (10)	
Lake Fork (14)	Corps of Engineers	Lake Fork Creek	28.1	507	1,094,100	98.1 } (14)	FC-Con-R-F&W
Carl L. Estes (14)	Corps of Engineers	Sabine River	475.6	1,146	1,354,600	80.3 }	
	NON-FEDERAL (4)						
Amon Carter	City of Bowie	Big Sandy Creek	31.0	99.8	6,600	0	Con
Bridgeport	Tarrant Co. WC & ID#1	West Fork	626.2	1,111	308,200	49.1	Con
Eagle Mountain	Tarrant Co. WC & ID#1	West Fork	583.3	1,970	110,600	8.4	Con
Lake Worth	City of Fort Worth	West Fork	572.1	2,064	31,500	0	Con
Marine Creek	Tarrant Co. WC & ID #1	Marine Creek	4.7	10	-	0	FC-Con
Weatherford	City of Weatherford	Clear Fork	39.8	106	3,100	0	Con
Arlington	City of Arlington	Village Creek	8.0	143	19,000	2.5	Con
Mountain Creek	Dallas P&L Co	Mountain Creek	4.1	295	5,900	0	Con
North Lake	Dallas P&L Co	So. Fork-Grapevine Creek	0.5	2.3	-	0	Con
White Rock	City of Dallas	White Rock Creek	12.0	100	-	0	Con
Ray Hubbard	City of Dallas	East Fork	21.8	1,071	463,000	53.6	Con
Tawakoni (Iron Bridge) (5)	Sabine River Authority	Sabine River	-	756	-	101.9 (5)	Con
Terrell	City of Terrell	Muddy Cedar Creek	9.8	13	-	0	Con
Trinidad	Texas P&L Co	(6)	-	-	-	0	Con
Joe B. Hogsett (Cedar Creek)	Tarrant Co. WC&ID #1	Cedar Creek	11.1	1,007	618,500	174.5	Con
Waxahachie	Ellis Co. WID #1	So.Prong-Waxahachie Creek	0.5	30.5	8,900	0	Con
Halbert	City of Corsicana	Elm Creek	0.7	12	-	0	Con
Flat Creek (7)	City of Athens	Flat Creek, Neches River	-	-	-	2.2	Con
Livingston	Trinity River Authority	Trinity River	129.2	16,503	-	663.7 (1)	Con
Anahuac	Chambers & Liberty Co. Nav. Dist.	(8)	-	129	-	13.4	Con
Palestine (7)	Upper Neches River Authrity	Neches River	-	-	-	102.0 (7)	Con
Houston County	Houston Co WC&ID #1	Little Elkhart Creek	-	-	19,500	6.2	Con
Lake Fairfield (Big Brown)	Texas Utilities (TPL, DPL, TESCO)	Big Brown Creek	4.2	34	50,600	0	Cooling-R
	RECOMMENDED FOR LONG RANGE PLAN BUT NOT AUTHORIZED AT THIS TIME (13)						
Boyd	-	West Fork	604.7	1,707	639,200	31.7	(13)
Upper Keechi	-	Upper Keechi Creek	11.0	486	134,500	54.3	(13)
Hurricane	-	Hurricane Bayou	7.0	91	151,900	17.5	(13)
Lower Keechi	-	Lower Keechi Creek	8.9	162	173,000	25.2	(13)
Bedias	-	Bedias Creek	19.2	327	376,700	94.4	(13)
Harmons	-	Harmons Creek	10.5	47	79,100	16.8	(13)
Gail	-	Gail Creek	25.3	91	169,900	31.0	(13)
Mustang	-	Mustang Creek	23.7	84	157,700	25.2	(13)
Caney	-	Caney Creek	7.7	74	135,600	25.2	(13)
Long King	-	Long King Creek	22.9	57	186,200	34.9	(13)

(1) Area or primary yield in million gallons per day based on a recurrence of the 1950-1957 drought period under 2085 conditions of watershed development. Return flows are not included; only portion of yield of out-of-basin lakes shown that is imported to Trinity basin.
(2) FC - Flood control; Con - Water Supply (incl. cooling, with incidental recreation and fish & wildlife usage), Nav - Navigation; R - Recreation; S - Salinity intrusion control; F&W - Fish and wildlife conservation; Q - Water quality control.
(3) Totals for 1,109 reservoirs - 622 constructed, including 3 of greater than 5,000 acre-feet storage capacity.
(4) Only those lakes with total storage of 5,000 acre-feet or greater are listed.
(5) Import from Sabine River basin for city of Dallas.
(6) Off-channel on left bank of Trinity River at mouth of Cedar Creek.
(7) Import from Neches River.
(8) Off-channel Turtle Bay.
(9) Livingston and Wallisville area yields combined under Livingston.
(10) Import from Red River basin.
(11) With proposed reallocation of flood control storage from Grapevine to Roanoke.
(12) With proposed reallocation of flood control storage from Lewisville to Aubrey.
(13) Conservation with possible flood control and other purposes; 2020 yields shown.
(14) Import from Sabine basin.

TABLE 3-3

TRINITY RIVER BASIN WATER RESOURCE DEVELOPMENT PROJECTS -
FLOOD PROTECTION & NAVIGATION

Project	Location: Stream or Locality	Location: River Mile	to River Mile	Type of Improvement	Remarks
		LOCAL FLOOD PROTECTION PROJECTS			
FEDERAL					
Fort Worth Floodway	Clear Fork	0	1.6	Channel improvement & levees	Existing
	Clear Fork	1.6	10.4	Channel improvement & levees	Existing
	West Fork	551.3	564.7	Channel improvement & levees	Existing
	West Fork	564.7	570.4	Channel improvement & levees	Existing
Big Fossil Creek Floodway	Big Fossil Creek	0	3.3	Channel improvement & levees	Existing
Dallas Floodway	Elm Fork	0	3.5	Channel improvement & levees	Existing
	West Fork & Trinity River	497.4	508.7	Channel improvement & levees	Existing
East Fork Channel Improvement	East Fork	0	31.8	Channel improvement & levee rehabilitation	Authorized, partially under construction
Elm Fork Floodway	Elm Fork	0	29.4	Channel improvement & levees	Authorized, preconstruction planning underway
	Denton Creek	0	11.1	Channel improvement & Levees	Authorized, preconstruction planning underway
Duck Creek Channel Improvement	Duck Creek	10.4	17.5	Channel improvement	Underconstruction
Liberty Local Protection Project	Trinity River	34	44.5	Levees	Authorized, inactive
West Fork Floodway	West Fork	505.5	551.5	Channel improvement & Levees	Authorized, preconstruction planning underway
Dallas Floodway Extension	Trinity River	486.5	497.9	Channel improvement & levees	Authorized, preconstruction planning underway
NON-FEDERAL					
Agricultural levees	Trinity River & Tributaries	-	-	Levees	Existing - 38 active local levee districts
		FEDERAL NAVIGATION PROJECTS			
		Channel Miles			
Trinity River, Channel to Liberty (9X150-foot channel)					
Houston Ship Channel to Anahuac	Galveston & Trinity Bays	0	23.2	Channel improvement	Constructed; not maintained
Anahuac to Liberty	Trinity River	23.2	48.9	Channel improvement	Authorized
Multipurpose Channel	Trinity River	0	369.7	Channel improvement	Authorized, preconstruction planning underway

TABLE 3-4

PROJECT LAND ACQUISITION

Reach	Lake, Channel & Floodways (Ac)	Lock & Dam (Ac)	Access Roads to Locks (Ac)	Recreation (Ac)	Waste Excavation (Ac)	Total Lands (Ac)	Number of Landowners
Houston Ship Ch to Wallisville Dam	22	--	--	--	234	256	6
Wallisville Dam to Lock 3	1,660	--	--	450	6,490	8,600	283
Lock 3, and Channel to Lock 4	1,158	50	80	200	1,938	3,426	78
Lock 4, and Channel to Lock 5A	936	50	20	150	1,254	2,410	73
Lock 5A, and Channel to Lock 5B	229	30	20	300	--	579	3
Lock 5B, and Channel to Lock 6	6,380	--	--	--	--	6,380	30
Lock 6, and Channel to Lock 7	3,700	40	70	300	5,576	9,686	57
Lock 7, and Channel to Lock 9	1,320	60	80	75	2,288	3,823	43
Lock 9, and Channel to Lock 10A	1,040	40	70	175	1,793	3,118	42
Lock 10A, and Channel to Lock 10B	210	30	120	--	--	360	14
Lock 10B, and Tennessee Colony Lake to Lock 12	178,886	2,700	114	6,500	--	188,200	550
Lock 12, and Channel to Lock 13	887	60	10	650	1,211	2,818	29
Lock 13, and Channel to Lock 15	1,008	60	20	75	1,315	2,478	54
Lock 16, and Channel to Lock 17	777	60	10	75	937	1,859	42
Lock 17, and Channel to Lock 18	6,076	50	10	250	2,115	8,501	297
Lock 18, and Channel to Lock 19	668	40	2	--	387	1,097	348
Lock 19, and Channel to Lock 20	4,236	40	10	--	1,332	5,618	230
Lock 20, and Channel to Lock 21	3,658	40	10	400	838	4,946	138
Lock 21, and Channel to FW Port	1,878	40	20	--	485	2,423	39
FW Port to Floodway at Riverside Dr.	2,928	--	--	--	750	3,678	122
TOTALS	217,657	3,390	666	9,600	28,943	260,256	2,478
PROPOSED RESERVOIR REGULATION FLOWAGE LANDS						45,000	
TOTAL LANDS						305,256	

As accumulative flows continue down the river from Dallas to Tennessee Colony Lake, the tainter gates at each lock and dam would be opened to pass flows from pool to pool around each lock. Numerous side tributaries might also contribute runoff depending on the timing and location of rainfall. Channel capacities in this reach would vary from 25,000 cfs at the upstream end to 32,000 cfs at the downstream end at Tennessee Colony Lake. County levee districts have constructed agricultural levee systems along the majority of this reach. Project construction would strengthen these levee systems to contain floods of about a 100-year frequency. Although levees in this area would be strengthened, they would not provide adequate flood protection for residential, commercial, or industrial development. In areas where there are no levees, flows which exceed the channel capacity would spread out into the surrounding flood plain, the coverage and depth being dependent upon the size of the flood.

At Tennessee Colony Lake, the water level would normally be maintained at elevation 275 feet msl for water supply purposes in accordance with standard procedures for operation of flood control/water supply lakes. Upstream uncontrolled runoff and/or regulated releases from upstream lakes would be caught by the lake. As flood flows raise the lake level above elevation 275, releases would be made at the spillway and/or the outlet works of the dam by operation of gates. Releases would be commensurate with the amount and rate of entry of floodwaters into the lake and downstream flooding conditions. The flood control capability of Tennessee Colony Lake would be essentially to catch high volume floodwater runoffs and gradually release this runoff so that flood damage downstream from the lake would be eliminated or minimized. The degree of flood protection provided by Tennessee Colony Lake would vary from about a 90-year frequency flood at the damsite to about a 60-year frequency flood at Wallisville Lake. Statistically, the lake could be expected to fill to the flood control pool level (elevation 292) an average of about once every 50 years.

Downstream from Tennessee Colony Lake, the channel design capacity would be 45,000 cfs from Tennessee Colony Lake to Wallisville Lake. Minor flood control releases and/or runoff from side tributaries would be contained within the channel and passed from pool to pool by the lock tainter gates as previously described.

Flood runoff into Lake Livingston would be caught for water supply purposes until the lake was full. Any additional flows would be passed through the spillway and outlet works at the dam. About 12 miles downstream from Livingston Dam a diversionary structure would route excess flows through the Multiple-purpose Channel while allowing regulated flows up to bank full capacity (about 20,000 cfs) to flow down the existing river channel for about 54 river miles, recombining with the Multiple-purpose Channel upstream from Lock and Dam 3. This would simulate existing flow conditions in part of this reach of the river (the upstream 23 miles) while minimizing flood damages in the area. Downstream from Lock and Dam 3, floodwaters would flow down the Multiple-purpose Channel into Wallisville Lake, fill the lake to elevation 4 msl, and then flow over the four mile long concrete weir at the Wallisville Dam into Trinity Bay.

3.05.02 Navigation Operations. It would require about an hour for waterborne traffic to pass through the average lock. This time is measured from the time a boat or barge tow begins to slow down until the time it has passed through the lock and regained its normal speed. Traffic traveling either upstream or downstream would be passed through a lock by valving water from the upstream pool to the lock chamber and then the downstream pool. Miter gates (hinged to both sides of the lock, like double doors, at both ends of the lock chamber) would operate to hold water and pass traffic. Plate 32 diagrams this procedure and Photographs 23 and 24, Appendix A, show aerial views of an existing lock on the Verdigris River near Tulsa, Oklahoma. The lock shown is very similar in design and operation to the project locks. Assuming the project could be operational by 1985, a detailed traffic analysis indicated the number of initial year lockages for both private and commercial traffic would range from a low of about eight per day (Lock 21) to a high of about 11 per day (Lock 13). Table 3-5 indicates the 1985 navigation water requirements. By the year 2035 (see Table 3-6 for navigation water requirements), the number of lockages are predicted to increase, ranging from about 18 per day to about 34 per day. The latter traffic volume would require construction of an additional lock beside the first lock. Because of the high lifts involved, tandem locks (two locks located about one mile apart) would be required at both Livingston Lake (Locks 5A and 5B) and Tennessee Colony Lake (Locks 10A and 10B). Major flood runoff would be expected to suspend navigation operations about one week per year. This is based on statistical flow estimates, but it could happen several weeks a year or about one month every four years. During dry periods, water in the channel would come primarily from municipal and industrial sewage, ground water seepage, and municipal storm sewer runoff, much as it flows into the river now. Flows in the channel would generally approximate present river flows and would move down the channel by a combination of lockages and tainter gate adjustments, since the navigation

TABLE 3-5

SUMMARY OF 1985 NAVIGATION WATER REQUIREMENTS

Pool No.	Pool Surface Area in Acres	Size of Lock in Feet	Lock Lift in Ft.	Commercial Lockages Per Year	Water Requirements in cubic feet per second: Comm. Lockage	Pleasure 1/ Craft Lockage	Evaporation	Leakage & Seepage 2/	Total
21	560	84X400	28	962	32.3	69.5	1.4	24.0	127.2
20	480	84X400	28	1,066	35.7	67.8	1.0	24.0	128.5
19	650	84X400	28	1,066	35.7	67.8	1.4	24.0	128.9
18	400	84X600	24	2,108	87.5	62.3	0.8	22.0	172.6
17	810	84X600	24	2,656	110.3	50.9	1.7	22.0	184.9
16	840	"	28	2,656	128.6	59.4	1.9	24.0	213.9
13	1,040	"	28	2,674	129.5	59.0	2.3	24.0	214.8
12	1,070	"	17	2,674	78.6	35.8	2.5	18.5	135.4
10B	880	"	38	1,624	106.8	114.6	2.0 3/	29.0	252.4
10A	80	"	27	1,624	75.9	81.4	0.4	23.5	181.2
9	1,980	"	32	1,258	69.6	106.6	3.5	26.0	205.7
7	1,840	"	40	1,258	87.0	133.3	3.2	30.0	253.5
6	4,150	"	7	1,258	15.2	23.3	6.3	13.5	58.3
5B		"	30	1,234	64.0	100.6	0.0 3/	25.0	[illegible]9.6
5A	290	"	29	1,234	61.9	97.2	0.6	24.5	1[illegible]4.2
4	1,970	"	36	2,222	138.4	89.9	2.9	28.0	259.2
3	2,160	"	32	2,222	123.0	79.9	3.1	26.0	232.0
1	2,830	"	4	2,222	15.4	10.0	1.7 3/	12.0	39.1
							36.7		

1/ Pleasure craft requirements are based on one lockage every 2 hours during each twelve-hour daylight period.

2/ Leakage through the gates was computed at 0.5 cfs per foot of lift and a constant flow of 10 cfs per lock was estimated for seepage.

3/ Evaporation for pools 10B, 5B, & 1 was computed and accounted for in Tennessee Colony, Livingston and Wallisville Lakes yield computations respectively. Pool 10B has some additional losses above Tennessee Colony Lake losses; Pool 1 has additional losses above Wallisville Lake losses.

TABLE 3-6

SUMMARY OF 2035 NAVIGATION WATER REQUIREMENTS

Pool No.	Surface in Acres	Size of Lock in Feet	Lock Lift in ft.	Commercial Lockages Per Year	Water Requirements in cubic feet per second: Comm. Lockage	Pleasure Craft Lockage 1/	Evaporation	Leakage & Seepage 2/	Total
21	560	84X400	28	3,862	129.5	94.4	1.4	24.0	249.3
20	480	"	28	4,316	144.7	86.7	1.0	24.0	256.4
19	650	"	28	4,316	144.7	86.7	1.4	24.0	256.8
18	400	84X600	24	9,374	389.2	2.4	0.8	22.0	414.4
17	810	"	24	12,306	510.9	0.0	1.7	22.0	534.6
16	840	"	28	12,306	596.0	0.0	1.9	24.0	621.9
13	1,040	"	28	12,422	601.6	0.0	2.3	24.0	627.9
12	1,070	"	17	12,422	365.3	0.0	2.5	18.5	38[illegible].3
10B	880	"	38	7,520	494.3	64.7	2.0 3/	29.0	590.0
10A	80	"	27	7,520	351.2	46.0	0.4	23.5	421.1
9	1,980	"	32	5,826	322.5	101.4	3.5	26.0	453.4
7	1,840	"	40	5,826	403.1	126.8	3.2	30.0	563.1
6	4,150	"	7	5,826	70.5	22.2	6.3	13.5	112.5
5B		"	30	5,778	299.8	96.3	0.0	25.0	421.1
5A	290	"	29	5,778	289.8	95.8	0.6	24.5	410.7
4	1,970	"	36	11,390	709.3	0.0	2.9	28.0	740.2
3	2,160	"	32	11,390	630.5	0.0	3.1	26.0	659.6
1	2,830	"	4	11,390	78.8	0.0	1.7 3/	12.0	92.5
							36.7		

1/ Pleasure craft requirements are based on one lockage every hour during each twelve-hour daylight period.
2/ Leakage through the gates was computed at 0.5 cfs per foot of lift and a constant flow of 10 cfs per lock was estimated for seepage.
3/ Evaporation for pools 10B, 5B and 1 was computed and accounted for in Tennessee Colony, Livingston and Wallisville Lakes yield computations respectively. Pool 10B has some additional losses above Tennessee Colony Lake losses; Pool 1 has additional losses above Wallisville Lake losses.

pools have no appreciable capacity to retain flows. Water requirements for navigation lockages would be rather small compared to flood flows but significant in terms of river flow. Upper basin return flows, primarily treated sewage effluents, would be sufficient to satisfy lockage needs in times of very low or no areal runoff (rain), except at Lock 21 which is upstream of most of the metropolitan area sewage discharge points. A pumpback capability has been included in the design of Lock 21 to transfer water from the pool of Lock 20 to the pool of Lock 21 for lockages during low flow periods. The navigation channel would normally be open to traffic 24 hours a day, 7 days a week, from Fort Worth to Galveston Bay. Reflective channel markers and/or elevated beacons would be provided throughout the length of the Multiple-purpose Channel for nighttime navigation by both commercial and private craft in accordance with standard U.S. Coast Guard criteria.

3.05.03 Water Supply Operations. Local interests could withdraw water from Tennessee Colony Lake for municipal and industrial use as needed within the permit limitations that would be issued by the Texas Water Rights Commission. The sustained water supply yield of Tennessee Colony Lake would be 748 cfs initially and be gradually reduced to 712 cfs after 100 years of sedimentation.

3.05.04 Recreation Operations. Boat ramps with their associated access roads and parking lots would be provided and maintained where highways in rural areas cross the Multiple-purpose Channel, at lock locations, at Tennessee Colony Lake, and at selected locations in the Dallas-Fort Worth metropolitan area. This would provide access throughout the project for water oriented recreational activities. Picnic and camping areas would be provided in the vicinity of each navigation lock along with a visitors center which would include an overlook view of the lock itself, restroom facilities, interpretive media, and a rest area. Some of the islands formed by the divergence of the river channel and the Multiple-purpose Channel would be designated as park areas, overnight camping areas, or primitive conservation areas. All lands acquired for the proposed project would become public lands and would generally be available to the public for low density recreation activities. Developed recreation areas totaling some 9,600 acres would be provided around Tennessee Colony Lake and would provide camping and picnicking areas, together with restrooms, drinking water, refuse cans, etc. Developed recreation areas totaling some 4,910 acres would be provided at selected locations along the Multiple-purpose Channel. In the Dallas-Fort Worth metropolitan area, land between the levees totaling some 16,874 acres on both the West Fork Floodway and Dallas Floodway Extension would be available for non-obstructive recreation facilities such as golf courses, bicycle trails, pedestrian trails, horse trails, athletic fields, etc. Appropriate sanitary facilities would be provided at public recreation areas.

3.05.05 Fish and Wildlife Programs. The Texas Parks and Wildlife Department, working in cooperation with the U.S. Fish and Wildlife Service, would provide for and regulate fish and wildlife programs within the project area. These would include fish and wildlife stocking, species regulation, habitat conservation, and wildlife-oriented recreation.

3.05.06 Hydroelectric Power Operation. Hydroelectric power generation at Tennessee Colony Dam would be accomplished by utilizing the lake pool to provide water under pressure that would be routed by gates through turbine-generators to produce electricity. Preliminary calculations indicate water releases of about 5, 00 cfs would be made for six to eight hours a day from May through September. The electricity produced (about 16,000 kw) would be a comparatively small amount of energy in terms of total area consumption but would be useful in meeting the peak demand of nearby urban areas Water releases for hydropower would cause a drop of approximately one-half inch per day in the conservation pool level; however, this would generally be more than offset by return flows and areal runoff coming into the lake. Normal water depth of the lake in the vicinity of the powerhouse would be about 47 feet. The ability to select from a particular level for generation of electricity would be provided to aid in downstream water quality control. The addition of hydroelectric power facilities as a project purpose would be contingent upon Congressional authorization.

3.05.07 Maintenance Dredging Operations. Removal of accumulated bottom sediment in the Multiple-purpose Channel to maintain navigation and flood control depths after construction would be directly related to the magnitude and frequency of flood flows. A major flood would cause high flow velocities, extensive erosion, and high sediment loads, and a significant amount of this sediment would be deposited in the channel as flood flow velocities decrease. It is estimated that one maintenance dredge would be in use somewhere on the 360-mile channel most of the time. During periods of drouth there would be almost no dredging activity. After floods, considerable maintenance dredging might be necessary, depending on the magnitude of the flood. Most of the time, dredging would be limited to localized areas. The areas of heaviest sediment deposition would be immediately downstream from locks, at intersections of major tributaries, at off-channel harbor entrances, and in the upstream ends of Livingston and Tennessee Colony Lakes. The sediment material would generally be similar to the surrounding alluvium, although in most cases it would contain various materials from upstream human activity. The estimated channel maintenance dredging quantities and the acreages that would be leased for disposal of these materials is shown in Table 3-7. These quantities were estimated on an average annual basis, and this is of primary importance for proper perspective, since the actual conditions would vary greatly from year to year. Major floods result in the accumulation of the most sediment, but major floods would not occur every year on the Trinity River. Examination of the column "Acreage Requirements for Sediment" indicates that about 72 percent of the total sediment deposition in the channel would be in three areas: Lake Livingston, Tennessee Colony Lake, and upstream of Lock and Dam 20 between the cities of Fort Worth and Arlington. It is estimated that Lake Livingston sediment deposition would occur at the rate of 0.71 feet per year, primarily in the upstream 34 miles of the 48.7 miles of channel reach between Lake Livingston Dam and Lock 6. At this rate of deposition, 3,063 acres would be needed over a 50-year period for disposing of sediment at an average depth of 12 feet. In Tennessee Colony Lake, sediment deposition would be expected to occur at the rate of 1.27 feet per year in the upstream 31 miles of the channel between Tennessee Colony Dam and Lock 12. At this rate, 5, 00 acres would be required over a 50-year period for disposal of sediment at an average depth of 12 feet. In the Tennessee Colony Lake area, it is anticipated that the majority of lands required for sediment disposal would be within the real estate acquisition line of the lake, and that some of the 43 million cubic yards required for construction excavation of the channel would be used to form irregularly shaped ring levees within the lake area for confinement of dredged materials. In the area upstream from Lock and Dam 20, and particularly upstream from Lock and Dam 21, most of the sediment is expected to originate from urban flood runoff since most upstream rural area sediment would be deposited in the water supply and flood control lakes upstream of Fort Worth. In the Dallas-Fort Worth area, it is estimated that only minor amounts of sediment deposition could be placed within the improved floodway limits without compromising the flood control capabilities of the Dallas-Fort Worth metropolitan floodway system, and that deposition in this area would have adverse aesthetic side effects. It is therefore anticipated that sediment dredged from the Multiple-purpose Channel in the Dallas-Fort Worth area would be either loaded aboard barges and transported downstream to rural deposition areas or deposited in abandoned sand and gravel pits outside the floodway levees.

In general, disposal of sediment from the Multiple-purpose Channel would be accomplished by leasing land from landowners, filling the leased land to predesignated elevations, and returning it to the landowners either revegetated or not, depending on the stipulations of the lease agreement. Part of the initial channel excavation material would be shaped into ring levees of from 5 to 50 acres (about one area per mile of channel) to contain periodic hydraulic

TABLE 3-7

ESTIMATED CHANNEL MAINTENANCE DREDGING QUANTITIES

Reach	Channel Reach Distance (Miles)	Average Annual Sediment Volume (Ac.-Ft./Yr.)	Average Annual Sediment Deposition Rate in Channel (Ft./Yr.)	Acreage Requirements for Sediment-12 Ft. Deep for 50 yrs. (Ac)
Houston Ship Ch to Wallisville Dam	28.3	*	*	*
Wallisville Dam to Lock 5B	62.9	50	0.03	208
Lock 5B to Lock 6 (Lake Livingston)	48.7	735	0.71	3,063
Lock 6 to Lock 7	49.6	450	0.30	1,875
Lock 7 to Lock 9	18.9	-	-	-
Lock 9 to Lock 10A	18.3	-	-	-
Lock 10A to Lock 10B	1.3	-	-	-
Lock 10B to Lock 12 (Tennessee Colony Lake)	44.6	1,200	1.27	5,000
Lock 12 to Lock 13	12.1	17	.05	71
Lock 13 to Lock 16	14.0	34	0.08	142
Lock 16 to Lock 17	11.2	30	0.09	125
Lock 17 to Lock 18	13.5	169	0.41	704
Lock 18 to Lock 19	11.2	63	0.23	263
Lock 19 to Lock 20	9.6	53	0.23	221
Lock 20 to Lock 21	7.9	111	0.58	463
Lock 21 to FW Port	5.1	135	1.09	563
TOTALS	357.2	3,047		12,698

* No quantities are shown for the reach across Trinity and Galveston Bays as the need for maintenance dredging of channels in this area is primarily dependent on the shifting of bottom materials by wave (wind) and tidal actions, and the final alignment has not yet been determined.

dredging materials. A significant portion of the toxic materials that tend to bind with sediment particles would be confined by these ring levees. Almost all sediment deposition areas would be located within one-half mile of the Multiple-purpose Channel. In the reach from Lock 7 to Lock 10B, no accumulation of sediment in the channel would be expected because the area would be downstream from Tennessee Colony Lake, and the relatively sediment-free waters flowing downstream from the lake would tend to pick up sediment here rather than deposit it.

Final selection of sediment disposal sites would be subject to the coordination with the Environmental Protection Agency, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the Texas Parks and Wildlife Department, and the Texas Water Quality Board.

3.05.08 Maintenance Responsibilities. Operation and maintenance (O&M) of the floodway, levees, and appurtenances in the metropolitan area would be the responsibility of local interests in accordance with written standards set by the Federal Government. Operation and maintenance of agricultural levees would be the responsibility of the respective levee districts or other local interests. The Corps of Engineers would be responsible for O&M on the Multiple-purpose Channel, the lock structures, and Tennessee Colony Dam as well as recreation facilities located adjacent to Federally operated facilities including visitor overlooks lock viewing areas, and fishing areas and boat ramps at locks and dams. This would include repairs and replacements to all navigation, flood control, and hydroelectric equipment. The Trinity River Authority would be responsible for O&M of all other recreational facilities on the project, unless sub-leased to other local agencies or private interests. Permits for construction, operation and maintenance of off channel marinas and harbor facilities would be issued by the Corps of Engineers subject to applicable Federal regulations and appropriate response from local interests. Cleanup of navigation accidents and/or spills would be the responsibility of the involved parties under supervision of the Corps of Engineers in cooperation with the Environmental Protection Agency and the State of Texas. Maintenance of navigation buoys, beacons, markers, etc. would be the responsibility of the U.S. Coast Guard. Operation and maintenance of the proposed National Wildlife Refuge would be the responsibility of the U.S. Fish and Wildlife Service. Operation and maintenance of fish hatcheries and the proposed wildlife conservation areas would be the responsibility of the Texas Parks and Wildlife Department.

3.06 Benefit-cost Ratio. The Authorized Project Plan benefit-cost ratio is 1.8 to 1.

3.07 Construction Changes to River Regimen. Impacts (or changes) to the existing natural river channel by construction would be extensive. Some of the changes that would occur are outlined by the quantities shown in Table 3-8; of the 551.5 miles of the Trinity River between Fort Worth and Trinity Bay, 134.4 miles of the river have already been, or would be, inundated by lakes; another 23.6 miles would be intermittently inundated by the Tennessee Colony Lake flood control pool; and an additional 18.3 miles is already channelized, but would be widened and/or deepened by the project. Of the remaining 398.8 miles, the channel would be in the river or crossing the river for 121.1 miles and out of the river for 277.7 miles.

Wherever the Multiple-purpose Channel would be in or crossing the river channel, the visual appearance of the river would be changed markedly. The Multiple-purpose Channel would be about as large from top of bank to top of bank as the downstream end of the existing river channel at Wallisville Lake and much larger than the upstream end of the river channel (Plate 3). The rather steep irregular river banks would be transformed into banks with uniform slope. The meanders of many of the river bends would be transformed into rather uniform horizontal curves. Sand bars along the river would disappear; and the alternating deep and shallow pool river bottom profile with some very shallow riffles in the upstream portions of the river would be replaced by rather uniformly deep (12 feet or more) stretches of water.

Examination of the columns titled "Channel in River (River Miles)" and "Number of Times Channel Crosses River" (Table 3-8) is also indicative of change. For instance, in the reach from Lake Livingston to Wallisville Lake the channel crosses the river 27 times and would replace 15.7 miles of the river with channel, rechannel 0.7 miles of river, and leave approximately 95.3 miles of river outside the Multiple-purpose Channel. Of significance in this particular reach is a departure from the river of some 54 river miles (Plate 28.2) between Lock 5A and Lock and Dam 3 with structural provisions to maintain approximate existing low and medium flows in a portion of this reach of the river. About 31 miles of this reach would be under the influence of the pooling effect caused by Lock and Dam 3, and water velocities would gradually decrease. Although this reach would contain by far the longest departure between the river and the proposed channel, there would be many other departures ranging in size from less than one mile of river up to approximately 17 miles of river in other areas.

TABLE 3-8

PROJECT CHANGES TO EXISTING RIVER

Reach	Channel Mile	Distance (Channel Miles)	River Mile	Construction Changes to River Alignment: Channel in River (River Miles)	Channel Out of River (River Miles)	Existing River Channeled (River Miles)	River Inundated by Lake (River Miles)	Total Distance (River Miles)	Number of Times Channel Crosses River
	369.8		551.5						
West Fork Floodway		31.0		9.8	31.9	4.2	-	45.9	14
	338.8		505.6						
Dallas Floodway (Existing)		7.7		-	-	7.7	-	7.7	
	331.1		497.9						
Dallas Floodway Extension		9.1		2.7	7.5	0.8	-	11.0	8
	322.0		486.°						
Dallas Fldwy. Ext. to Tenn. Col. Lake (Cons. Pool)		51.3		33.9	52.4	1.0	-	87.3	71
	270.7		399.6						
Tennessee Colony Lake (Cons. Pool)		34.7		-	-	-	57.9*	57.9	-
	236.0		341.7						
Tenn. Col. Lake to Livingston Lake		95.3		59.0	90.6	-	-	149.6	59
	140.7		192.1						
Livingston Lake (Existing)		41.5		-	-	-	63.1	63.1	-
	99.2		129.0						
Livingston Lake to Wallisville Lake(8 mi. equation subtracted)		55.1		15.7	95.3	0.7	-	111.7	27
	36.1		17.3						
Wallisville Lake (Under const.)		7.8		-	-	-	13.4	13.4	-
	28.3		3.9						
Wallisville Lake to mouth of River		3.9		-	-	3.9	-	3.9	-
	24.4		0.0						
Mouth of River to Houston Ship Channel (Trinity & Galveston Bays)		24.4		-	-	-	-	-	-
	0.0		-						
Totals =		361.8		121.1	277.7	18.3	134.4	551.5	179

*An additional 23.6 river miles would be intermittently inundated by the flood control pool of Tennessee Colony Lake.

Although specific plans have not been finalized at this stage of planning, extensive treatment of these oxbow-like areas is envisioned. Wherever a navigation lock would be sited on the channel between the upstream and downstream ends of a sizable segment of river channel, a potential to maintain flowing water in the river channel would exist by the hydraulic head available between the upper and lower pool elevations of the lock and dam. The potential to maintain flows would also exist between two locks where fairly reliable flows from significant tributaries enter the river channel of a cutoff loop. In river channel areas between two locks, without significant tributaries, the river channel could be plugged on both ends to create an oxbow lake, or left open on both ends for recreation and additional habitat for aquatic vegetation and wildlife, or other variations for enhancement of recreation and fish and wildlife considerations.

Wherever the alignment of the river channel and the Multiple-purpose Channel diverge and later merge, an island between the two alignments would be formed. These areas would range in size from less than 10 acres to more than 35,000 acres. Access by landowners to these areas could be reestablished as a part of the construction activities, but in the case of small areas of less than about 100 acres, land acquisition by the Federal Government might be more economical than reestablishing access.

In the departures between the Multiple-purpose Channel and the river channel, there would tend to be a long-term sedimentation buildup in the river channel because of the slack water effect associated with the intersection of the two channels. This would be counteracted to some degree by the flushing action of local runoffs, controlled releases through these areas, maintenance dredging, or combinations of these actions. Many of these areas could be planned in conjunction with the sizable forested bottom land areas that would be purchased as reservoir regulation flowage and wildlife conservation areas as already described. The flood protection provided to these cutoff areas by the project would encourage private development on the more select of these parcels. Included would be potential industrial, commercial and residential activities.

There has already been significant residential development around some of the existing natural oxbow lakes, especially below Lake Livingston. It is assumed, unless public ownership or some form of land use regulations prevents it, that this type of development would also occur around project-created oxbow lakes, provided conditions conducive to development exist. Should this development occur, it is anticipated that additional activities necessary to support this use would also take place, such as access roads, service facilities, and utilities. This induced development would cause a loss of flora, the displacement of fauna, and create additional pollution, all of which would have adverse effects. The addition of these developments would, however, add to the tax base of the locality affected and could provide additional recreational opportunities.

3.08 Channelization of Tributaries, Metropolitan Area. There are numerous tributary streams intersecting the West Fork and the Trinity River in the Dallas-Fort Worth Metropolitan Area. Some 37 miles of these tributaries would be channelized for flood control purposes in the metropolitan area, but about 10 of these 37 miles have been previously channelized, and much of the remainder has been disturbed by such activities as gravel mining, sanitary land fills, and agricultural activities. Table 3-9 identifies the tributaries, indicates their point of connection to the Trinity River, and delineates the channel mileage involved for each tributary system.

3.09 Flow Velocities. As previously indicated, Trinity River stream velocities during low flow stages are less than one foot per second (fps), with total flow time between Fort Worth and Trinity Bay on the order of 50 days, or about 0.7 fps. The Multiple-purpose Channel would be significantly shorter and deeper than the existing river channel, which would tend to slightly increase velocities. However, the Multiple-purpose Channel cross section would be significantly larger than the river cross section, which would tend to reduce velocities. The net result would be that, under low flow stages, the project would reduce flow velocities to a range of about 0.1 to 0.3 fps, and total travel time would be in the range of 70 to 90 days. In the Multiple-purpose Channel reach between Fort Worth and Tennessee Colony Lake, velocities would range from about 0.1 fps for very low flows, to about 6 fps at channel capacities, and to about 8 fps for flows which exceed the channel capacity.

The Multiple-purpose Channel would not experience still or slack water pools at any time, primarily because of upper basin municipal return flows during times of no areal runoff. In the Multiple-purpose Channel reach between Tennessee Colony Lake and Lake Livingston, velocities would vary from a low of about 0.3 fps to a high of about 7 fps. Velocities would be highest when the discharge exeeds channel capacities. Hydroelectric power releases from Tennessee Colony Lake would provide velocities in the pool of Lock and Dam 9 in the range of about 1.5 to 3.0 fps. In the lower basin reach from Lake Livingston to Trinity Bay, velocities would be about 0.3 fps for low flows in the river channel and 0.1 fps for low flows in the Multiple-purpose Channel. Velocities in the existing channel such floods would range from about 3.0 fps to about 9.0 fps, and velocities in the

TABLE 3-9

METROPOLITAN AREA TRIBUTARY CHANNELIZATIONS

Name of Tributary(ies)	Connecting River Mile	Length of Proposed Channel (Miles)	Tributary Length (Miles)		
			Unchannelized	Previously Channelized	Total
Five Mile Creek and 2 Tributaries	487	5.4	3.5	2.7	6.2
Elam Creek	489	0.4	0.5	-	0.5
Honey Springs Branch	492	1.5	1.3	-	1.³
White Rock Creek (Dallas Turning Basin)	493	4.2	5.1	-	5.1
Delaware Creek and West Irving Creek	508	2.5	1.4	0.8	2.2
Mountain Creek	508	3.8	2.7	1.5	4.2
Bear Creek and Estelle Creek	517	2.9	4.9	1.1	6.0
Hurricane Creek	529	0.7	0.4	0.7	1.1
Sulphur Branch Creek	531	1.4	-	1.2	1.2
Walker Branch Creek and 1 Tributary	530	2.2	0.6	3.3	3.9
Big Fossil Creek	543	0.9	2.0	-	2.0
Little Fossil Creek (Fort Worth Turning Basin)	544	0.9	1.0	-	1.0
White Lake Outfall Channel	545	0.7	0.8	-	0.8
TOTALS		27.5	24.2	11.3	35.5

Multiple-purpose Channel would range from about 3.0 fps to about 7.0 fps. In the long term, secondary clearing and drainage of wetlands for agricultural and subdivision development would result in accelerated surface runoff during rainy periods, and little or no augmentation of flows during dry periods. Where sizable forested wetlands still exist, as in the flood plain downstream from Lake Livingston, the reverse would be true. Long-term alterations of this nature usually result in peaking of flows during rainy seasons and decreased flows during dry periods.

3.10 Tennessee Colony Lake Level Fluctuations. If construction were to be completed on the project, deliberate impoundment of water to form Tennessee Colony Lake would be a major impact in numerous ways. Assuming that areal runoff would approximate the average annual rate, and that downstream releases from Tennessee Colony Dam would approximate existing low flows in this area, it would take about one year to fill the lake to the conservation pool level. Thereafter, the lake pool would fluctuate above and below this level, primarily depending on timing and volume of areal runoff together with water supply yield withdrawals. On a strictly statistical basis, the pool level of the lake could be expected to fluctuate upwards five feet (elevation 280 msl) about one time every 4 years, 10 feet (elevation 285 msl) about one time every 10 years, and 15 feet (elevation 290 msl) about one time every 30 years. River hydrology historical data for the Trinity River Basin was applied to a computer program mathematical model, simulating the Basin under 2085 development conditions, to determine pool level fluctuations. The results indicated that the flood period of March to June 1945 would have yielded the highest pool with the longest duration for pool elevations above the conservation pool level. With peak inflows coming into Tennessee Colony Lake periodically for the four month period, the pool level would have remained above elevation 280 msl for 84 consecutive days, above elevation 285 msl for 55 consecutive days, and above elevation 290 msl for 30 consecutive days. The highest pool level reached was elevation 292 msl, the top of the flood control pool, and this pool level would then have been maintained by regulation of gates at the spillway. In contrast, the record period of drought (1950 to 1957) would have resulted in a minimum pool elevation of 265 feet msl, or ten feet below the conservation pool level. These two extreme conditions do not indicate the variety of conditions between them. In this regard it should be noted that the pool elevation would have been between elevation 270 msl and elevation 280 msl about 82 percent of the time over the 47-year period of record. On a year-to-year basis, severe pool level fluctuations would not be observed.

3.11 Tennessee Colony Lake Water Quality.

3.11.01 Waste Water Effluents. Because the Dallas-Fort Worth metropolitan area is located some 150 river miles upstream from the proposed Tennessee Colony Lake, a significant amount of the inflow to the lake would be municipal and industrial waste water effluents, or return flows. The average annual areal (rainfall) runoff into Tennessee Colony Lake is estimated to be about 1,957,000 acre-feet/ year, or about 2,702 cubic feet per second (cfs) (about 1750 mgd). Table 3-10 below indicates the estimated return flows and areal runoff amounts into Tennessee Colony Lake under 1985, 2035, and 2085 conditions of basin development.

TABLE 3-10
TENNESSEE COLONY LAKE WATER INFLOWS

Year	Average Annual Municipal & Industrial Return Flows (cfs)	Average Annual Areal Runoff (cfs)	Total Average Annual Lake Inflows (cfs)	% of Return Flows to Total Flows
1985	599	2,702	3,301	18
2035	1,632	2,702	4,334	38
2085	1,218	2,702	3,920	31

The following assumptions were made in estimating the flows shown in the "Average Annual Municipal and Industrial Return Flows" column:

Under 1985 and 2035 conditions, there would be no recycling of municipal return flows, but there would be recycling of 50 percent of the industrial return flows. Under 2085 conditions, almost all of the industrial return flows would be recycled together with about 50 percent of the municipal return flows.

3.11.02 Potential for Oilfield Contamination. Because of the possibility of contamination to the lake waters by unplugged oil wells, a search was made of the Texas Railroad Commission files to determine the number of abandoned wells and unplugged wells within the area below the flood control pool elevation. A total of 174 dry or abandoned holes were located on oilfield maps, and by a selective sampling of the plugging records, it was estimated that up to about 20 percent of these were unplugged. Information from the files also showed that plugged wells conformed essentially to the general conservation rules and regulations of Statewide application as set forth by the

Railroad Commission of Texas, 1964 Recodification, supplemental to June 1, 1973. Prior to embankment closure, an on-the-ground survey would be necessary in order to verify and supplement data on unplugged well locations. All wells would then be plugged in conformance with the aforementioned rules and regulations. The possibility of contamination by unplugged wells was discussed with Mr. James Smith and Mr. Roy Payne, of the Texas Railroad Commission, Kilgore office. Mr. Payne stated that wells in this area would offer no apparent hazard, regardless of the manner in which they were plugged, since the producing formation is subgradient in pressure and does not contain sufficient natural hydraulic pressure to flow contaminants to the surface.

3.12 Multiple-purpose Channel Water Quality. The significant effects of the project on water quality fall generally into the categories of construction and operation. The expected impacts of construction activities on the water quality include primarily that of exposing soil previously covered by vegetation to erosion and the washing into the stream of oils, fuels, etc. around construction areas. The erosion of bared soils and excavated materials would be kept to a minimum by careful contract specifications. However, it is recognized that increased turbidity and sedimentation would continue to present a problem for a number of years until vegetative cover becomes reestablished.

In the area downstream from Dallas, the individual lock pools, with their decreased velocity and increased detention time, would not be expected to improve the quality of the water although they would provide areas where continued oxidation of municipal, industrial, urban, and rural wastes could occur. Surface agitation by commercial and industrial watercraft and tainter gates might slightly add to the oxygen which would be present and aid in degradation of oxygen-demanding organic and inorganic substances. Watercraft would be required to have approved marine sanitation devices in compliance with State and Federal regulations. Nutrient turnover would be high in these pools and excessive algal and vascular plant growth would be probable as far downstream as Tennessee Colony Dam.

Water from Tennessee Colony Lake for municipal water supply use would be likely to contain higher concentrations of nitrates and phosphates than do present municipal water supplies. This condition could be expected unless treatment technology greatly improves, since removal of these substances beyond a given concentration is inordinately expensive. The water quality downstream from Tennessee Colony Dam could be expected to improve because of the biogeochemical cycling within the lake. This would not be expected to result in significantly reduced eutrophication in Lake Livingston or a reduced level of nitrates or phosphates in discharges from Lake Livingston. This is because lakes that have supported excessive plant growth for several years have accumulated so much organic debris that they would be expected to support continued plant growth even if all nutrient inputs were eliminated (AWWA, 1970). The quality of water in the lock pools in the lower portion of the Trinity River Basin would be good, but the maintenance of good water quality in this segment would depend upon the prevention of accidental spills and adequate regulations to prevent secondary developments along the Multiple-purpose Channel from adding pollutants.

3.13 Oil Spills. Barge transportation of crude oil and other liquid hydrocarbons would not be expected to occur in any appreciable volume in the first few years after completion of the project. In recent years, construction of new pipelines has reached its zenith, and although new transmission facilities are still being built, the indications are that these facilities have caught up with present oil and gas production. In 1973, the Texas Railroad Commission promulgated a 100 percent market-demand factor, and production of oil and gas in Texas was virtually at capacity. Even so, production in 1973 was down slightly from 1972, in both liquid hydrocarbons and natural gas. With the impetus of higher prices caused by increasing demand for these commodities, exploration for new fields, during the life of the project, may change that transmission-production balance and necessitate the transportation of some liquid hydrocarbons by barge. Currently, Trinity River Basin crude oil production is most intensive in the northern tier of counties, especially Cooke and Grayson Counties; in Van Zandt, Anderson and Henderson Counties; and in the lower three counties; Liberty, Hardin, and Chambers. Barge transportation of crude oil or natural gas liquids in small volumes could occur from any of these points to refineries in the Houston area or to more distant points. Upbound traffic of liquid petroleum products from Houston refineries also could occur. On-loading of liquid hydrocarbons would usually occur in off channel slips. With current technology, one of the requirements for oil spill damage prevention might be the construction of air bubble curtains (bubble barriers) across the mouths of these slips. Depending on channel flows, channel and slip configuration, traffic patterns, and the possibility of accidental spills outside of the slips, alternative designs might consist of these cross channel curtains, placed downstream or both upstream and downstream from the slips. The state of the art is undeveloped in many respects, but it is anticipated that methods for detecting and combatting oil spills would be much more effective by the time the Authorized Project Plan could become operational. Research is continuing in the use of remote sensing for oil spill detection. Various methods for isolation and containment, such as floating booms and bubble curtains, are being studied. Research in clean-up of floating oil includes the use of polyurethane foam sorbents, vacuum systems, and various types of skimmers.

3.14 River Flow Modifications into Trinity Bay. Of increasing concern to many State and Federal agencies and the general public is the quality and quantity of river water running into Trinity Bay and the Galveston Bay complex, particularly from the viewpoint of the long-term maintenance of the brackish water bay systems for marine species as discussed previously.

3.14.01 Water Quantity. Extensive calculations were made to estimate the quantitative project effects on river flows into Trinity Bay. The 1985 and 2035 expected water resource development conditions were predicted, and the effects on flows by water supply yields including transfers in and out of the Basin (Plate 1), upper Basin waste water return flows, Soil Conservation Service projects, sedimentation, estimated power generation releases from Tennessee Colony Lake, evaporation losses, lockage releases, and flood spills from all Basin lakes were estimated. These variables were applied to the 1925-1965 historical record of river flows under both 1985 and 2035 expected Basin water resource development conditions. The summarized tabulation is shown in Table 3-11 They are considered conservative, since the most significant influence on river flows into Trinity Bay is water supply lakes, and the full dependable yield of all water supply lakes was considered to be withdrawn throughout the reconstructed period of record. This would not be the case at all times in the future, but it does depict the approximate critical conditions that could exist in the long term with future expected economic and population growth and a recurrence of historical droughts.

3.14.02 Record Low Flow Year. Examination of the record low flow year (1956) data in Table 3-11 indicates that there would be more water flowing into Trinity Bay with the project under 1985 development conditions than there would be without the project. Some uncontrolled runoff would occur in either case, but navigation lockage releases into Trinity Bay would be added by the "With Project" condition. Under 2035 conditions, return flows from the upper basin metropolitan area increase the "Without Project" condition, while water supply catches and evaporation losses by Tennessee Colony Lake offset lockage releases into Trinity Bay under "With Project" conditions. The 2035 conditions also reflect increased flows into Trinity Bay because sedimentation buildup in all lakes reduces water supply dependable yields, and municipal and industrial return flows effluents are increased by out-of-Basin water supply lakes.

TABLE 3-11

ESTIMATED TRINITY RIVER FLOWS INTO TRINITY BAY [(1)]
(Ac.-Ft./Yr.)

	Record Low Flow Year (1956)		Record High Flow Year (1945)		Average Annual Basis	
Estimated Period of Record Flows at Mouth of River [(2)]	799,000 [(3)]		12,933,000		5,371,000	
	Basin Water Development		Basin Water Development		Basin Water Development	
	1985 Conditions	2035 Conditions	1985 Conditions	2035 Conditions	1985 Conditions	2035 Conditions
Without Project	120,000	656,000	10,269,000	11,167,000	3,523,000	4,227,000
With Project	309,000	657,000	10,080,000	10,510,000	3,329,000	3,539,000

(1) All data estimated from the 1925-1965 Period of Record at the Romayor Cage, river mile 96.
(2) The estimated period of record flows at mouth of river reflect adjustments for unmeasured areal runoff downstream from the Romayor Gage.
(3) Adjusted to reflect record drought year irrigation withdrawals downstream from the Romayor Gage reported to the Texas Water Rights Commission.

3.14.03 Record High Flow Year. In contrast, the record high flow year (1945) data reflect that during years of heavy rainfall, much of the runoff could not be contained by Basin lakes and would flow into Trinity Bay. The high flows are two to three times the average annual flows under all conditions.

3.14.04 Average Annual Basis. Possibly the most revealing data contained in Table 3-11 are the average annual basis figures; the 1985 conditions without the project reflect approximately the current existing conditions and show that, on an average annual basis, the flows into Trinity Bay would be about 66 percent of the estimated period of record flows without the project and 62 percent with the project. The 4 percent reduction with the project is primarily because of Tennessee Colony Lake water supply catches and evaporation losses, even though the water supply yield of the lake is not expected to be utilized until after 1985. The 2035 conditions reflect the full water supply yield of Tennessee Colony Lake with a 13 percent flow reduction with the project when compared to the estimated period of record flows. In summary, for the various conditions imposed the following would be true:

Condition	Flow Effect at Mouth of River
Water supply yields from in-Basin lakes	Reduces flow
Water supply yields from out-of-Basin lakes	Increases metropolitan effluents which increases flows.
Lake sedimentation	Decreases water supply yields which increases flows.
Lake evaporation losses	Decrease flows.
Lockage releases	Increase flows.
Flood spills at all lakes	Total volume of water approximately the same, but over somewhat longer time periods.
Municipal & Industrial effluents	Partly replaces water supply yields taken from in-Basin lakes.
Tennessee Colony Lake and Lock and Dam 3 hydropower releases	Increase flows.
Soil Conservation Service lake projects	Decrease flows.
Metropolitan areas and channelization projects	Increases efficiency of rainfall runoff, increases flows.

3.14.05 Mouth of River Water Quality. There would be few short term effects resulting from construction or maintenance operations of the project on mouth-of-river flows, other than temporary turbidity. Long term adverse effects could result from induced municipal and industrial development, along with increased recreational use.

3.15 Inundation of Fossil and Type Localities. The type locality for the Kerens member of the Wills Point formation as well as the *Cornuspira carinata* fossil locality for the Kerens member would be inundated by Tennessee Colony Lake. The type locality is exposed in the bank of the Trinity River near channel mile 268. The top of the exposure would be under about 15 feet of water at conservation pool level (275.0 msl). The fossil site is situated about a mile upstream from the type locality and is slightly higher in elevation, but would also be inundated by the lake at conservation pool level. Although these sites would be mainly of academic interest, they have been described in geologic literature as typical of this stratigraphic member and fossil occurence and have in the past been of some academic value. Jones, H. L. (1973) states:

> It is felt that the flooding of the type locality of the Kerens member and the *Cornuspira carinata* fossil locality will not be an important loss. Both localities have been adequately described, and new satisfactory alternatives could probably be located.

3.16 Effects on Ground Water. Construction of the navigation pools would raise the river stage to which the alluvial ground water is tributary upstream from each lock and dam for about three-fourths of the length of the pool. The river stage would be lowered in the upstream one-fourth of the pool where channel deepening would be required.

A digital computer model was developed by the U. S. Geological Survey in a cooperative study with the Corps of Engineers to assess the effects of the navigation pools and Tennessee Colony Lake on the alluvial ground water and on the Carrizo Wilcox aquifer. Input data were from published ground water level data, alluvial aquifer pumping tests, permeability tests of alluvial materials and a flood plain well monitoring program. Preliminary results of the study were obtained for the area from Dallas to a few miles downstream from the proposed Tennessee Colony Dam. Output data consisted of preconstruction and post-construction contours on the potentiometric surface. Ground water in the Trinity River flood plain is confined in a few places by overlying clay layers, and the potentiometric surface represents the level to which the water table would rise if unconfined.

3.16.01 Tennessee Colony Lake.

3.16.01.01 Effects on Carrizo-Wilcox Aquifer. Tennessee Colony Lake would have an effect on both the ground water table and the Carrizo-Wilcox aquifer in the general area of the lake and downstream. The Carrizo formation overlies the Wilcox and outcrops in a northeast trending belt that varies from about three miles wide in Freestone County to about one mile wide through Anderson and Henderson Counties. The Wilcox outcrop varies from 10 to 22 miles in width across Freestone, Anderson, and Henderson Counties (Plate 8.2). The Wills Point formation, composed of relatively impermeable clays and silts, underlies the Wilcox and outcrops in the upper end of the lake. Tennessee Colony Dam would connect the right abutment on the Carrizo outcrop with the left abutment founded on the Reklaw formation. The Reklaw formation overlies the Carrizo and consists of interbeded sands and clays which are relatively impermeable. Conservation pool depths would vary from about 40 feet immediately upstream from the dam to less than 5 feet at the northern limit of the Carrizo-Wilcox outcrop near mile 396. An additional 17 feet of head would be provided when the lake is at the top of the flood control pool level. At this level, (elevation 292.0 msl) the lake would be confined generally to the flood plain and terraces above Trinidad but would inundate the flood plain terraces and uplands marginal to the flood plain between Trinidad and Tennessee Colony Dam. It would be subjected initially to indirect infiltration through the alluvium in the flood plain and terraces. In upland areas the Carrizo-Wilcox would be exposed to almost direct infiltration of the lake waters. Although thin clay layers in the alluvial materials would restrict vertical permeability, hydraulic conductivity appears to be higher in the alluvium than in either the Wilcox or Carrizo formations. Over a period of years, reservoir siltation would be expected to gradually reduce permeability in the alluvium. Hydraulic conductivities of the Carrizo Sand, determined from aquifer tests in the area (Garza, 1974) ranged from about 3 to 64 feet per day; the average is probably about 25 feet per day. The thickness of the underlying Wilcox in the subsurface ranged from 800 to 1,100 feet in Henderson and Freestone Counties to more than 2,200 feet in southeastern Anderson County (Garza, 1974) and northern Houston County (Tarver, 1966). The sands are generally fine-grained and relatively thin, but locally some sands are coarse-grained and relatively thick. Garza (1974) reported values of hydraulic conductivity ranging from 2 to 45 feet per day for the Wilcox group within the area. The average value is probably about 12 feet per day. A digital computer model was used to project the effects of Tennessee Colony Lake on the Carrizo-Wilcox bedrock aquifer along the shoreline of the lake and in the artesian area downstream from the proposed dam.

The projected rises are stated by Garza (1974) as follows:

> Relatively large rises of 20 to more than 30 feet will extend to those land areas that are adjacent to or in close proximity to the reservoir shoreline. Rises of 5 to 20 feet will not extend much beyond the shoreline in the outcrop area, but they will spread out to greater distances in the artesian area. The rises in head will be slightly more than 5 feet in the Palestine area and only slightly less in the Oakwood area. Very small rises, if any, will be noted in the Buffalo and Athens areas, which are located on or near the outcrop region. Other than in the low-lying areas near the reservoir shoreline, depth to water in wells in the Carrizo-Wilcox outcrop will be more than 5 feet and significantly deeper in most areas in the outcrop.

Trinity River waters in the Tennessee Colony Lake area currently contain significant amounts of many pollutants (river miles 340 to 400, Plates 15.1 through 15.19). Percolation of these waters through the Carrizo-Wilcox aquifer would be expected to eliminate the particulate contaminants and the chemical pollutants, except nitrates and nitrites (Garza, 1974a). River water samples taken above Tennessee Colony Dam site indicate that concentrations of nitrate and nitrite do not exceed U. S. Public Health Service drinking water standards (EPA, 1971). Chemical analyses of water from Carrizo-Wilcox wells in the artesian area that would be influenced by the lake indicate that 85 percent contain less than 0.4 mg/l of nitrate and in the remaining 15 percent, nitrate levels range from 0.4 to 3.6 mg/l. The U. S. Public Health Service recommends a limit of 45 mg/l for drinking water.

3.16.01.02 Effects on Trinity River Alluvium Above Tennessee Colony Damsite. As the lake begins to fill, the ground water which is tributary to the river would experience a gradual reversal in direction of flow. After the lake level reaches elevation 275 msl the pool level would remain fairly stable and the water table would gradually adjust until the flow is again tributary to the lake. According to Garza (1974):

> Rises in aquifer head in the Trinity River alluvium upstream from the proposed reservoir will be relatively small; areas where the potentiometric surface will be within 5 feet of land surface are confined to the low-lying areas near the shoreline in the flood plain. In some places, between the Texas Power and Light Company Lake and the proposed reservoir, rises in head may be 10 feet or more, and depth to water in wells may be at or near land surface.

Hydrographs for the period of record (47 years) indicate that the level would then be maintained between elevation 270 and 280 msl for 82 percent of the time. With each vacillation of the pool level the effect would be felt immediately at the shoreline but more indirectly at increasing distances from the shoreline. On a year to year basis the pool would be expected to exceed elevation 280 about once every four years, elevation 285 about once every 10 years and the 290 level about once every 30 years. Assuming normal operations with average conditions prevailing the pool would not remain above the 275 level for more than 30 or 40 days. During this period, the water table would rise, the ground water flow would be away from the lake, and areas up to about a mile from shoreline would be affected, before the pool would again be lowered to the 275 level. Declines in pool level would have the same delayed-reaction-lowering effect on the peripheral ground water table depending on the amount and duration of the decline.

3.16.01.03 Effects on Trinity River Alluvium Downstream From Tennessee Colony Damsite. Older fluviatile-terrace deposits would be affected in many places along this reach of the Trinity River as well as the alluvial aquifer. The alluvium in this area is underlain by the Reklaw Formation and the Queen City Sand, both regarded as poor aquifers with relatively impermeable clay members. Rises in aquifer head would not extend more than 5 miles downstream from the dam. The potentiometric surface projected by the computer model is above the land surface in most of the area on the east side of the river within about 2 miles downstream from the dam, however, seepage treatment in the dam was not considered in the computer program. Foundation design could include a cut-off trench along the full length of the dam, curtain grouting (especially in the west abutment), and a system of relief wells downstream from the embankment to control under seepage and relieve hydrostatic pressure produced by the lake. The pressure relief provided by these measures would be expected to substantially reduce the downstream effects on the alluvial aquifer.

3.16.02 Multiple-Purpose Channel.

3.16.02.01 Effects on Primary and Secondary Aquifers. All ground water aquifers crossed by the Multiple-purpose Channel would be subject to recharge, although very minor in most cases. Excavated channels which expose aquifer formations would provide a direct access for infiltrating water and the charged condition of the alluvial aquifer immediately upstream from individual locks and dams would provide an indirect access. Hydraulic conductivities in the flood plain alluvium from Dallas to Trinidad were derived from pumping tests by USGS. Results varied from 60 to 300 feet per day in this area and are probably somewhat less in the downstream areas of the flood plain. Since the alluvium is much more permeable than any of the formational aquifers, the aquifers would be subjected to the induced hydraulic head in pools that inundate aquifer recharge areas. Table 3-12 shows the pools that would occupy these recharge areas, the applicable differential head, and hydraulic conductivity of the aquifer.

TABLE 3-12
EFFECTS ON TRINITY BASIN AQUIFERS

Pool		Aquifer	
Number	Maximum Differential Hydraulic Head (feet)	Name	Hydraulic Conductivity (feet/day)
4 & 5A	15 to 30	Gulf Coast (Evangeline)	variable
6	negative	Sparta	15
7 & 9	10 to 25	Queen City	7
10B (Tennessee Colony Lake)	30 to 75	Carrizo - Wilcox	12 to 25
19 & 20	20 to 25	Woodbine	2

By comparison, the effects induced by Tennessee Colony Lake on the Carrizo-Wilcox aquifer, would be expected to exceed navigation pool effects on any other aquifers by about two orders of magnitude.

3.16.02.02 Effects on Trinity River Alluvium, Fort Worth to Dallas. The ground water table in these materials, which are considered to be relatively permeable, would react more quickly and directly to changes in river stage induced by the project. Hydraulic conductivities up to 300 feet per day are estimated for these materials and a lowering of the water table would be anticipated in restricted areas immediately downstream from Locks and Dams 18, 19, 20, and 21, but especially below Locks and Dams 19 and 21. Areas in which the water table would be expected to rise and stabilize within five feet of the surface occur above all four locks, but these effects would be more pronounced above Locks and Dams 18 and 20.

3.16.02.03 Effects on Trinity River Alluvium, Dallas to Trinidad. Ground water conditions in this area would be influenced by navigation pools 12, 13, 16 and 17 (Locks and Dams 7, 8, 11, 14, and 15 were deleted in navigation restudies but the original numbers have been retained). The flood plain in this area varies from about two to seven miles and averages about four miles in width. Hydraulic conductivities as determined from aquifer tests ranged from 60 to over 300 feet per day. Preliminary reports indicate that the area above Lock and Dam 13 is the most critical and that within an area about one mile wide and about four miles long, the potentiometric surface would be at or above land surface. This area could be subject to ground seeps and ponding in low areas. This area is included in a larger zone of about 14,000 acres immediately above Lock and Dam 13 in which the potentiometric surface would be from one to five feet below the ground surface. Similar areas of about 2,400 acres above Lock and Dam 12, and 7,000 acres above Lock and Dam 16 would be likely to occur. Ground water rises above Lock and Dam 17 would be very restricted. Although no specific areas have been identified, USGS maps of potentiometric or water table contours indicate that a slight lowering (as much as 10 feet in restricted areas) could occur. These areas would be expected in relatively permeable alluvium, immediately downstream from each lock and dam.

3.16.02.04 Effects on Trinity River Alluvium, Tennessee Colony Dam to Riverside. This reach includes navigation pools 6, 7, and 9 where the width of the flood plain varies from about one to six miles. It is anticipated that fairly large areas, in which the post-construction potentiometric surface would lie within five feet of the ground surface, would occur above Lock and Dam 9 and smaller areas would occur immediately above Lock and Dam 6. A lowering of the water table would probably occur in small areas below Locks and Dams 6 and 9. Lock and Dam 7 would be located approximately one mile north of the abandoned Hurricane Shoals Lock and Dam site (old Lock and Dam 21 completed in 1919), in a narrow constriction of the flood plain. The flood plain is confined here by the upper Weches formation to about a mile width. At Kickapoo rapids, situated on the west side of the flood plain constriction, the river flows over resistant beds of the exposed Weches formation. The rapids are in the river loop that would be cut off by the channel and Lock and Dam 7. The siting of the lock, in this river reach where the gradient is high, would serve to moderate the effects of the 40-foot lift which would be accomplished by the lock. Plate 31.2, indicates that the river thalweg drops over 20 feet in 1.5 channel miles at this site. Upstream from the site, the flood plain contains low intermittently marshy areas. Some of these areas could develop permanent seeps, and fairly large areas could develop with the water table at depths of one to five feet. Below the site it is anticipated that the flood plain water table would be lowered only in relatively small areas north of State Highway 7.

3.16.02.05 Effects on Trinity River Alluvium, Livingston Dam to Wallisville Lake. The flood plain area from Livingston Dam to the upper end of Wallisville Lake would include Lock 5A, about two miles downstream from Livingston Dam, and Locks and Dams 3 and 4. The alluvium is composed of silt, clay and sand with a fairly ubiquitous basal fine gravel layer. The area has very little relief. The flood plain elevation averages about 35 msl at Lock and Dam 3 and about 70 msl at Lock and Dam 4. The width of the flood plain is greater through this reach of the river than in upstream reaches and varies from four to about 10 miles. The flood plain becomes progressively more wet and marshy from Livingston Dam to Wallisville Lake, but this condition is most evident below State Highway 105 near Lock and Dam 4. Abandoned sand and gravel pits form permanent lakes in the flood plain terraces (Deweyville Formation) for about three miles south of the State Highway 105. Ground water effects below Locks and Dams 3 and 4, in contrast to those in upstream flood plain areas, would consist mainly of declines in the water table under low to moderate flow conditions. Declines of up to 25 feet would be experienced immediately downstream of Locks and Dams 3 and 4. Rises in the alluvial ground water table would occur adjacent to the dikes between Locks 5A and Lock 5B, and in areas immediately upstream from Locks and Dams 3 and 4.

3.17 Impacts on Vegetation, Tennessee Colony Lake. The vegetaion within the greater portion of the conservation pool would be totally lost, either cleared during construction, or killed by inundation. Woody and herbaceous plants in the shallow water around the shore and in the flood pool, would have varying degrees of survival success depending on their degree of adaptability to the higher water levels. Table 3-13 lists the relative tolerance to inundation of 36 selected woody species. Species not likely to be killed by inundation of up to 45 days include the first 24 species listed. Because of the difficulty in determining the quantity of inundated vegetation which would survive, the acreages listed in Table 1-45 and in Tables 3-14, 3-15, and 3-16, assume that all the vegetation inundated by the conservation pool of Tennessee Colony Lake would be lost. As indicated by Table 3-16 approximately 30,000 acres of forest currently within the 100-year flood plain (bottomland hardwoods) and 13,000 acres of forest outside the 100-year flood plain (partly composed of upland species) would be permanently lost following inundation. Table 3-16 lists the acreages that would be lost or otherwise affected by Tennessee Colony Lake. The quantative investigations of Nixon (1973) and Nixon and Willett (1974) were used to estimate the quantities, sizes, and species composition of the woody vegetation which could be expected to be lost by clearing or inundation.

TABLE 3-13

APPROXIMATE ORDER INUNDATION TOLERANCE OF SELECTED WOODY SPECIES (ARRANGED IN ORDER OF DECREASING TOLERANCE)

1.	bald cypress	19.	sugarberry
2.	tupelo	20.	winged elm
3.	water locust	21.	sycamore
4.	water elm	22.	river birch
5.	black willow	23.	blue beech
6.	common buttonbush	24.	catalpa
7.	green ash	25.	<u>water oak</u>
8.	overcup oak	26.	<u>black gum</u>
9.	red maple	27.	<u>Shumard oak</u>
10.	box elder	28.	<u>southern red oak</u>
11.	deciduous holly	29.	<u>white oak</u>
12.	cottonwood	30.	<u>loblolly pine</u>
13.	sweetgum	31.	<u>smooth alder</u>
14.	hawthorn	32.	<u>eastern red cedar</u>
15.	willow oak	33.	<u>American holly</u>
16.	persimmon	34.	<u>sassafras</u>
17.	honey locust	35.	<u>flowering dogwood</u>
18.	American elm	36.	<u>black cherry</u>

For those species underlined, inundations of 45 days and up likely to be lethal.

Data Source: Nixon (1972a)

TABLE 3-14

ESTIMATED NUMBERS OF WOODY PLANTS IN GIVEN AREAS OF TENNESSEE COLONY LAKE

Areas	Number per acre	1-10 cm* (0.4-3.9 in)	11-20 cm (4.3-7.9 in)	21-30 cm (8.3-11.8 in)	31-40 cm (12.2-15.8 in)	over 41 cm (over 16.1 in)	Totals
Conservation Pool in flood plain (30,083 acres)	400	3,008,300	4,933,600	3,128,600	842,300	120,300	12,033,100
Conservation Pool outside Flood plain (13,202 acres)	300	594,100	1,663,500	1,188,200	435,700	79,200	3,960,700
Flood Control Pool in Flood plain (10,915 acres)	400	1,091,500	1,790,100	1,135,200	305,600	43,700	4,366,100
Flood Control Pool outside Flood plain (15,471 acres)	300	696,200	1,949,300	1,392,400	510,500	92,800	4,641,200
Real Estate Acquisition outside Flood plain (11,523 acres)	300	518,500	1,451,900	1,037,100	380,300	69,100	3,456,900
Real Estate Acquisition in Flood plain (8,129 acres)	400	812,900	1,333,200	845,400	227,600	32,500	3,251,600
(89,323 acres total)		6,721,500	13,121,600	8,726,900	2,702,000	437,600	31,709,600

* It should be emphasized that many woody plants, although small in size, are none-the-less ecologically valuable, and may provide food and shelter to a variety of wildlife (e.g., grapes, Mexican plum, persimmon, mulberry, possum-haw, yaupon, American hop-hornbeam, black cherry, and others).
Diameters given are diameter breast height (d.b.h.)
Source: Nixon and Willett (1974).

TABLE 3-15

SIZE DISTRIBUTION OF TREES IN THE TENNESSEE COLCNY LAKE SITE WEST SIDE OF RIVER *

Common Names	1-10 cm (0.4-3.9 in)	11-20 cm (4.3-7.9 in)	21-30 cm (8.3-11.8 in)	31-40 cm (12.2-15.8 in)	41-50 cm (over 16 in)	Overall percentages
Texas sugarberry	18 %	69.7%	63.7%	42 %	-	53.1%
cedar elm	4.3%	8 %	12 %	37.7%	90.3%	14.7%
green ash	13.3%	12.3%	17 %	12.7%	4.7%	15.1%
gum bumelia	10 %	3.7%	4.7%	-	-	5.9%
bur oak	-	0.3%	-	7 %	4.7%	1.1%
hawthorn	8 %	2.3%	0.7%	-	-	2.9%
honey locust	8.7%	-	-	-	-	1.4%
red mulberry	1.3%	0.7%	0.7%	-	-	-
osage orange	1 %	0.7%	-	-	-	-
soapberry	2.3%	1.7%	-	-	-	1.9%
swamp privet (forestiera)	32 %	0.7%	-	-	-	3.6%
Others **	1.1%	0.6%	1.2%	0.6%	0.3%	0.3%

* Based on projections of the quantitative vegative studies of Nixon (1973).

** Includes: water hickory, pecan, black willow, water elm, eastern cottonwood, shumard red oak, box elder, sycamore, American elm, roughleaf dogwood, gum bumelia, flowering dogwood, river birch, blue beech, red maple.

TABLE 3-16

LAND USE IMPACTS, TENNESSEE COLONY LAKE
(Acres)

	Inundated by Conservation Pool		Flood Control Pool		Real Estate Acquisition Line		Recreation
	Within Flood Plain	Outside Flood Plain	Within Flood Plain	Outside Flood Plain	Within Flood Plain	Outside Flood Plain	Total
FOREST							
Permanently lost	30,083	13,202	899				
Temporarily lost			747*				
Altered			10,915	15,471			3,300**
Preserved					8,129	11,523	
GRASSLANDS							
Permanently lost	31,334	12,126					
Temporarily lost					3,940	13,713	
Altered			4,356	15,163			3,200**
CROPLANDS							
Permanently lost (all)	1,082	874	32	308	60	574	
SAND, GRAVEL & LIGNITE MINING (Lost)	387	-	23	4	97	17	
RIVER, TRIBUTARY & LAKE SURFACES							
Replaced by Lake	3,115	297					
Altered			888	275	974	301	
HIGHWAYS & RAILROAD R.O.W. AFFECTED	767	292	76	313	79	325	
RURAL HOUSING & STRUCTURES AFFECTED	27	35	7	253	3	93	
INDUSTRIAL AREAS AFFECTED	-	-	-	1,057	-	1,151	
DRAINAGE & IRRIGATION DITCHES AFFECTED	59	-	38	-	21	-	

*Forested area which would be cleared for disposal of excavated material would be reforested following shaping of excavated material.

**Estimated.

3.17.01 Indirect Impacts. Vegetation outside the conservation pool of Tennessee Colony Lake would be expected to undergo long term successional changes caused by changes in the water table around the perimeter of the lake (Nixon, 1972a). The extent of these changes would depend primarily upon local edaphic characteristics. The acreage involved in this change is listed as "Altered" in Table 3-16. Partial clearing would be expected on much of the acreage above the conservation pool for recreation facilities, access. and operation and maintenance associated activities. Since cypress trees once grew along the Trinity River in this area, it might be feasible and desirable to plant cypress and other water tolerant trees in the upper portions of Tennessee Colony Lake as a part of the reforestation activities to be carried out in connection with the project. Those forested areas within the acquisition line for Tennessee Colony Lake which would be cleared for deposition of excavated material would be reforested, as would leased areas whose owners so desire. As previously indicated, Tennessee Colony Lake would cause a rise in the water table downstream from the dam. A study conducted by the Soil Conservation Service (1970) on the after-effects of ground water changes caused by the Arkansas River Multiple-Purpose Project (as it was then known) indicated that crop and forest areas were harmed where the water table was raised to within one foot or less of the land surface. Water table rises to within five to one foot below the land surface were found to be beneficial to both crops and trees, with faster growth rates evident. Where the water tables were raised to within six or more feet beneath the surface, effects upon crops and trees were determined to be neither beneficial nor harmful. An area downstream from the proposed Tennessee Colony Dam of less than 200 acres could be expected to have the water table within one foot of the surface and these would be areas which are presently marshy in character. The area which could have the water table raised to within one to five feet is estimated to be several thousand acres. Currently, this area is forested and is the property of the Coffield Unit of the Texas Penal System. Their long range plans call for clearing the land for grazing and cropland, with or without Tennessee Colony Lake construction.

3.17.02 Operation and Maintenance Impacts. Operation and maintenance impacts which could be expected to occur over the life of Tennessee Colony Lake include:

Operation of the hydroelectric facilities currently proposed for Tennessee Colony Lake could be expected to have both beneficial and adverse downstream impacts. The operation of this facility has already been discussed. During periods of thermal stratification in the lake, the water which passes through the turbine could be a managed mixture of water from various levels, in order to optimize the quality of the released generating water. It may however, be low in oxygen and have a heavy organic load, as is often typical of water in the lower strata (hypolimnion) of lakes. This water quality would be likely to improve as it passed on downstream from Tennessee Colony Lake, but could adversely affect the stream biota for some distance. Overall, the water quality downstream from Tennessee Colony Lake would likely be much better than it would without the presence of Tennessee Colony Lake, as evidenced by the effect of Lake Livingston on downstream water quality (Plates 15.1-15.19).

Maintenance dredging required for Lock Pool 10B within Tennessee Colony Lake for a distance of about 31 miles would be expected to disrupt aquatic ecosystems somewhat. Table 3-7 lists the estimated quantities which would have to be dredged and the acreage which would be required to dispose of the dredged material. Over the economic life of the project, 5,000 acres would be required to dispose of dredged material in that reach. The navigation aspects of the project would be expected to continue for much more than 50 years (50 years is the maximum period for which economic benefits may be calculated for navigation). Current planning envisions the construction of ring levees, and the subsequent pumping of dredged material into these leveed areas. These areas would be within or on the edge of the conservation pool of Tennessee Colony Lake along the Multiple-purpose Channel and would be of little long-term value in providing aquatic habitat, although for a few years it should support a rich and varied fauna. As more and more dredged material is pumped into the leveed areas, the value as aquatic habitat would decline, species diversity would be lowered, and the area would become virtually devoid of significant quantities of fauna. It is estimated that after about 100 years, roughly 120,000 acre feet of the conservation pool would have been forgone for dredge material disposal, unless some other disposal method were determined to be more desirable.

Operations of barge tows through Tennessee Colony Lake would present the possibility of spillage of toxic materials. These would endanger fish and wildlife as well as vegetation, etc., and although dilution by the waters of Tennessee Colony Lake should preclude severe damages, operational safeguards would be formulated to deal with the problems.

3.17.03 Rare, Endemic, and Endangered Vegetation and Champion Big Trees. Appendix B lists the rare and/or endangered and endemic species of plants reported from the Trinity River Basin (Mahler, 1972; Nixon, 1972a and 1972b) with specific locations given when known. Nixon stated:

> Of greatest concern among these species is the spring-flowering bearded grass-pink orchid. It is found in moist, sandy, acid soils on the edge of bogs, swamps and marshes and in moist, open woodlands. Its only recorded occurrence is in Henderson County (Correll and Johnston, 1970). Based on location and habitat, plants of this species could be within the confines of the proposed lake.

Since the 1972 studies of Nixon, additional field investigations by Nixon (1973) and Nixon and Willett (1974) have been made with no discovery of the rare bearded grass-pink orchid.

The Champion Big Trees and Famous Trees of Texas are shown on Plate 18, Appendix A, and also listed in Appendix B. There are believed to be two such trees which would be directly affected by the Tennessee Colony Lake. One, a State Champion honey locust, has already been superseded by a larger one recently found near Texas State Highway 21 in San Jacinto County. The other, a State Champion green ash, is located on Rush Creek in Navarro County. Tennessee Colony Lake would kill both of these trees by inundation. Another, the National Champion gum bumelia, is located near Fairfield, Texas, and appears to be well outside any area likely to be directly affected. It should be pointed out, however, that the flood plain of the Trinity River and its Tributaries in the Tennessee Colony Lake site have many large trees which are close to the size of present champions and which would be killed by inundation of Tennessee Colony Lake. Although it is unlikely that there would be secondary impacts which would adversely affect any additional present champion or famous trees, there is no guarantee of their preservation or safety, either with or without the project.

3.18 <u>Impacts on Vegetation, Multiple-Purpose Channel and Urban Floodways</u>. Table 3-17 summarizes the forested areas in each portion of the Trinity River Basin which would be cleared for: (1) The Multiple-purpose Channel and right-of-way, (2) the deposition of excavated channel materials, (3) the deposition of dredged channel materials, (4) dam construction, (5) navigation locks, and (6) access roads. The table also indicates the extent and location of areas where project inundation would destroy forested areas. Table 3-18 lists the number of woody plants over 1 cm (1/2 inch) in diameter which would be lost by the construction of various reaches of the Multiple-purpose Channel. Appendix B includes an impact assessment of all plants reported from the Trinity River Basin.

TABLE 3-17
FORESTED ACREAGES WHICH WOULD BE CLEARED OR INUNDATED
BY THE PROJECT

Pool Number	Floodways and MP Channel R.O.W.	Excavated Material Deposition	Dredged Material Deposition	Dam Construction	Navigation Locks	Access Roads	Inundated	Total
Pool 1	1,370	-	6,090	-	-	-	-	7,460
Pool 3	671	1,435	-	10	13	83	200	2,412
Pool 4	295	389	-	-	-	15	4,000	4,699
Pool 5A	20	-	-	-	2	21	-	43
Pool 5B	260	-	980	-	2	-	-	1,242
Pool 6	1,600	1,003	-	8	8	67	-	2,686
Pool 7	304	412	-	23	20	79	-	838
Pool 9	354	843	-	12	13	72	-	1,294
Pool 10A	174	-	-	-	13	122	-	309
Pool 10B	899*	747*	-	950	11	83	43,285	45,975
Pool 12	326	-	-	50	40	-	-	416
Pool 13	585	281	-	10	-	-	-	876
Pool 16	359	-	-	50	100	-	-	509
Pool 17	1,950	237	-	-	-	6	-	2,193
Pool 18	16	-	-	1	3	2	-	22
Pool 19	618	-	-	1	3	7	-	629
Pool 20	680	-	-	1	2	22	-	705
Pool 21	662	21	-	1	2	2	-	688
Port to Riverside Dr.	702	45	-	-	-	-	-	747
Totals	11,845	5,413	7,070	1,117	232	581	47,485	73,743**

*Outside the Conservation Pool
**In addition, a certain portion of the areas acquired for recreation are expected to require additional forest clearing.

TABLE 3-18

NUMBER OF WOODY PLANTS AFFECTED BY THE MULTIPLE-PURPOSE CHANNEL 1/

	Forested Excavation Easement	Forested Floodways and Channel R.O.W.	Forested L & D Area	Forested Access Roads	Total Forested	Approx Density of Forests
Pool 1	4,263,000	959,000	-	-	5,222,000 87% in 1-10 cm (½"-4") size class 679,000 over 10 cm	700/acre
Pool 3	1,291,500	603,900	200,700 2/	74,000	2,170,800 85% in 1-10 cm (½"-4") size class 325,600 over 10 cm	900/acre
Pool 4	194,500	147,500	2,000,000 3/	7,500	2,349,500 78% in 1-10 cm (½"-4") size class 516,900 over 10 cm	500/acre
Pool 5A	-	8,000	800	8,400	17,200 75% in 1-10 cm (½"-4") size class 4,300 over 10 cm	400/acre
Pool 5B	294,000	78,000	600	-	372,600 74% in 1-10 cm (½"-4") size class 96,900 over 10 cm	300/acre
Pool 6	401,200	640,000	6,400	26,800	1,074,400 83% in 1-10 cm (½"-4") size class 182,600 over 10 cm	400/acre
Pool 7	164,800	121,600	17,200	31,600	335,200 79% in 1-10 cm (½"-4") size class 70,400 over 10 cm	400/acre
Pool 9	337,200	141,600	10,000	28,800	517,600 72% in 1-10 cm (½"-4") size class 144,900 over 10 cm	400/acre
Pool 10A	-	87,000	6,500	61,000	154,500 75% in 1-10 cm (½"-4") size class 38,600 over 10 cm	500/acre
Pool 10B 4/	298,800	359,600	384,400	33,200	1,076,000 25% in 1-10 cm (½"-4")size class 807,000 over 10 cm	400/acre
Pool 12	-	97,800	27,000	-	124,800 83% in 1-10 cm (½"-4") size class 21,216 over 10 cm	300/acre

(Continued)

TABLE 3-18 (CONT'D)

	Forested Excavation Easement	Forested Floodways and Channel R.W.O.	Forested L & D Area	Forested Access Roads	Total Forested	Approx Density of Forests
Pool 13	112,400	234,000	4,000	-	350,400 84% in 1-10 cm (½"-4") size class 56,100 over 10 cm	400/acre
Pool 16	-	215,400	90,000	-	305,400 89% in 1-10 cm (½"-4") size class 33,600 over 10 cm	600/acre
Pool 17	284,400	2,340,000	-	7,200	2,631,600 88% in 1-10 cm (½"-4") size class 315,800 over 10 cm	1200/acre
Pool 18	-	12,800	3,200	1,600	17,600 90% in 1-10 cm (½"-4") size class 1,800 over 10 cm	800/acre
Pool 19	-	309,000	2,000	3,500	314,500 78% in 1-10 cm (½"-4") size class 69,200 over 10 cm	500/acre
Pool 20	-	204,000	900	6,600	211,500 83% in 1-10 cm (½"-4") size class 36,000 over 10 cm	300/acre
Pool 21	26,400	545,600	1,200	800	574,000 81% in 1-10 cm (½"-4") size class 109,100 over 10 cm	400/acre
		Total Woody Plants		=	17,819,600	
		Over 10 cm		=	2,702,016	

1/ Utilizing the frequency data of Nixon (1973), and assuming forested areas have basic composition of area, since areas were chosen on the basis of exemplary features.

2/ Includes 180,000 trees inundated by the pool of Lock and Dam 3.

3/ Inundated by the pool of Lock and Dam 4.

4/ Channel upstream from Tennessee Colony Lake; see Table 3-14 for number of woody plants inundated by lake.

Table 3-19 summarizes the acres of cleared land (most of which has been cleared for grazing or cropland) which would be required for each of the listed purposes. Table 1-46 is a summary of various existing land uses within the 100-year flood plain.

3.19 Summary of Vegetative Impacts.

3.19.01 Forest Impacts. The estimated total forested land in the flood plain from Riverside Drive, in Fort Worth, to Wallisville Lake, as extracted from aerial mosaics, is 267,000 acres. About 12,000 acres would be cleared for the floodways and multiple-purpose channel acres would be cleared for deposition of excavated and/or dredged channel materials, 600 acres would be cleared for access roads, and 1,300 acres would be cleared for locks and dams. The Tennessee Colony Lake conservation pool would inundate about 30,000 acres of forest in the flood plain and 13,200 acres outside the flood plain and the pools above Locks and Dams 3 and 4 may inundate about 4,200 acres. The total acreage of forested areas which would be cleared and/or inundated for the entire project would be about 74,000 acres, which is about 28 percent of the present existing forest area in the flood plain. This quantity and percentage of forested area is certainly significant, both in terms of total acres of the bottomland hardwood forest as a vegetative area and habitat and as the percentage which would be lost. Although the current clearing rate is likely to ultimately result in as much or more clearing, the project would be certain to result in this loss. For more precise areas of clearing and inundation, see Table 3-17, which breaks down the areas by reaches.

Secondary effects on vegetation would include project-induced clearing and vegetative successional changes relatable to changes in the water table and surface drainage although surface soils in the lower Trinity River Basin do not lend themselves to drainage. It is much more difficult to obtain precise acreages for these induced changes, but they could be expected to result in a further decrease in total forested area, unless land use regulations or governmental acquisition prevent this from occurring.

3.19.02 Revegetation. Techniques of and attitudes toward revegetation are changing. It now appears that revegetation of areas exposed during construction and operation, as well as those acquired areas which lend themselves to revegetation

TABLE 3-19

ACREAGE OF CLEARED OR "IMPROVED" LAND AFFECTED BY THE PROJECT

Pool Number	Floodways and MP Channel R.O.W.	Excavated Material Deposition	Navigation Locks and Dam Construction	Access Roads	Totals
Houston Ship	22	234	-	-	256
Pool 1	290	400	-	-	690
Pool 3	487	503	50	80	1,120
Pool 4	641	865	50	20	1,576
Pool 5A	209	-	30	20	259
Pool 5B	6,120	-	-	-	6,120
Pool 6	2,100	4,573	40	70	6,783
Pool 7	1,016	1,876	60	80	3,032
Pool 9	686	950	40	70	1,746
Pool 10A	36	-	30	120	186
Pool 10B	(See Tennessee Colony Lake Conservation Pool, Table 1-45)				51,303
Pool 12	561	1,211	60	10	1,842
Pool 13	423	1,034	60	20	1,537
Pool 16	418	937	60	10	1,425
Pool 17	4,126	1,365	50	10	5,551
Pool 18	652	300	40	2	994
Pool 19	3,618	1,033	40	10	4,701
Pool 20	2,978	650	40	10	3,678
Pool 21	1,216	355	40	20	1,631
Port to Riverside Dr.	2,226	536	-	-	2,762
		Total cleared or improved land			97,192

or reforestation, should be accomplished, where possible, by using native seed hay and native and localized trees (Dyksterhuis, 1974). Current planning includes the planting of grass on the slopes of each navigation pool and trees on the Multiple-purpose Channel slopes. Water-loving trees would be planted on the 6 to 1 slope at about the water line for prevention of wave erosion, aesthetics, and biological benefits (wildlife food, cover, shade, etc.). Other trees would be planted on the 3 to 1 slopes in the upstream end of each lock pool except for Pool 5A and Pool 10A (where only grassed slopes would be planned).

Areas cleared during construction would be revegetated to the maximum extent possible, the exception being where maintenance or other access would preclude it.

3.20 Impacts on Trinity Bay Fauna. The authorized project alignment for the navigation channel in Trinity Bay calls for a widening and deepening of the existing "Channel to Liberty" using the route across Trinity Bay to Smith Point and then following the "Channel to Liberty" northward to the mouth of the Trinity River at Anahuac. Prior dredging in the segment between Smith Point and the Houston Ship Channel has left the channel about 8 to 9 feet deep. This area has been reported by the National Marine Fisheries Service to contain most of the major productive oyster reefs left in Galveston Bay (Plate 33). The widening, deepening and disposal of dredged materials associated with the authorized alignment in this area would be expected to damage these reefs. In addition, the proposed widening and deepening of the channel between Smith Point and Double Bayou would traverse an area currently regarded as a valuable habitat for many species of fishes and crustaceans which use this area for feeding, breeding and juvenile development. The channel in this area has not been maintained and is less than three feet deep. Affected species include flounder, red drum, black drum, spotted seatrout, menhaden, Atlantic croaker, sheepshead, white and brown shrimp, and blue crab. These species would also be adversely affected by the channeling and maintenance dredging. Further damages could be inflicted by barge tows that might break loose or be blown out of the channel.

A tentative recommendation for channel realignment on a route which would be less damaging to existing biota has been made by the National Marine Fisheries Service. Subsequent detailed interagency planning would be made to determine the least-impact channel alignment across Trinity and Galveston Bays.

A major consideration of any plan to alter freshwater inflows into a productive marine estuary must address itself to a discussion of the nature of the reduction and a summary of the anticipated ecological implications. The historic flows of freshwater into Trinity Bay along with a discussion of past alterations to freshwater flows has been previously described. That discussion also predicts future freshwater inflows into Trinity Bay without the project. As the demand for municipal, industrial, and agricultural freshwater increases, it can be anticipated that freshwater inflows may be reduced to the point where severe ecological damage would result. It is important, therefore, to carefully assess any reduction in flows which can be attributed to the project, or portions thereof. The degree to which the alteration of flows attributable to the project would affect the bay ecosystem is difficult (at best) to assess. The largest reduction in freshwater inflows to Trinity Bay would be the flows caught by Tennessee Colony Lake for water supply purposes. The regulated release of large volume floodwater catches by Tennessee Colony Lake would lengthen the time of floodwater flows into Trinity Bay and could reduce volume totals because of withdrawals from the Multiple-purpose Channel by downstream water users. During drouth periods, the amounts of freshwater entering Trinity Bay would actually be greater with the project than without it, as a result of the releases for navigation lockages (see River Flow Modifications into Trinity Bay, this section). It is felt that distribution of flows is at least as important as the total annual flow with respect to ecological well-being. Mean daily flows are also misleading, since they are actually relatively rare occurrences in rivers (Leopold et. al., 1964).

Expert opinions vary as to the biological impacts of reduced flows into estuarine areas. Odom and Wilson (1962) expressed the possibility that "...bays with little flushing may develop higher productivity and more effective regeneration of nutrients. Low river flow would obviously favor these effects." Reduced salinities, however, are known to often result in damage to commercially valuable species. For example, oyster drills can invade valuable oyster reefs if salinities are sufficiently raised. Juvenile shrimp may become more vulnerable to predation by finfish which are not tolerant of lower salinities. The intermittent controlled release of freshwater from Lake Okechobee to the St. Lucie Estuary in Florida is reported to have enhanced the fisheries by nutrient supply and stabilization of salinity gradients, according to Gunter and Hall (1963). Cronin (1967) states that a better release pattern could be of increased benefit to fisheries. The desirable pattern of releases into Texas estuaries is known to be under investigation by several agencies (Nelson, 1974), and if optimum flows can be determined, the possibility of enhancing estuarine fisheries exists. It would be necessary, however, to modify the present position of fish and wildlife in the priorities of water rights (currently, "fish and wildlife" is last on a list of Texas water rights priorities). It is anticipated that the flow alterations of the project would adversely affect the Trinity Bay sports and commercial fisheries to a degree which at present would be inordinately difficult to determine.

Birds and mammals utilizing the area around Trinity Bay should experience little impact. The direct and secondary effects of upstream alterations are discussed elsewhere in this Section.

3.21 Impacts on Terrestrial and Aquatic Fauna, Tennessee Colony Lake. Appendix B lists the birds, mammals, amphibians, reptiles and fish that are found in the Trinity River Basin with an effect assessment based on the Authorized Project Plan.

3.21.01 Birds. Generally, species which would be expected to decline are those which are closely associated with the bottomland hardwood forests (because of net decrease in these habitats), and species which would be expected to increase are those found in aquatic habitats, primarily waterfowl, large wading birds and various shorebirds. The loss of the forest and bottomland populations would be expected to be greater and of more significance than the gain in aquatic populations, so that the net effect of the lake and channel on the avian fauna would be detrimental (Fisher and Hall, 1973). No rare or endangered birds are known to breed in the Tennessee Colony Lake area. However, three species of birds considered rare and/or endangered in Texas migrate through this part of Texas and occasionally winter in the area: the bald eagle, the peregrine falcon and the osprey. All three birds are commonly associated with large bodies of water, such as lakes, rivers and coastal bays and estuaries. These species should not be adversely affected by the construction of Tennessee Colony Lake. While there are no known heron rookeries within the proposed Tennessee Colony Lake pools, one large rookery area lies only a few miles from the area of the dam and might be disturbed during construction activities.

3.21.02 Mammals. Those animals associated with pastures, open fields, thickets, woodland edges and dry upland forest would not be expected to experience severe long term population changes in the area, although permanent reduction in numbers would occur until the carrying capacity of the remaining habitat is reached.

As concerns game species, a decline in both white-tailed deer and the gray squirrel populations would be expected, since both these species have their preferred habitat within the Trinity River Basin in the bottomland hardwood forest areas, and a decline of an estimated 41,000 acres of such habitat would occur with the impoundment of Tennessee Colony Lake. The conservation pool of Tennessee Colony Lake would inundate a total of about 98,000 acres of mixed forested and cleared land Raccoons would also be expected to show decreased populations, while fox and rabbit populations would not be expected to show much change. Furbearing animals which could be expected to decline in numbers are the beaver and the mink. Fisher (1972) predicted that the only mammal in the area of Tennessee Colony Lake which could be expected to increase after the lake is completed would be the nutria. As is the case with the avian fauna, the net effect of Tennessee Colony Lake upon the mammalian fauna (excluding humans) would be expected to be detrimental.

3.21.03 Fishes. The water in the Trinity River from Fort Worth to the headwaters of Lake Livingston is not presently of sufficient quality to maintain desirable stream fisheries. The value of Tennessee Colony Lake for recreation, fish and wildlife, and water supply would depend directly upon the quality of water which enters the lake. Although not presently anticipated if the general water quality were significantly improved by the time Tennessee Colony Lake could be built, then it is axiomatic that the water quality in the Trinity River could support a valuable stream fishery and river recreation in the same time-frame, without Tennessee Colony Lake being built. The construction of dams is known to result in considerable change in the fish fauna of a river system (Keith, 1964; Fritz, 1968; Stroud, 1969), Any artificial impoundment brings about a reduction of flows downstream. River and tributary flows are altered and periods of natural flooding are modified. Fishes typical of flowing water would, in most cases, be replaced by those indigenous to more sluggish waters. Certain fish species reported from the proposed Tennessee Colony Lake site are characteristic of the deeper parts of a major river channel where the current is of varying velocity (Rainwater and Fisher, 1972). These species would probably be confined largely to the main channel above or below Tennessee Colony Lake. It could be anticipated that for a short-term period (up to 20 years) sport fishing would be good. The yield of sport fish would be high following the completion of Tennessee Colony Lake, similar to recent experience at Lake Livingston. Fisheries management could significantly extend the period of productive sport fishing. Hall (1973) prepared a "fish species profile analysis" of 18 species which he regards as being among "...the most important fish species in the river system." The "profiles" appear in Appendix B. Of the 18 species listed, at least half are predicted by Hall to be negatively affected by the project (Tennessee Colony Lake plus the Multiple-purpose channel) in the long term. Many of these adverse effects could be reduced or eliminated by optimum management, which would include optimal water quality withdrawals from Tennessee Colony Lake, rough- and trash-fish control, maintenance of flows through cut-off portions of the natural river, prevention of damaging flooding and siltation, allowing for littoral vegetation in shallow areas along the Multiple-purpose Channel, and minimizing the wave erosion in those shallow areas.

3.21.03.01 Water Quality. The above discussion on fishes in the Tennessee Colony Lake assumed that severe pollution problems in the Trinity River would be eliminated by the time Tennessee Colony Lake could be operational.

If this goal were not attained, the fisheries would be of considerably less benefit than as presented. The pollutants that man dumps into his rivers do not simply disappear downstream. They accumulate, along with naturally contributed materials, in lakes, estuaries and bays. Most of the pollutants in the Trinity River can be attributed to municipal and industrial wastes and to urban and rural runoff. The heavy load of nitrates and phosphates in the Trinity River has been documented by North Central Texas Council of Governments (1970), McCullough (1972a, 1972b), McCullough and Champ (1973), and TRA (1974).

Regardless of alternatives, eutrophication will continue to present problems for the Trinity River. Beeton (1965) has estimated that one pound of phosphates in water can grow 700 pounds of algae provided the other necessary nutrients (principally nitrates and carbon) are present. North Central Texas Council of Governments (1970) lists the average amount of phosphates carried daily by the Trinity River past Trinidad as 90,000 lbs. Assuming that half of this quantity would be bound by the sediments of Tennessee Colony Lake, this still would mean that the potential exists for the growth of 1.2×10^{10} lbs, or 5.75 million tons (dry weight) of algae per year (45,000 lbs/day x 365¼ days/year x 700 lbs algae/lb of phosphate). This quantity of algae could be considered as a sustained yield, since the nutrients would be constantly added from upstream while they are being taken up by the algae. Moderate numbers of aquatic plants are desirable, but the amount listed above cannot be construed to be "moderate". As previously described, the human population in the Dallas-Fort Worth Metroplex is expected to increase by 2.9 times during the next 45 years. This means that to maintain the current level of treatment, sewer plant capacity will have to be increased by 2.9 times present capacity. The capability of removing enough nutrients to appreciably reduce excessive algae growth appears unlikely (Ivy, 1972). The aquatic weed problem would result in secondary impacts associated with control efforts. Herbicide uses would be strictly regulated and control efforts would require coordinated efforts of various State and Federal agencies. Excessive aquatic plant growth will often cause a severe oxygen depletion to the extent that fish are unable to inhabit many parts of lakes and streams.

3.21.04 Amphibians and Reptiles. Inundation of the bottomland hardwood forests in the Tennessee Colony Lake area would force some species to migrate into areas which might not be favorable to their survival. Some amphibian and reptile species listed in Appendix B either have a variety of habitats or are generally regarded as upland species which would not be affected. However, secondary development around the lake could be expected to diminish their habitat somewhat. This might be offset by the lands above the flood pool which would be set aside and on which no development would be permitted.

3.22 Impacts on Terrestrial and Aquatic Fauna, Multiple-Purpose Channel. The adverse effects of channelization (deepening, widening, and straightening of streams and rivers) on biological assemblages has been well documented (Bayless and Smith, 1971; Condon, 1971; Folkerts, 1973; Hansen, 1971; Hines, et al., 1966; U. S. Congress, House of Rep., 1971; U. S. Congress, U. S. Senate, 1971; Little, 1973; Starrett, 1972; Tarple et al., 1971). A large proportion of the stream or river channelization projects have been drainage projects or flood control projects in which woody vegetation along the streambank was removed and the stream or river ditched and straightened by dragline, bulldozer and/or hydraulic dredge. Usually, the local water table was lowered, most fish life was destroyed, runoff was hastened, perennial streams became intermittent, silt loads were increased, and water temperatures were increased. In most cases, the benefits have been primarily short-term benefits to individual property owners at the expense of the long-term ecosystem productivity.

While the above generalities are often true, variations occur with virtually every channelization project which significantly alters many of the effects alluded to. Further, the above effects which are attributable to drainage and/or flood control projects are not directly comparable to channelization projects in which water is pooled within each given reach of the channel. Based upon studies by the USGS of the probable ground water effects by the project (where significant ground water changes could be expected), roughly four to five times as much of the change would be a rise in the water table as would be a decline. However, there would be more wetlands which would lend themselves to drainage (especially in the lower portions of the flood plain) than are currently feasible. This would be a secondary impact and could be regulated by State and/or local agencies.

3.22.01 Aquatic Fauna. Reports concerning the Oklahoma portion of the McClellan-Kerr Navigation System (on the Verdigris River) by Smith (1972) indicate that after several years of operation, the fisheries productivity is growing rapidly and offers a wide variety of fishing potential, especially in the cut-off river segments and tail waters of lock pools. Continuing high quality fishing will depend upon fisheries and water quality management practices.

It appears that a potential for good sport fishing would exist during the early years of the project, provided the current water quality problems can be solved. Long-term fisheries quality would depend upon management capabilities.

The adverse aquatic faunal changes which could be expected to occur with the Multiple-purpose Channel include: (1) A decrease in those species which require rather swiftly-flowing water for spawning, feeding, etc., in much of the Basin; and (2) an overall reduction in aquatic species diversity.

Fish species expected to be affected as a result of the Multiple-purpose Channel construction are summarized in Appendix B.

The invertebrate population changes would be expected to vary. As previously discussed, the invertebrate populations currently are severely influenced by the poor water quality in the reach from Fort Worth to Lake Livingston; however, they would be expected to recover if better quality water becomes characteristic of the flow in the Trinity River. The bottom of the Multiple-purpose Channel would not be expected to provide suitable habitat for aquatic benthos, and wave action severely limit invertebrate populations along the channel edges. Reduction of flooding would be likely to result in less disruption of invertebrate populations and the lowering of species diversity in the natural channel. The cutoff loops of the river which have little flow would be expected to develop invertebrate populations more characteristic of oxbow lakes. Those cutoffs in the lower third of the Trinity River Basin in which flows would be maintained by hydraulic head and/or by tributary stream flow would be likely to continue to support populations characteristic of flowing streams, provided good water quality is maintained.

3.22.02 Terrestrial and Avian Fauna. There is a direct relation between the changes which could be expected in the terrestrial and avian fauna and the changes in land use which would occur directly and indirectly as a result of the construction of the Multiple-purpose Channel. The most significant changes which would affect terrestrial and avian populations in connection with the Multiple-purpose Channel would be the net loss of about 30,000 acres of bottomland hardwood forest. The net addition of 101,500 acres of aquatic habitat would mean a loss of 101,500 acres of land. The degree to which the animals would be affected would vary according to their dependence upon the specific habitat lost, but it can be stated that the anticipated loss would be reflected in reduced populations of most mammals (nutria and humans excepted), many reptiles and amphibians, and a number of avian species directly dependent upon bottomland hardwood forests. However, while surface and ground water rises associated with Lock Pools 3 and 4 (and to some degrees, other lock pools) would result in the killing of woody vegetation, stumps of these trees could provide future nesting sites prothonotary warblers, wood ducks, and others, as well as suitable habitat for many migrating birds.

The adverse impacts on fauna would be less severe as one moves upstream, because of the already depauperate state of the biota from about river mile 350 upstream to the uppermost part of the Multiple-purpose Channel in Fort Worth.

A study of the ecological aspects of periodic flooding along a Texas river was made by Gallaher (1974). Although the dogmatic view that valuable nutrients are contributed by floodwaters appears to be questioned in the above study, periodic flooding was shown to be valuable in maintaining ecological diversity and productivity. Temporary flood plain ponds were shown to aid in species propagation and added significant quantities of food energy to the river system. Although existing levees presently limit flooding between Dallas and the Ellis-Navarro County line, large portions of the flood plain from that point downstream are subject to periodic flooding. Any reduction of flood frequency would be expected to result in lowered species diversity and stream productivity.

3.22.03 Secondary Impacts. It can be anticipated that secondary impacts would result as accelerated clearing of bottomland hardwood forests occurred following reduction of flood potential. Loss of habitat would occur with a potential loss up to the boundaries of the public lands. The forecasting of secondary impacts is extremely difficult since it involves predicting political action (nature of future land use legislation, flood plain zoning, etc.), industrial activity (port and/or industrial plant sitings), economic conditions, recreation trends, water quality improvement. and many other factors. Assuming current trends continue, it could be expected that maximum economical clearing for grazing and other agricultural pursuits will occur; that residential developments will continue to flourish in areas adjacent to the river with attendant forest clearing; that water quality will continue to be a problem; that the population of Texas and the Trinity River Basin will continue to grow at faster than the national rate; that demand for water-related recreation will continue, not because of the project, but in addition to the project and whether or not the project is constructed. In fact, it would be impossible to predict the preservation of the bottomland hardwood forests of the Trinity River based upon past and current trends.

The acquisition of project lands would preclude man's further disruptions of significant parts of the bottomland hardwood forests contained therein. Just as railroad rights-of-way today often contain the last vestiges of natural prairie vegetation, the lands associated with the project would contain and allow for the maintenance of significant segments of the remaining bottomland hardwood forest associated with the Trinity River.

3.22.04 Impacts on Rare and Endangered and/or Endemic Fauna. Impact analyses of the previously described rare, endangered, and/or endemic species are summarized below.

The red wolf's preferred habitat in Texas now appears to be confined to the upper coastal plain (Fisher, 1972, and Fisher and Hall, 1973), and only remote potential for harm to the red wolf as a result of the project would be expected as a secondary impact through increased urbanization.

The river otter, believed to be a rare inhabitant of the lower Trinity River, would likely be displaced by the direct and secondary effects of the project. Acquisition of some river cutoff areas would provide suitable habitat for this species where this option exists, and several large areas proposed for wildlife conservation to offset project damages would be expected to enhance the future of this species in Texas.

Although cougars are doubtful inhabitants of the Trinity River Basin, the public lands in east Texas (National Forests) may be able to support a few pair of cougars. The project should have little adverse or beneficial impact on the cougar.

Black bears are believed to be found in Texas only in small numbers in the western mountains and are therefore regarded as rare. The project should have no effects on the black bear population.

The American alligator should be benefitted by some of the river loop cutoffs and enlarged surface water areas in Lock Pools 1, 3, and 4. The induced draining of wetlands, however, could result in a net negative impact on alligator populations.

Wood ibises, reported by Fisher (1972) to be frequent visitors along marshes, swamps, and lakes of the Trinity River during the summer, should benefit from the river loop cutoffs and increased water surfaces associated with the downstream portions of Lock Pools 3 and 4. Induced or secondary impacts, however, would be adverse, especially those which result in clearing and draining of existing wetlands. The adverse and beneficial effects should be nearly equal.

Roseate spoonbills could be expected to benefit by the creation of additional water surfaces but would be adversely affected by induced draining and clearing. These beneficial and adverse effects should be approximately equal based on acreage of suitable habitat created and lost.

Mississippi kites should in general be benefitted by the partial clearing (direct and induced) which would occur with the project.

The osprey's decline is expected to continue, even with continued surface water development, because of the presence in food chains of the persistent pesticides, DDT, DDE, etc.

Bald eagles should be benefitted by the putting of additional acreage of flood plain into the public domain, although adjacent clearing and draining would probably provide negative impacts in excess of those beneficial. DDT, DDE, etc. are also responsible for their decline.

Red-cockaded woodpecker populations should be unaffected by the project.

The ivory-billed woodpecker (if it is in existence) might be potentially benefitted by large tracts of wildlife management lands proposed for the project.

Peregrine falcons, probably winter residents along the Trinity River, should be little affected by the project, adversely or beneficially.

The Attwater's prairie chicken has been staging a comeback with the cooperation of game management personnel of the Texas Parks and Wildlife Department and the rice farmers in coastal areas. The project should have little effect on this species.

The Houston toad reported to occur in Liberty County, would be adversely affected by a reduction in temporary flooding.

3.23 Impacts on Archeological Resources. As described in Section 1, the archeology of the Trinity Basin is better known in the upper part than in the middle and lower parts. There are approximately 180 significant archeological sites recorded in the Dallas-Fort Worth area above the East Fork confluence. About twenty of these sites are recorded in or near the 100-year flood plain. The sites in the flood plain are divided about evenly between the Neo-American and Archaic periods.

Salvage projects were carried out prior to construction at Lake Livingston and at Wallisville Lake. No discrepancy was found in the chronological framework described for the area by Suhm et al.

(1954). At Wallisville, evidence of early Archaic through early Historic habitation was found. Late Archaic and Neo-American occupancies were indicated by the Lake Livingston salvage project.

Since very little was known about the reaches between Tennessee Colony Dam and the upper end of Lake Livingston and between Wallisville Lake and Livingston Dam, a preliminary reconnaissance was performed by the Texas Archeological Survey Project, based in Austin (Sorrow, 1973). The alignment of the channel has not reached final design stage, and consequently the principal aim of the study was to provide quantification of site density in the vicinity of the alignment. Although the archelogical resources of a given area should not be measured by the number of sites discovered, the more closely an area is searched, the less likely a significant discovery would be foregone. Eighteen sites were described and located which were outside the area of previous salvage projects. Based on project design data and their relationship to these sites and other sites in more intensively surveyed areas, an estimate was made as to the number of sites per channel mile that would be affected by the channel, locks and dams, access roads and other related construction activities. Sorrow (1973) has estimated that a minimum of one site per channel mile would be affected.

Upstream from the Five Mile Creek confluence, the areas affected by construction would include the channel and locks and dams along with the levee, sump, and waste excavation areas involved in the construction of the West Fork Floodway and Dallas Floodway Extension. About 60 archeological sites would be affected by construction in this area.

Between 400 or 1000 sites would be inundated by Tennessee Colony Lake. Of those subject to inundation, it is expected that approximately 450 sites would lie below elevation 270 msl and would be inundated for the life of the project, while about 100 sites would occur between elevations 270 and 280 msl and would be subject to shoreline wave action and to exploitation by casual relic collectors. About 100 sites occurring between elevation 280 and 292 msl would be subject to infrequent inundation. The total number of sites affected directly by construction and by operation of the project would be expected to range from 675 to 1275 and would be considered lost if salvage programs were not performed. The Archeology Research Program at Southern Methodist University received two grants from the National Park Service to conduct an evaluation of the historic and prehistoric remains that would be affected by the construction of Tennessee Colony Lake. Field work was initiated in May 1974. The investigations are concentrated along three transects, approximately ½ mile wide spanning the width of the lake. These transects coincide with the Cedar Creek to Fort Worth pipeline in the upper end of the lake and with the U. S. Highway 287 and State Highway 31 crossings. A fourth transect, approximately one mile wide, encompasses the construction area for the embankment, spillway and outlet work structures. Skinner (1974) states:

> The transects have been divided into environmental zones and archeological sites will be recorded with regard to these zones and to period of time, types of sites, and activities that were carried out at each site. Using the transect technique, we will be able to determine site density and the relationship that particular site types or occupation periods have to the environmental zones.

Coordination with the Texas State Historical Committee indicates that there are three archeological sites in the Trinity Basin on the National Register of Historic Places. These sites are located in Liberty and Chambers Counties. None of these sites would be affected by the project.

3.24 Impacts on Paleontologic Strata. Project effects would be restricted to Cretaceous Tertiary, and Quaternary outcrop areas. Those fossiliferous strata which could be affected by the project are summarized below.

3.24.01 Quaternary. The project would have no effect on strandline and near-shore deposits of Pleistocene age in the coastal areas. Potential sources of Pleistocene fossils in terraces immediately upstream from the Tennessee Colony Dam site would be subject to periodic inundation, and the top of the broad first terrace near the left abutment would be below the conservation pool level. The off-river channel alignment between Livingston Dam and Lock and Dam 4 would be excavated in Deweyville terrace deposits for about 18 miles. Because of the nature of Pleistocene fossil occurrences, it appears unlikely that existing fossils might be detected prior to construction. If fossil occurrences were discovered during construction, operations could be suspended so that recovery could be made by a qualified paleontologist.

A slight beneficial effect might be realized, since fossils deeply buried in the terraced materials might be exposed in the channel slopes in some areas. No other disturbance or inundation of terrace materials would be anticipated by construction of the project.

3.24.02 Middle and Late Tertiary. The Oligocene, Miocene, and Pliocene sediments include a variety of terrestrial, strandline, and near-shore deposits. The stratigraphy is not completely understood and is based largely on correlation in other parts of Texas and other states. Fossil occurrences are few in this outcrop area. This area has produced a large number of Tertiary fossils, now housed in major museums around the country, without locality data (Gillette and Thurmond, 1971). These strata outcrop in the upland areas of Lake Livingston, and some sites were located along the riverbank prior to inundation (Slaughter, 1965). At the present time, outcrops probably occur in the riverbank between the lake and Lock and Dam 6. None of these outcrops would be inundated. A beneficial result might be obtained by excavation of the Multiple-purpose Channel upstream to Lock and Dam 6. These strata would most likely be exposed intermittently in the channel side slopes for several miles, facilitating recovery from fossil-bearing strata.

3.24.03 Early Tertiary. These strata contain an abundance of invertebrate fossils which are important in stratigraphic correlation. The Tehuacana Creek area has produced an abundance of these fossils, and many type localities occur in this watershed. The area would be inundated only when Tennessee Colony Lake would be at full flood control pool level, which is expected to occur on the average of once every fifty years. These localities have been described in geologic literature (Sellards et al., 1932), and since they would be infrequently inundated, would not be considered to be an irretrievable loss. No project-related excavation is anticipated in this area; however, incidental construction activities may result in secondary impacts. The fossil locality for Cornuspira carinata in the Kerens member of the Wills Point formation will be inundated, however, this locality has been adequately described in geologic literature and satisfactory alternate localities could probably be located (Jones, H. L., 1973).

3.24.04 Upper Cretaceous. This sequence consists of largely near shore and offshore deposited sandstones and limestones. The stratigraphy is fairly well known, owing to an abundant fossil content which includes occasional large mesozoic marine reptiles. Locks and Dams 12 through 20 would be located in this outcrop area. The flood plain alluvium in this area is relatively shallow with numerous rock exposures in the valley walls Bedrock would be exposed in the channel banks in the upper reaches of most navigation pools in this area. It is anticipated that no fossil occurrences would be adversely affected.

3.25 Impacts on Historical Structures and Sites.

3.25.01 Destruction of Structures. An historical structure is considered to be a work of man, consciously created to serve some form of human activity. The only known man-made structures which may be considered historical within the project area are the locks and dams which were constructed in the early 1900's (Plate 21). Three of these early structural works; Locks 4, 7, and 20, are easily located during periods of low river flow. Old Lock and Dam No. 20, situated near Highway 7, is a popular fishing area in the spring. The project channel alignment would eradicate these structures.

3.25.02 Alterations of Sites. Within the Trinity River flood plain, and especially along the river banks, there are numerous sites which were once the location of towns, ports, and ferries. The exact locations of many of these sites are open to conjecture as there are few, if any, structural remains to indicate that they ever existed. The facilities at these sites were primitive and not designed for extended use. The towns, ports, landings, and ferries may only have been utilized for several months, or at most, several years, and as a result left few remnants of their existence.

Lake Livingston has inundated Jones' Bluff, Harrell's Landing, Johnson's Bluff, and Grace's Landing, sites which were located in San Jacinto County (McDonald, 1972). Undoubtedly, the sites of the ports, landings, and ferries that are not situated on potential cut-off portions of the river would be impacted by alterations ranging from slight to complete removal by the project.

The exact number of sites that would be affected by the project is unknown because information is insufficient on the precise location of these sites. Natural changes of the river channel have added to the difficulty of locating these sites, and it is assumed that any future alterations, whether man-made or natural, will cause more confusion in determining their locations.

Those sites which would be situated on cut-off portions of the river would probably be subjected to less flooding than at present. Few of these sites have historical markers at present; those without markers would need to be designated as having National, State, regional, or local historical significance before they could qualify for registration.

Individually, those sites which were concerned with receiving goods or were river crossings would be of little historical consequence, as many of them were in existence only a short time. Collectively, however, the activities that transpired on these sites were important in the settling of this portion of Texas, even though little structural evidence of their existence remains.

3.25.03 Protective Measures and Coordination. Coordination with the Texas State Historical Committee indicates that there are no historical sites or structures listed on the National Register of Historic Places that would be directly impacted by the project. Additional visitation to currently listed sites and structures in the area could be expected by project-related tourism.

All known sites and/or structures that have been recognized as having historic significance and that could reasonably be protected from adverse impacts by the project would receive this consideration. Coordination with the Texas State Historical Survey Committee and the Historical Societies of the counties affected would assure proper consideration of all historically significant areas.

3.26 Impacts on Life Quality and Socio-Economic Factors.

3.26.01 Displacement of People. Displacement of people occurs when a public entity acquires land and associated facilities and thereby forces the residents to move from the land to a new or replacement residence. Under the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970, displaced people are entitled to assistance over and above normal compensation. It is estimated that 1,100 families would be affected by Multiple-purpose Channel land acquisition, and 103 would require relocations help under this Act. It is estimated that 325 of the 1,030 families affected by Tennessee Colony Lake land acquisition would also require assistance under this Act.

The relocating of rural people creates problems somewhat different from those encountered in urban relocations. The emotional and psychological effects, as well as financial burdens encountered, would be similar in both urban and rural settings, however, impacts on community institutions such as churches and schools are often more severe in rural areas. Any numerical changes in membership of these small community institutions could lead to the demise of these institutions or be the causative factor necessitating an expansion program. It is not anticipated that the project would involve a large enough concentration of relocations to cause a significant impact on the functioning of any community institution. Relocating individual families, however, would undoubtedly cause disruptions ranging from temporary inconveniences to severe hardships to those families being relocated. The Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 would assist in defraying the expected expenditures to those persons being relocated.

3.26.02 Leisure Opportunities and Recreation. The demand for outdoor recreation opportunities depends upon a number of complex variables. Clawson (1963) included increased life expectancy, changes in age distribution, population shifts from rural to urban, and increased leisure time as the variables that have most influenced society's changing life patterns. Others consider leisure time income, mobility, and population change as the primary variables which influence demand.

Generally, more leisure time will be available for most people in future years. The average work week in the United States decreased from 70 hours in 1820 to 39 hours in 1960 and is expected to continue to decline to 36 hours by 1976 and 32 hours by the year 2000 (Bureau of Outdoor Recreation, 1970).

The per capita personal income for the 40-County Study Area, as depicted below, indicates that personal income will continue to increase in the foreseeable future.

1969	-	$ 3,202
1985	-	$ 5,140
2000	-	$ 7,860
2010	-	$10,380
2020	-	$13,720
2035	-	$20,840

(U. S. Army Corps of Engineers, 1974b).

Increased per capita personal income, a greater amount of leisure time, continued high mobility of area residents, the expected continuation of a population shift from rural to urban areas, increased life expectancy, and a larger population will have a significant influence on future recreation demands.

It is anticipated that the project would have a substantial positive impact on future leisure and recreation demands within the recreation market area of the project. Projected participation indicates that the project would provide for nearly 26 million man-days of recreation annually (U. S. Army Corps of Engineers, 1974b). This would be an increase of some 25 million man-days of recreation annually over that expected in the same area without the project. The project would provide for general recreation activities such as picnicking, camping, sightseeing, hiking, boating, nature study, etc., in addition to sport fishing and hunting.

The recreation land requirements would be 31,384 acres, which would include: 16,874 acres in the metropolitan area, 1,600 acres between Dallas and Tennessee Colony Lake, 910 acres in the mid-Basin and 2,400 acres in the lower Basin. The remaining 9,600 acres would be located on the perimeter of Tennessee Colony Lake.

The creation of these public use areas would assist in easing the expected overuse of existing facilities and, in addition, would reduce the latent demand for public recreation areas. Thus, from society's viewpoint, the project would have a positive effect on recreation as it would annually provide recreation areas to accommodate an additional 10 million visits in the metropolitan area, 3 million between Dallas and Tennessee Colony Lake, 875 thousand in the mid-Basin, 2.4 million in the lower Basin, and 9.6 million visits at Tennessee Colony Lake.

Although the riverbed is owned by the State of Texas for the benefit of the public, access to the Trinity River generally exists only at highway crossings. Increased public access to the river would therefore result from completion of the project by the changes in land ownership from private to public.

Land-based recreational activities in the flood plain are currently limited almost entirely to hunting and camping on private lands. The project would make available to the public some 9,600 acres acquired for public use areas. In addition to these lands acquired for this specified use, there would also be available for public use many of the acres acquired for other project purposes. Hiking and biking trails for public use would be developed along portions of the Multiple-purpose Channel right-of-way. Much of the flood pool area surrounding Tennessee Colony Lake would be available for public use on a limited basis. Areas for overviews and visitor centers would be established at lock and dam sites in conjunction with public use lands.

Inundation of bottomlands by Tennessee Colony Lake would cause a decrease in number of terrestrial hunting man-days. Alteration to other bottomlands, because of the Multiple-purpose Channel, would also modify hunting activities in the Basin. It is anticipated that a significant increase in waterfowl hunting would occur. The major effect on terrestrial hunting activities would be observed in deer and squirrel hunting because of diminished habitat. Overall, it is anticipated that there would be a total increase of nearly 39,000 man-days of hunting annually.

Sport fishing in the Trinity River is generally restricted, because of poor water quality, to the river above Fort Worth and to the reach from State Highway 7 to Trinity Bay. Assuming some improvement in the water quality of the Trinity River in the future, it is expected that sport fishing would improve throughout the entire length of the river. Based on this assumption, over 2.2 million man-days of sport fishing would occur annually on the Trinity River with the project. This is in contrast to the 425 thousand man-days of sport fishing anticipated without the project. The availability of public access and the fishing attraction created by the locks and dams of the project account for a large portion of the additional man-days attributed to the project. Tennessee Colony Lake would provide a slack-water area for fishing. It is predicted that nearly 2.7 million man-days of sport fishing could be expected annually at Tennessee Colony Lake, whereas 30,000 man-days would be expected on the river flowing through this area without the project.

The advent of the project could provide the impetus for pleasure boating from Fort Worth to Trinity Bay. Assuming sufficient fuels exist, it is anticipated that substantial pleasure boating on the Multiple-purpose Channel, Tennessee Colony Lake, and selected portions of the remaining natural river channel would occur. This potential pleasure craft use could create a conflict with commercial craft utilizing the Multiple-purpose Channel unless proper precautions were taken by all the people involved in using the waterway. The public, in general, is unaware of the dangers involved in boating near river tows, and a system of informing the public of these dangers would be necessary. The Multiple-purpose Channel would be a public conveyance, and as such, would be available for use by the general public as long as all regulations pertaining to water craft operation were adhered to.

3.26.03 Pollution Attributable to Recreation. The predicted visitation of nearly 26 million man-days annually to the project could present some pollution problems unless properly planned for. Existing regulations pertaining to discharging wastes into water should enable control of water pollution caused by recreation activities. It would be essential that sufficient facilities be made available to recreationists for waste disposal to enhance enforcement of these regulations.

The amount of noise pollution attributable to recreationists would be dependent upon a number of variables, i.e., type of activity, number of participants, topography, vegetation, design of project, time of day, enforcement of existing regulations, etc. Intensity of noise has a direct relationship to the number of recreationists creating the noise, therefore, it can be assumed that the greatest amount of noise would occur at those times and places where the largest congregation of recreationists would be located. This would probably occur at Tennessee Colony Lake on a peak-load holiday. Based on Corps of Engineers records which indicate visitation trends at other Corps of Engineers lakes, it would be entirely possible for a visitation peak of some 200,000 persons to occur at Tennessee Colony Lake on a given day. The amount of noise generated would depend to a large extent on the activities of the visitors. Should fuel supplies allow it, and assuming little change in engine design, together with the ever increasing use of motorboats and off-the-road vehicles, it would become necessary to regulate the use of these recreation devices and utilize innovative park designs to reduce the noise generated.

Sanitary facilities would be provided at all public use areas and would be designed to meet sanitation regulations in effect. The disposal of refuse and solid waste materials collected at public use areas would meet the existing criteria for solid waste disposal in effect during the life of the project. The potential of some 200,000 persons on a peak use day at Tennessee Colony Lake would create a solid waste problem equal to a city of that size or larger if the public continues to support the "throw-away" craze that exists today. The fact that public use areas are conducive to the use of convenient throw-away containers adds to the solid waste problem. A national study of roadside litter revealed that it consisted of 59 percent paper, 16 percent cans, 6 percent bottles, 6 percent plastic and 13 percent miscellaneous items. It would seem appropriate to assume that public use areas would have a similar solid waste composition. Should the per capita solid waste generation be only half of the National average of 4.5 pounds per day, a total of over 200 tons of solid waste could accumulate around Tennessee Colony Lake on a peak use day. This would not be an everyday occurrence. Much of the solid waste disposed of at public use areas reduces the amount that would be disposed of at the visitor's home station.

Most air pollution is directly related to the utilization of internal combustion engines. The future modes of transportation will be tempered by the availability of energy sources. If present modes of transportation, i.e., the automobile, continues to provide mobility to man, there would be an increase in air pollution in the rural public use areas over that which exists there today. The extent of this potential pollution will remain undertermined until such time as more data are available.

3.26.04 Community and Population Growth. Significant growth factors would be attributed to the project. It would not be so much the magnitude of growth related to the project as it would the type and location of growth that would be most significant. The permanent growth would be twofold, that directly related to project operation and that induced by the project. The people concerned with the operation and maintenance of the project would be dispersed throughout the project area as needed. This growth would be easily absorbed into the existing communities and would cause little disruption to these communities. The induced growth (that attributed to secondary growth) would be larger and more concentrated in those areas where industrial growth would occur and near Tennessee Colony Lake where commercial development would occur because of recreation demands.

The increase in population that could be attributed to the project in the metropolitan area would be insignificant when the expected growth of the metroplex without the project is considered. The growth that could be expected in the rural counties would have a greater effect because it would be imposed on much smaller communities. Many of the rural communities have been suffering population and economic losses, thus causing a financial burden on the remaining inhabitants. Although some adverse conditions would be created, it is anticipated that any reversal of the rural migration to the urban setting would be considered beneficial, based on the goals of the Rural Area Development Act of 1972.

The formation of residential developments on the perimeter of the natural oxbow lakes would probably continue, but in addition development would be expected around some project-created oxbow lakes. The larger developments could be considered quasi-communities in themselves and could place additional burdens on existing public facilities and services. Recent and evolving legislation at various levels of government could affect the growth rate and the growth patterns of communities and population dispersals. These regulations should provide the incentive for an orderly mode of growth. A lack of foresight, planning and regulation by the proper authorities would allow problems to be created by poorly designed and constructed developments.

3.26.05 Cemetery Relocations. There are no known cemeteries that would require relocation within the right-of-way of the Multiple-purpose Channel. Flood plains are not commonly used for cemeteries because of the high water tables and the potential of being flooded. Tennessee Colony Lake however, would encompass an area that includes two cemeteries within its flood control pool. These cemeteries are in the Trinidad area and would be protected by levees to eliminate the need for relocation. There are several small cemeteries located on the perimeter of the flood control pool of the lake. These cemeteries are not expected to be adversely affected by the project, but they would receive protective measures if necessary.

The possibility exists that small, unmarked cemeteries may exist within the boundaries of Tennessee Colony Lake. At this time there are no known cemeteries within this area, but small family type cemeteries may exist that would not be located until a more refined planning stage is reached, at which time necessary steps would be taken to relocate these cemeteries should they exist within the area to be inundated.

3.26.06 Aesthetic Values.

3.26.06.01 Natural (Urban). The uppermost portion of the project is within the grassland vegetation zone. Therefore, the only natural tree growth exists along the streams and rivers. Much of the tree growth in the flood plain has been disturbed by man's activities, and there is little natural climax tree growth remaining.

Alignment of the West Fork Floodway and the Dallas Floodway Extension would generally follow that recommended in the "Trinity River Greenway - a Prototype" (Mertes et al., 1972). This plan would avoid adverse effects on about 30 miles of natural river channel, most of which lies between Beach Street in Fort Worth and the beginning of the Dallas Floodway at the confluence of the Elm Fork in Dallas. As delineated, the greenway plan would set aside over 2,000 acres of open space and would include most of the remaining river-bottom forest.

The Multiple-purpose Channel through the greenway would be routed generally north of the natural river. This routing would take advantage of the abandoned sand and gravel pits and utilize this previously disturbed land for the Multiple-purpose Channel and the deposition of excavation materials.

Assuming public ownership of much of the land in the greenway, it is anticipated that an enhancement of natural aesthetics would take place in the urban area as this land would be maintained as public park land rather than being subject to the various disruptions of present activities.

3.26.06.02 Natural (Rural). The reach between Dallas and Tennessee Colony Lake is leveed for almost its entire length. This has resulted in the removal of nearly all of the natural vegetation outside the levee system and the conversion of this land to agriculatural usage. Within the levees there are areas containing natural vegetation which are aesthetically attractive, especially the wooded areas. The project would have a significant impact on these areas as channel straightening would require the removal of most of the woody plants between the levees. The existing levee system has already removed much of the natural aesthetic appeal as viewed from the river, and therefore any additional disruption to the remaining natural vegetation would most probably destroy its remaining aesthetic value.

The area that would be inundated by Tennessee Colony Lake could no longer be considered as having any natural aesthetic value as it would be a man-made lake. The vegetation surrounding the lake area would undergo a change with a resulting change in aesthetic value. Land use changes in this encompassing area would also have a significant influence on the aesthetic values of this reach.

Much of the land in the reach between Tennessee Colony Lake and Lake Livingston is utilized for agricultural purposes and forestry and, if forested, has been logged at various times. The remaining natural vegetation has been strongly influenced by man's presence and activities. The project would further influence the aesthetic values of the remaining natural areas, especially those associated with bottomland hardwoods. Cutoff river meanders could be managed in such a way as to regain a natural appearance, providing conditions conducive to natural growth exist.

It is more heavily forested along the river in the reach from Lake Livingston to Trinity Bay than in other reaches. Relatively extensive residential development has altered the natural appearance in this reach as have logging operations, grazing, and oil and gas well operation. The project would enlarge on these alterations to the natural appearance of the area, and although development within this reach is presently occurring, it is anticipated that the project would accelerate the rate of development, further reducing the aesthetic appeal of the area.

Careful placement of the excavation material from the project is planned to prevent further degradation throughout the entire length of the project. Revegetation of these disturbed areas would assist in returning these areas to a condition that could be considered as having natural aesthetic value.

3.26.06.03 Man-Made. It is not anticipated that the project would have any impact on the aesthetic value of those man-made structures that are currently in existence within the project area. The potential would exist, however, for increasing the visitation to those structures adjoining the project area.

The project would present an opportunity for designing project facilities that are aesthetical. The lock and dam sites would present areas of special concern due to the anticipated visitation to these areas. The seeding of native grasses and the replanting of native trees along the right-of-way of the man-made channel would improve the aesthetic appeal of the altered channel.

Tennessee Colony Lake, which would become a major attraction to millions of people, would have the appeal that is characteristic of any large body of water, whether natural or man-made. The proper design and layout of recreation lands surrounding the lake would enhance this attraction. The water quality of Tennessee Colony Lake would determine to a great extent the long-range appeal that the lake would have for recreation visitation.

3.26.07 Ground Water Effects on Agricultural Production. The most noticeable effect of increasing ground water levels would be in those areas where the levels are raised to within 5 feet or closer of the land surface. Such conditions could affect man's activities as related to land use. In agricultural areas raised water tables could provide substantial benefits by furnishing necessary moisture during the growing seasons. However, if the root zones become saturated, the rise could be detrimental to plant growth. This situation could be corrected and excess soil moisture removed by means of ditches, subsurface drains, relief pumps, or pumped wells which would remove surface water, promote internal drainage, and maintain the water table at the desired level.

Drainage of swamps and marshes could facilitate clearing of the land for more productive agriculture in areas where the water table would be lowered. Although not ecologically desirable, this could result in increased land values and could contribute to meeting the food and fiber needs of man.

Arkansas River navigation studies of the effects induced by ground water changes on agricultural productivity in the flood plains indicated that productivity on 75 percent of the land was increased, there was no change in 24 percent of the land and an adverse effect occurred in 1 percent of the flood plain (Soil Conservation Service, 1970).

3.26.08 Waterborne Transportation. The Multiple-purpose Channel would serve as a main transportation artery linking the productive agricultural region of the Trinity River Basin and surrounding area to the markets of the world. Development of the Lighter Aboard Ship (LASH) system makes it possible to load the barges near the centers of production, transport the cargo to a coastal port, and load barge and cargo aboard a seagoing ship. At the destination, the process is reversed, thus eliminating considerable handling of the cargo.

Navigation would also lower the transportation cost for materials and equipment used in the Basin and surrounding area. Trinity River navigation connecting to the Gulf Intercoastal Water Way and other navigable waterways would add to the network of water borne transportation between production and consumption centers (Plate 25).

The availability of low-cost waterway transportation would attract industry to those areas adjacent to the channel which have rail and/or highway connections (Anderson, 1974). This would influence not only the land occupied but also adjoining areas because of the nature of many industries that produce impacts that extend beyond property lines.

3.26.09 Agricultural Land Use Changes. Multiple-purpose Channel alignment, disposal, access roads, levees, and public-use area rights-of-way would affect agricultural land pursuits. Some land might be taken out of agricultural production should the parcels be isolated between the river and the Multiple-purpose Channel. The Federal Government would either provide access or purchase the land, depending upon the size and the cost of the parcel, and the cost of providing access.

The adverse effects on the agricultural industry would not be severe; benefits to agriculture would occur as a result of the project. The project could induce the conversion of some woodlands to agricultural lands. Undoubtedly, some of this clearing would occur with or without the project. This action would result in the loss of some existing forest habitat of economic, aesthetic and cultural value to local residents. These include values associated with outdoor recreation, hunting, and nature opportunities, and a source of lumber and related wood products.

3.26.10 County Boundary Changes. The Trinity River serves as a County boundary for Ellis, Kaufman, Navarro, Henderson, Freestone, Anderson, Leon, Houston, Madison, Trinity, Walker, San Jacinto, and Polk Counties. The project, by cutting off many river meanders, would create parcels of land which would be separated from the counties to which they are politically bound. Although these parcels might have access, they would be isolated by the Multiple-purpose Channel from their politically affiliated counties.

The borders of those counties which use the Trinity River as a boundary line probably would not be affected by the project, as approval by a majority of the voters in each county affected, is required prior to any change in county boundaries.

3.26.11 Riparian Rights. The project would result in a shifting of riparian rights from private to public ownership because of land acquisition. "The riparian right arises by operation of common law concepts as an incident to the ownership of land abutting a stream or watercourse, requiring no act other than the acquisition of title to the land." (Yarbrough, 1968). The project would require a minimum of fifty feet on either side of the Multiple-purpose Channel for maintenance purposes and would therefore remove from private ownerships those lands which abut that portion of the Trinity River which would be included. The effect that this change in riparian right ownership would have is unknown as there are no data available at present to determine current domestic and livestock use of Trinity River waters.

3.26.12 Secondary Land Use Changes (Commercial, Industrial and Residential). Based on land use changes that have occurred following similar past projects, significant secondary land use changes could be expected adjacent to this project. The attraction of 9.6 million visitors to the recreation attributes of Tennessee Colony Lake would spawn commercial development on surrounding lands as the private sector reacts to furnish the goods and services demanded by the public utilizing the lake's recreational facilities. Public facilities would need to be expanded to cope with the problems created by the rapid growth of the area.

Residential development would be expected to occur on suitable lands adjacent to the Government-owned lands surrounding the lake. In addition to the land converted from forest or agricultural to residential, there would also be lands converted to the services supporting these developments.

Recent legislation which would affect the quality, number and pattern of residential subdivisions adjacent to the project area include the Interstate Land Sales Full Disclosure Act, 15 U.S.C. 1701, the Flood Disaster Protection Act of 1973, PL 93-234 (87 Stat. 975), and the Texas Water Quality Act (V.T.C.A., Water Code, Sec. 21.001). This legislation would not prevent development but should enhance the quality of development that would occur. There has already been significant residential development around some of the existing natural oxbow lakes, especially below Lake Livingston. The aforementioned legislation has probably slowed the rate of development in these areas, but it is assumed that the advantages created by the project would accelerate residential development. The project would create man-made oxbows which would, because of the flood protection provided by the channel, encourage residential development on the shorelands of those oxbows which are conducive to such development. This in turn would generate additional development to provide access and necessary services to these areas. This induced development would also cause a loss of flora, the displacement of fauna, and create additional pollution, all of which would have adverse effects on the natural environment.

It is anticipated that industrial growth would occur because of the project. Industries utilizing navigation facilities for shipping of raw and finished products would affect the current land uses in their immediate area. The rural areas would undergo changes near sites that lend themselves to port development. Industries in the Dallas-Fort Worth area could generally be confined to the ports and to the north side of the Trinity River, as described by Mertes et al. (1972), and could utilize abandoned sand and gravel pit areas for much of their development. Much of this industrial growth would be in lieu of development elsewhere.

3.26.13 <u>Effects on Oil and Gas Production, Tennessee Colony Lake Area</u>. There are 14 oilfields in Anderson, Henderson, Freestone, and Navarro Counties which would be affected to varying degrees by the construction of Tennessee Colony Lake. The Cayuga Field in Anderson County and the Kerens, South Field in Navarro County, make up 82 percent of the total subordination damages to active wells. Table 3-20 shows the number of wells involved, anticipated daily production on January 1, 1974, and on January 1, 1979, and the anticipated depletion during this period.

Mineral rights in the affected fields, as well as in non-producing areas, would be subordinated to the project purposes rather than acquired outright. Although much of the activity would be expected to continue, there is considerable "subordination damage" in producing areas, consisting of cost of rehabilitation and loss of value. Rehabilitation would consist of precautionary measures taken to protect lease and well equipment and to avoid pollution of the lake. The computed loss of value would be the compensation to the operators for increased operating costs and for the effect that the knowledge that the area has been subordinated would have on prospective purchasers. Owners of non-producing mineral rights would still have the right to test the properties by drilling, even if it might be necessary to drill directionally.

The Nesbitt field in Navarro County is expected to be depleted by 1979. The Flag Lake field in Henderson County should be so near depletion that no rehabilitation costs would be included

TABLE 3-20

OIL AND GAS PRODUCTION-TENNESSEE COLONY LAKE AREA

COUNTY FIELD	Active Wells (A) Oil	Active Wells (A) Gas	1 Jan 74 Anticipated Daily Production Oil (Barrels) (B)	1 Jan 74 Anticipated Daily Production Gas (MCF)	1 Jan 79 Anticipated Daily Production Oil (Bbls)	% Depleted since 1974	Gas (MCF)	% Depleted since 1974
ANDERSON								
Bethel	1	6	26.5	7,220	8.1	69	2,290	68
Bethel Dome, East	2	5	82.3	2,260	30.7	63	830	63
Cayuga	60	31	668.3	4,670	308.0	54	1,185	75
TOTAL ANDERSON COUNTY	63	42	777.1	14,150	346.8	56	4,295	0
FREESTONE								
Nan-Su-Gail		55	8.3	2,803	3.3	60	730	74
Stewards Mill, Northeast		3	15.0	560	3.3	78	100	82
TOTAL FREESTONE COUNTY		58	23.3	3,363	6.6	72	830	75
HENDERSON								
Cayuga, Northwest	17		140.0		29.0	79		
Flag Lake	1		4.2		2.0	52		
Malakoff	3	1	34.0	20	14.0	59	Dep.	100
Malakoff, South	4	1	40.0	10	14.0	65	Dep.	100
TOTAL HENDERSON COUNTY	25	2	218.2	30	59.0	73		100
NAVARRO								
Kerens, South	30		1,000.0		350.0	65		
Nesbitt	3		2.0		Dep.	100		
Powell	43	3	483.3	5,000	183.3	62	80	98
Reka	2	2	51.7	770	18.7	64	260	66
Roundhouse		4	42.0	3,070	16.2	61	520	83
TOTAL NAVARRO COUNTY	78	9	1,579.0	8,840	568.2	64	860	90
TOTAL PROJECT	166	111	2,597.6	26,383	980.6	62	5,985	77

(A) Dual Completions Counted As Two Wells
(B) Includes Condensate Production

Compiled from Gross Mineral Appraisal, Tennessee Colony Lake by Lee Keeling and Associates, Petroleum Consultants.

and only loss of value would be considered. About one-half of the original productive area of the Cayuga field would be below the top of the flood control pool, including approximately 3,900 acres below the top of the conservation pool level. For this reason, and because of the advanced stage of depletion, rehabilitation of the Anderson County portion of the Cayuga field would probably not be feasible. About 60 percent of the Nan-Su-Gail field in northeastern Freestone County, would be within the project limits. This field is also nearing depletion and a small amount of rehabilitation is anticipated. Substantial rehabilitation would be done in the Cayuga Northwest Rodessa Unit, of which about 25 percent would be within the project limits. In the Kerens, South Field, Navarro County, 75 percent of the total project rehabilitation costs would be incurred along with substantial loss in value. Almost all wells and lease equipment would lie between the conservation pool and flood control pool levels. It is expected that there will have been no decline in the market for oil and gas by the time construction of Tennessee Colony Dam could be completed. With the exception of the Cayuga Field, almost all wells in the Tennessee Colony Lake area that have not been depleted would remain in operation.

The only anticipated loss in actual production would occur in the Anderson County portion of the Cayuga Field. By equating loss of value to loss of production, it is estimated that as of January 1979, the production loss for the Cayuga Field would be 63 bbls/day of oil and 243 MCF/day of natural gas. The Cayuga Field oil production will have declined by 54 percent and gas production by 75 percent in the five years preceding 1979. It is anticipated that Tennessee Colony Dam could not be completed by 1979 and that production rates would decline still further, thus reducing the estimated loss in production.

3.26.14 Multiple-Purpose Channel Effects on Oil and Gas Fields.

3.26.14.01 Long Lake Oilfield. There is more potential impact on this field caused by channel construction than any other field. Without the construction of side channel levees, approximately 12 to 15 wells would be inundated two or three of which are presently in production. These wells would require rehabilitation, assuming they were still in production at the time of project completion. Two inactive wells lie within the channel right-of-way. If undiked, the pool of Lock and Dam 9 would inundate several hundred acres in the southern part of the Long Lakefield.

3.26.14.02 Navarro Crossing Oil and Gas Field and Oakwood Gas Field. These fields are nearing depletion and very few wells are still in operation. Depending on the exact location of the final alignment, one or two active wells might be within the Multiple-purpose Channel right-of-way. About 20 wells inside of Mitchell Bend would be isolated by construction of the channel. Most of these wells are part of the Oakwood Gas Field (Leon County) and were active as of February, 1969. Five of the 20 wells would be inundated by Pool 7, and about half of these would probably be rehabilitated if still active by the time the project could be completed. Access, probably from Leon County, also would have to be provided. In addition to oil and gas wells, two flowing water wells near Stanmire Lake lie in the channel right-of-way at channel miles 205.9 and 203.6. Both wells would probably be saved depending on the location of the final alignment.

3.26.14.03 Fort Trinidad Oilfield. One well falls within the channel right-of-way near river mile 225. This well was active as of February, 1969, and could be rehabilitated if still active in 1985.

3.26.14.04 Davis Hill Oilfield. This field would be crossed by the channel right-of-way, but the entire field has been abandoned.

3.26.14.05 South Liberty Oilfield. About a dozen wells and numerous oilfield facilities would be disturbed by construction of the Multiple-purpose Channel, as presently aligned. Since the channel alignment through this reac would not be controlled by the configuration of the river channel, it appears likely that in final design of the channel alignment, almost all of the South Liberty wells and facilities could be avoided. In either case, renewed access would have to be provided to many wells in this field.

3.26.15 Sand and Gravel. With construction of the Multiple-purpose Channel, the sand and gravel market traffic pattern is expected to change, because of the availability of barge transportation of large deposits from the middle reaches of the river. Barge transportation of sand and gravel is predicted to increase from 9,922,000 short tons in 1985 to 50,057,000 short tons in 2035. (Table 3-21). At present, the proportion of total usage is about 60 percent in the Houston-Galveston Metropolitan Area and 40 percent in the Dallas-Fort Worth Metropolitan Area.

3.26.15.01 Houston-Galveston Metropolitan Area. The sand and gravel market area or radius of influence extends slightly over 100 miles to the west and includes deposits south of Cuero on the Guadalupe River and the Columbus-Altair-Eagle Lake area on the Colorado River. Northward, the market area includes the San Jacinto River deposits and the Trinity River deposits near

TABLE 3-21

SAND AND GRAVEL CONSUMPTION
HOUSTON-GALVESTON AND DALLAS-FORT WORTH
METROPOLITAN AREAS AND PROSPECTIVE WATERWAY COMMERCE
(Thousand Tons)

YEAR	CONSUMPTION	PROSPECTIVE WATERWAY COMMERCE
1966	16,625	5,200
1985	31,728	9,922
2000	50,155	17,197
2010	68,061	23,336
2020	92,360	31,664
2035	146,004	50,057

Data compiled from: U. S. Army Corps of Engineers 1974b

Urbana. Deposits north of Urbana will be exploited with or without the project, but a substantial savings would be incurred with the Multiple-purpose Channel in operation because of lower freight rates and extraction by hydraulic rather than dry land production methods. It is anticipated that sand and small gravel from the Urbana area will capture a substantial portion of the Houston-Galveston market after 1985. The Trinity River deposits do not contain appreciable quantities of gravel larger than 3/4 inch size, and until the year 2000, the larger aggregates required to meet concrete quality specifications will continue to be supplied from the Colorado and Guadalupe River sources. With the projected depletion of deposits south of Cuero on the Guadalupe River and south of La Grange on the Colorado River by the year 2000, crushed stone from the San Antonio and Georgetown areas is expected to become competitive with large aggregate sources north of Cuero and La Grange and to capture the majority of the large aggregate market. Limestone reserves in the San Antonio and Georgetown areas are enormous with a life expectancy that exceeds 100 years. Low quality sand, used principally as fill material will continue to come from the San Jacinto River deposits and from the Trinity River deposits near Liberty with or without the construction of the waterway. Sand and gravel reserves in the Liberty-Urbana area have a life expectancy that exceeds the economic life of the project.

3.26.15.02 Dallas-Fort Worth Metropolitan Area. Sand and gravel deposits near Seagoville are expected to be depleted by the time the project could be completed in 1985. Thereafter, deposits between Seagoville and central Navarro-Henderson Counties (vicinity of Trinidad) will be exploited with or without the project. With the Multiple-purpose Channel completed, these deposits, in competition with the Brazos River deposits, would probably retain a major portion of the Dallas-Fort Worth market for sand and gravel. It is expected that crushed limestone from the Chico-Bridgeport area will continue to make up about 85 percent of the large aggregate for concrete. About half of the gravel and about 55 percent of the sand for the Dallas-Fort Worth area is expected to come from Trinity River deposits south of Seagoville, with the balance of the sand derived from local deposits in Tarrant, Dallas, and Denton Counties and from the Brazos River deposits. Trinity River reserves of sand and gravel from Seagoville to Trinidad, along with those from Mineral Wells to south of Cleburne on the Brazos River, are believed to be sufficient to supply the Dallas-Fort Worth area through the year 2035.

3.26.16 Stone.

3.26.16.01 Dallas-Fort Worth Area. With the Multiple-purpose Channel in operation, the stone industry in the Dallas-Fort Worth area would not be expected to decline. Large-sized aggregates would continue to be in demand for concrete, and the stone industry would be expected to retain approximately the same proportion of the aggregate market.

3.26.16.02 Houston-Galveston Area. Approximately 20 million tons of accountable stone reserves occur in Walker, Polk, Trinity, and San Jacinto Counties. With the project operational these deposits would be expected to be economically minable. The market for this stone would be in the Houston-Galveston area and along the Gulf Coast. Reserves of high quality stone at Butler Dome, in Freestone County, which are presently considered economically minable, are expected to be depleted by 1985. Savings realized by availability of barge transportation would make additional reserves at this site economically minable. It is estimated that about one million tons per year would be moved to markets in the Houston-Galveston area and along the Gulf Coast.

3.26.17 Cement. Shell reserves are predicted to be depleted by 1985. If the project were operational at this time, it is expected that cement would be transported by barge from Dallas, Fort Worth and Midlothian to the Gulf Coast. In addition, limestone would probably be barged to Houston for use in cement manufacture.

3.26.18 Lignite. Approximately 25,400,000 tons of lignite to be used by the Big Brown Electric Generating Plant would be affected by Tennessee Colony Lake. Operating at full capacity, the plant burns about 5 million tons of lignite per year and company personnel have estimated that, on notification of a construction start on the dam, the 25,400,000 tons could be extracted in 5 to 8 years. Construction of the dam would take about 10 years.

3.27 Summary of Measures to be Taken to Reduce, Protect, or Compensate for Adverse Ecological Effects of the Project. There are increasing concerns about adverse effects on natural biological communities by the general developmental trends that are a part of increasing population pressures. Part of the current planning responsibilities in any water resources development project are concerned with the actions that could be taken to reduce both the number and the severity of these adverse effects, particularly those resulting from the construction and operation of a project.

3.27.01 Multiple-Purpose Channel Alignment. A major departure between the Multiple-purpose Channel and the natural river channel is proposed between Lock and Dam 3 and Lock 5A. The net benefits of this type of departure to the existing natural river terrestrial and aquatic ecosystems would seem to outweigh other considerations, and it is anticipated that this same type of activity would be enlarged upon in future planning, particularly where a hydraulic head exists because of the location of a navigation lock and could result in the diversion of flowing water through the natural river channel. A good example of this situation would be the physical conditions in the vicinity of Lock and Dam 9 where a 15 mile reach of the river channel would connect to the Multiple-purpose Channel above and below Lock and Dam 9. These flowing water reaches would contribute to both the natural river flowing water regimen and recreational activities. A different design would be required where the river channel departs from and re-enters the Multiple-purpose Channel within the pool of one lock. Unless a perennial tributary stream enters the river in such a reach, it would be impossible to maintain appreciable low water stream flows in the river channel under these conditions without extensive pumping capabilities. However, tentative plans include leaving existing streambank vegetation undisturbed and allowing water to enter the river channel by backwater effect from the downstream lock and dam, instead of filling in or plugging both ends of the natural river channel with excess construction excavation as was originally envisioned. Where the natural river channel and the Multiple-purpose Channel alignment are concurrent for appreciable distances, a slight realignment of the Multiple-purpose Channel would be made in order to avoid destruction of the riverbank vegetation on one side of the natural river channel. Multiple-purpose Channel realignment could also be considered in some areas so that it would proceed across previously cleared areas as opposed to forested or wooded areas.

3.27.02 Single Stage Multiple-Purpose Channel Construction. Initial construction of the full 250 foot bottom width of the Multiple-purpose Channel as opposed to 150 or 200 foot bottom width with subsequent enlargement to 250 foot bottom width a number of years later, is considered less ecologically adverse since whatever vegetation and wildlife existing in and around the Multiple-purpose Channel would be disturbed twice by construction under two-stage development procedures.

3.27.03 Six to One Side Slopes at Normal Pool Water Lines. The provision for six to one side slopes on the Multiple-purpose Channel 3 feet above and below the normal pool levels is considered a reduction of adverse effects in that bank erosion from wave action would be less severe. This provision would be more conducive to the reestablishment of vegetation near the water edge.

3.27.04 Revegetation Along Multiple-Purpose Channel. Water-loving trees (such as those species normally found along the natural river) would be planted at about the water line on the six to one slope of the Multiple-purpose Channel. The side slopes would be planted with native grasses using seed hay, and the three-to-one side slopes in the upper portions of each lock pool would be planted with native trees. These actions would: provide food and cover for biota, provide shade, reduce bank erosion (thus reducing turbidity, downstream siltation, and frequency of maintenance dredging), and provide a more aesthetically pleasing system. The provision for prohibition of clearing a 25 foot strip immediately inside the acquisition line on both sides of the Multiple-purpose Channel is considered a reduction of the adverse effects on native vegetation and should aid the revegetation of adjacent cleared areas with native vegetative stock.

3.27.05 Disposal of Waste Excavation. Disposal of waste excavation along either side of the Multiple-purpose Channel by shaping and subsequent replanting of native vegetation is considered less adverse on natural resources particularly from the viewpoint of erosion during reestablishment of vegetation and visual aesthetics.

3.27.06 Lands for Wildlife Conservation. A portion of the lands (about 70,000 acres) to be acquired for flood control, water supply, and increased reservoir regulation flow capacity would be codesignated for wildlife conservation. Wildlife conservation activities would be carried out by the Texas Parks and Wildlife Department. These areas are similar to wetlands and bottomland hardwood forests that would be disturbed or destroyed by the project, and would preclude their future destruction. An additional 31,000 acres of water and adjacent lands within the Tennessee Colony Lake project area would be made available to the U. S. Fish and Wildlife Service for operation as a National Wildlife Refuge.

3.27.07 Multilevel Drawdown Capabilities. The design of the outlet works and hydroelectric power intake structures now includes the capability of selecting withdrawals from various levels of Tennessee Colony Lake for downstream water quality purposes. This would provide for the control of lake water releases to maximize the quality of downstream water.

3.27.08 Galveston Bay Navigation Channel Alignment. Cooperative studies are now proposed between appropriate Federal and State agencies to optimize the navigation channel alignment across the Trinity and Galveston Bay areas to reduce adverse on bay ecosystems.

3.27.09 Maintenance Dredging Ring Levees. Provision for sufficient ring leveed areas during channel construction for disposal of future maintenance dredging materials should provide net benefits in terms of aesthetics and water quality by confining materials dredged from the Multiple-purpose Channel to these areas. Care would be taken to locate these areas where the adverse environmental effects would be minimized.

3.27.10 Non-Structural Flood Plain Management. Although not directly a Federal responsibility from the enforcement viewpoint, the recommendation is made that local interests institute and carry out flood plain management practices. Technical assistance would be provided by the Corps of Engineers and the National Oceanic and Atmospheric Administration and the Department of Housing and Urban Development. Adoption of such practices could be expected to result in a reduction in the rate at which adverse effects accrue to flood plain ecosystems, although the primary purpose of flood plain management is to protect the public health, safety and well-being by reducing flood damages.

3.27.11 Clearing of Woody Vegetation. All future planning studies would include design and construction features and requirements to eliminate unnecessary clearing of woody vegetation.

3.27.12 Tennessee Colony Lake Fish Hatchery. If so desired by the State of Texas, and if the necessary cost sharing agreements were reached, structural requirements would be provided in the Tennessee Colony Dam for water releases to a fish hatchery to be operated by the Texas Parks and Wildlife Department. This would include a raceway with a minimum continuous flow of about 55 cfs.

SECTION 4-AUTHORIZED PROJECT PLAN WITHOUT NAVIGATION

4.01 Contents of Section 4. In order to reduce repetition, this section addresses the physical differences between the Authorized Project Plan and an Authorized Project Plan Without Navigation, together with the differences in environmental effects that could be expected between the two plans.

4.02 Non-Navigation Project Purposes. The Authorized Project Plan Without Navigation would consist of the following four increments: (1) Tennessee Colony Lake for mid and lower Basin flood control, water supply, and hydroelectric power; (2) the Dallas Floodway Extension and (3) the West Fork Floodway for flood control in the Dallas-Fort Worth metropolitan area; and (4) a Reservoir Regulation Channel for reduction of flood damages between the Dallas Floodway Extension and Tennessee Colony Lake caused by regulated releases from upstream Federal flood control lakes. The project would include recreation and fish and wildlife conservation.

4.03 Project Description. The differences in the physical features between the Authorized Project Plan, and the Authorized Project Plan Without Navigation are described below.

4.03.01 Tennessee Colony Lake. Present land use in the Tennessee Colony Lake area with the Authorized Project Plan Without Navigation is shown in Table 4-1. The embankment of the lake would be 5 feet higher and 3,700 feet longer to increase the capability of the lake to temporarily retain additional flood waters. The extra flood storage is needed because downstream natural river channel capacities are significantly less than the capacity of the Multiple-purpose Channel in the Authorized Project Plan. The flood control pool elevation would be seven feet higher, and the maximum water surface would be 5.3 feet higher. The conservation pool of the lake would be the same size. Other lake areas would be larger as follows:

Description	Authorized Project Plan (acres)	Authorized Project Plan Without Navigation (acres)
Flood Control Pool	147,200	164,800
Maximum Water Surface	187,500	201,000
Real Estate Acquisition	188,200	204,610

TABLE 4-1

NON-NAVIGATION PROJECT

TENNESSEE COLONY LAKE AREA LAND USE

LAND USE	Conservation Pool Within Floodplain (Ac)	Conservation Pool Outside Floodplain (Ac)	Flood Control Pool Within Floodplain (Ac)	Flood Control Pool Outside Floodplain (Ac)	Real Estate Acquisition Line Within Floodplain (Ac)	Real Estate Acquisition Line Outside Floodplain (Ac)	Total (Ac)
Forest	30,083	13,202	14,320	21,005	7,893	11,189	98,192
Grasslands	31,334	12 126	5,914	20,587	3,826	13,315	87,102
Croplands	1,082	374	43	418	58	557	3,032
Sand, Gravel & Lignite Mining	387	-	31	5	94	16	533
River, Tributary & Lake Water Surfaces	3,115	297	1,206	374	946	292	6,230
Highway & Railroad Right-of-Ways	767	292	103	425	77	316	1,980
Rural Housing & Structures	27	35	10	344	3	90	509
Industrial	-	-	24	4	-	-	28
Oil & Gas Fields	3,114	1,206	-	1,435	-	1,118	6,873
Drainage & Irrigation Ditches	59	-	52	-	20	-	131
Totals	69,968	28,032	22,203	44,597	12,917	26,893	204,610

The spillway and outlet works structures would be essentially unchanged, as would the water supply dependable yield and sediment storage. Hydroelectric power capability would be increased from 16,000 kw to 28,000 kw by redesignation of navigation lockage waters for hydroelectric use.

4.03.02 Reservoir Regulation Channel. The Authorized Project Plan Without Navigation would include a Reservoir Regulation Channel from the Dallas Floodway Extension to Tennessee Colony Lake. This Channel would have 3 to 1 side slopes and dimensions as follows:

Reach (river mile)	Bottom Width (ft)	Approximate Top Width (ft)
487 to 483	80	278
483 to 482	100	298
482 to 478	50	248
478 to 471	65	221
471 to 466	100	250
466 to 455	125	281
455 to 452	150	306
452 to 441	125	281
441 to 430	150	320

The minimum and maximum excavation and right-of-way dimensions would be as follows:

	Minimum (ft)	Maximum (ft)
Approximate Depth Below Existing Flood Plain	20	50
Approximate Channel Width at top of slope	120	400
Approximate Right-of-way for Channel	270	500

Design Channel flow capacity would vary from 15,000 cfs in Fort Worth to 35,000 cfs near the headwaters of Tennessee Colony Lake. There would be no construction downstream from the spillway stilling basin of Tennessee Colony Dam.

4.03.03 Dallas Floodway Extension and West Fork Floodway. The length and alignment of metropolitan area main stem and tributary channelization work would be unchanged. The channel bottom widths for the West Fork Floodway and Dallas Floodway Extension would vary from 125 to 250 feet instead of 200 to 250 feet. The scope of tributary channelization work, levee construction, and sump area construction would be unchanged.

4.03.04 Low Water Dams. There would be about 21 sizable natural river cutoffs formed by the Reservoir Regulation Channel on the alignment from Fort Worth to Tennessee Colony Lake. Low water dams across the Reservoir Regulation Channel would divert low flows through many of these natural river channel reaches. These structures would be 4 or 5 feet high and would provide for flowing water aquatic flora and fauna. Low water dams similar to the existing structures on the Clear Fork of the Trinity River in west Fort Worth would be constructed in some areas across the flood control channel in the Dallas-Fort Worth area and at some places along the Reservoir Regulation Channel between Dallas and Tennessee Colony Lake. These low water dams would pond low flows without interfering with flood flows to a significant degree. Both the above variations would be expected to enhance aesthetic considerations, providing the water quality improves sufficiently to prevent excessive algae blooms, and their associated problems.

4.03.05 Relocations. Relocations would be limited to changes needed to accommodate the Reservoir Regulation Channel, the lake, and the metropolitan area floodways and levees. The number of transportation and utility relocations would be considerably less with this project because there would be no construction downstream from Tennessee Colony Lake. These relocations would be as follows:

Type of Relocation	Authorized Project Plan	Authorized Project Plan Without Navigation	Decrease
Highways	38	20	18
Railroads	13	6	7
Gas & Oil Pipelines	145	16	129
Water & Sewer Pipes	13	13	0
Power Lines	44	25	19
Telephone Lines	18	10	8

The 7 foot rise in the flood control pool elevation of Tennessee Colony Lake would necessitate increases in the scope and cost of relocations in the lake area. Highways and railroads crossing the lake would be higher, protective works for the city of Trinidad, Texas, and the Nipak fertilizer factory would be increased in scope, and protective works for the Cedar Creek Lake and Lake Fairfield embankments would be more extensive.

4.03.06 Construction Excavation. The treatment of excavated materials would be the same as described for the Authorized Project Plan. The volume of materials and the acreages affected would be reduced. Clearing and replanting acreages required for the Authorized Project Plan Without Navigation are shown in Table 4-2. Similar data for the Authorized Project Plan are shown in Table 3-1.

4.04 Land Acquisition. Land acquisition for this project would be as shown in Table 4-3. Similar data for the Authorized Project Plan may be found in Table 3-4.

4.05 Lands for Wildlife Conservation. The rationale for acquisition and codesignation of lands for wildlife conservation would be the same as with the Authorized Project Plan. Table 4-4 gives a comparison of these acreages and their designations.

TABLE 4-4

LANDS FOR WILDLIFE CONSERVATION

	Authorized Project Plan (acres)	Authorized Project Plan Without Navigation (acres)
National Wildlife Refuge	31,000	31,000
Wildlife Conservation Area, Tennessee Colony Lake	25,000	25,000
Flood Plain Lands Acquired and Codesignated for Wildlife Conservation	45,000	23,500
Totals	101,000	79,500

TABLE 4-2

CLEARING AND REPLANTING

Reach	Clearing Forest				Replanting Vegetation			
	Dam(Ac)	Access Roads(Ac)	Channel Areas(Ac)	Waste Excavation Areas(Ac)	Turfing Channel Areas(Ac)	Reforestation of Channel Areas (Ac)	Turfing Exposed Areas(Ac)	Reforestation of Waste Areas (Ac)
Tennessee Colony Lake	986	83	--	--	--	--	440	--
Reservoir Regulation Channel (Tennessee Colony Lake to Dallas Floodway Extension)	--	5	1,183	183	768	190	1,670	183
Dallas Floodway Extension & Dallas Floodway	--	8	348	154	303	57	1,010	154
West Fork Floodway	--	31	442	43	496	118	2,180	43
TOTALS	986	127	1,973	380	1,567	365	5,300	380

Note: Clearing for the Tennessee Colony Lake area does not include selected or partial clearing for recreational areas, fish and wildlife purposes, or water quality.

TABLE 4-3

LAND ACQUISITION

	Lake, Channel & Floodways (Ac)	Dams (Ac)	Access Roads (Ac)	Recreation (Ac)	Excess Material (Ac)	Total Lands (Ac)	Number of Landowners
Tennessee Colony Lake	195,100	2,900	110	6,500	--	204,610	600
Reservoir Regulation Channel (Tennessee Colony Lake to Dallas Floodway)	2,245	4	22	150	1,770	4,191	83
Dallas Floodway Extension	6,198	2	8	100	1,263	7,571	294
West Fork Floodway	12,730	4	30	250	2,142	15,156	819
TOTALS	216,273	2,910	170	7,000	5,175	231,528	1,873
RESERVOIR REGULATION FLOWAGE LANDS						23,500	
TOTAL LANDS						255,028	

4.06 Project Operations. There would be no change in the water supply operation of the Authorized Project Plan Without Navigation from that of the Authorized Project Plan. Changes in the operation of other aspects of this project are described below.

4.06.01 Flood Control Operations. In the Dallas-Fort Worth metropolitan area, flood control operations would be essentially the same as previously described in Section 3. Channel and levee floodway systems would be designed to contain all floods up to the Standard Project Flood.

The channel capacity of the Reservoir Regulation Channel between the Dallas Floodway Extension and Tennessee Colony Lake would be less than that of the Authorized Multiple-purpose Channel. Channel excavation materials in this reach would be used to strengthen existing agricultural levee systems to contain floods up to the 100-year frequency flood.

At Tennessee Colony Lake, the flood control pool would be 7 feet higher. This is because the existing river channel capacity downstream from the dam is about 20,000 cfs as compared to the 45,000 cfs that would be provided by the Multiple-purpose Channel. The floodwater release rate at the dam would be lowered accordingly. This lower release rate would result in longer retention times at higher pool levels within the lake. The estimated times required for flood storage evacuation of the lake at a regulated release rate of 20,000 cfs would be as follows:

Flood Storage Frequency	Estimated Evacuation Time
50 years (top of flood control pool)	79-158 days
25 years	63-126 days

Lake floodwater catches which exceed flood control capabilities would be released at a rate in excess of the regulated release rate. This could result in longer evacuation times and prolonged downstream flooding.

Downstream from the Tennessee Colony Dam spillway and stilling basin structures, no construction would be required for the Authorized Project Plan Without Navigation. Floodwater releases from Tennessee Colony Lake would flow downstream within the natural channel at rates up to the regulated release rate. These flows would not be retained by Lake Livingstor or Wallisville Lake unless the lakes happened to be below their conservation pool levels. Flows entering these two lakes when they are at full conservation pool level would pass through the spillway tainter gates at Lake Livingston Dam and would flow over the 4-mile long weir at Wallisville Lake. Floodwater flows above river channel capacity between Tennessee Colony Lake and Lake Livingston would spread out onto the surrounding flood plain. The degree of flood protection provided to the structures and other properties in the flood plain downstream from Tennessee Colony Dam by the Authorized Project Plan Without Navigation would be less than that provided by the Authorized Project Plan. Although Tennessee Colony Lake would provide approximately the same degree of downstream protection from upstream floodwaters, the river channel downstream from the dam would be smaller than the Multiple-purpose Channel of the Authorized Project Plan. Floodwaters from the 6,000 square miles of runoff area downstream from Tennessee Colony Dam would overflow the riverbanks more frequently.

4.06.02 Navigation Operations. There would be no navigation operations in connection with the Authorized Project Plan Without Navigation. However, navigation authorized under other documentation is operational from the Port of Liberty, Texas, downstream to Trinity Bay on a 6-foot depth run-of-the-river alignment.

4.06.03 Recreation Operations. Recreation operations in the Dallas-Fort Worth metropolitan area and in the Tennessee Colony Lake area would be essentially the same as presented in Section 3 of this report. Limited recreational facilities would be provided along the Reservoir Regulation Channel below Dallas as visitation to this area would be relatively low.

4.06.04 Hydroelectric Power Operation. Deletion of the navigation feature would result in reallocation of waters previously planned for navigation lockages to hydroelectric power generation and would increase the capacity at the Tennessee Colony Damsite from 16,000 kw to 28,000 kw. Preliminary calculations indicate water releases for peaking power production would be about 9,000 cfs for 6 to 8 hours a day from May through September.

4.06.05 Maintenance Dredging Operations. Maintenance dredging activities for the Authorized Project Plan Without Navigation would consist largely of periodic sediment removal and clearing of debris and woody vegetation from the Reservoir Regulation Channel in order to maintain hydraulic efficiency. About 99 percent of the sediment being conveyed down-channel and deposited in Tennessee Colony Lake. The frequency of maintenance is estimated to be in the range of once every 5 to 10 years for the Reservoir Regulation Channel.

4.06.06 General Project Maintenance. Operation and Maintenance (O&M) in the Dallas-Fort Worth metropolitan area would be essentially unchanged. Local interests would be responsible for operation and maintenance of the floodway, levees, and appurtenances, while the flood control channel, and the Reservoir Regulation Channel downstream to Tennessee Colony Lake would be the responsibility of the Corps of Engineers. Local levee districts would be responsible for O&M on all their levees and the 100-year frequency containment would depend on this maintenance. The Trinity River Authority of Texas would be responsible for O&M on all project recreational facilities except for those operated by the Corps of Engineers as overlooks, visitors centers, etc. The Corps of Engineers would be responsible for O&M of all flood control and hydroelectric equipment at the dam.

4.07 Authorized Project Plan Without Navigation Benefit-Cost Ratio. The benefit-cost ratio for the Authorized Project Plan Without Navigation is 1.9 to 1.

4.08 Modifications of River Flow Into Trinity Bay. Table 4-5 shows the expected differences in freshwater flows into Trinity Bay. The numbers in Table 4-4 represent the minimum flows likely under all conditions since they are based on the assumption that the maximum dependable yields of all water supply lakes are being used at all times.

The significant differences in flow volumes between the Authorized Project Plan and the Authorized Project Plan Without Navigation are because of the lack of navigation releases and an increase in hydroelectric power releases with the latter.

4.09 Impacts on Water Quality. The Reservoir Regulation Channel as presently designed has already been described. The overall length of the existing river channel between Five Mile Creek and the headwaters of Tennessee Colony Lake is about 63 miles. The river is leveed on both sides over most of this reach at present, although these levees are not well maintained and contain many breaks. The existing river channel is often overtopped during high flows and significant amounts of water breach the levees. Many of the sediments, nutrients, and pollutants are deposited outside the existing river channel. With the Reservoir Regulation Channel operational, the measured water travel distance during low flows would be about 53 miles, and the measured travel distance during high flows would be about 44 miles. The difference between low flow travel distance and high flow travel distance results from the low flow diversions through many of the cutoff river loops. These diversions would be formed by the Reservoir Regulation Channel and low water dams. The cross sectional area of the Reservoir Regulation Channel would be considerably larger than the existing river channel average, and much less frequent overtopping of banks would occur. Since velocity for a given flow is inversely

TABLE 4-5

ESTIMATED TRINITY RIVER FLOWS INTO TRINITY BAY [1]
(Ac.-Ft./Yr.)

	Record Low Flow Year (1956)		Record High Flow Year (1945)		Average Annual Basis	
Estimated Period of [2] Record Flows at Mouth of River	799,000 [3]		12,933,000		5,371,000	
	Basin Water Development		Basin Water Development		Basin Water Development	
	1985 Conditions	2035 Conditions	1985 Conditions	2035 Conditions	1985 Conditions	2035 Conditions
Without Either Project	120,000	656,000	10,269,000	11,167,000	3,523,000	4,227,000
With Authorized Project Plan	309,000	657,000	10,080,000	10,510,000	3,329,000	3,539,000
With Authorized Project Plan Without Navigation	197,000	237,000	10,140,000	10,525,000	3,338,000	3,533,000

(1) All data estimated from the 1925-1965 Period of Record at the Romayor Gage, river mile 96.
(2) The estimated period of record flows at mouth of river reflect adjustments for unmeasured areal runoff downstream from the Romayor Gage.
(3) Adjusted to reflect record drought year irrigation withdrawals downstream from the Romayor Gage reported to the Texas Water Rights Commission.

proportional to cross sectional area of the channel, the velocities would be expected to be much lower with the Reservoir Regulation Channel than with the existing river channel; however, the actual movement of water downstream (in cfs or volume per unit of time) would be faster. These factors, together with the anticipated direct and induced vegetative clearing, would be expected to result in higher turbidity levels than now occur, especially during very high flows, and downstream siltation problems. Other expected effects include: (1) Higher water temperature (because of the loss of tree cover, decrease in average water depth, and increase in average surface area); (2) reduced aeration (hence reduced oxygen uptake); (3) higher BOD levels; (4) reduced nutrient uptake by soil and vegetation adjacent to the channel; (5) more rapid transport of pollutants from the Dallas-Fort Worth metropolitan area (both from point and non-point sources) into the headwaters of Tennessee Colony Lake; and (6) more severe erosion of tributary streams caused by the increased gradient where they enter the Reservoir Regulation Channel.

The majority of the water quality changes in this reach would be related to the differences in channel bottom configurations. The Reservoir Regulation Channel bottom would be much wider and deeper, and would be flat instead of rounded. The channel profile would be a uniform slope as opposed to the alternating pools and riffles of the natural channel or the series of lock pools which would be a part of the Authorized Project Plan. This would result in a much higher transfer efficiency for a given volume of water between Fort Worth and the headwaters of Tennessee Colony Lake. There would also be an almost complete, direct transfer of detritus, sediments, dissolved and suspended materials, etc., into Tennessee Colony Lake.

It is therefore anticipated that there would be a larger net negative impact on the water quality in Tennessee Colony Lake with the Authorized Project Plan Without Navigation than would occur with either the Authorized Project Plan or with no Corps of Engineers action.

Water quality in the reach between Tennessee Colony Dam and the headwaters of Lake Livingston would be expected to be better than currently exists in that reach or would be likely to exist in the absence of Tennessee Colony Lake. However, the eutrophication problem in Lake Livingston would be expected to continue for some time.

Hydroelectric power releases with the Authorized Project Plan Without Navigation would be increased resulting in a different pattern of downstream flows than would occur with the Authorized Project Plan. These releases would be about 9,000 cfs (4,039,200 gpm), six to eight hours a day during the period May through September. These flows would result in increased streambank erosion and downstream siltation.

4.10 Impacts on Vegetation. A comparison of the woody vegetation which would have to be cleared for the Multiple-purpose Channel with the Authorized Project Plan and that which would have to be cleared for the floodways and the Reservoir Regulation Channel with the Authorized Project Plan Without Navigation for that reach between Fort Worth and the headwaters of Tennessee Colony Lake is given in Table 4-6.

TABLE 4-6

WOODY VEGETATION WHICH WOULD BE CLEARED BETWEEN FORT WORTH AND TENNESSEE COLONY LAKE

Project	Area Size (acres)	Number of Woody Plants Lost		
		1-10 cm	Over 10 cm	Total
Authorized Project Plan	6,482	4,529,800	642,800	5,172,600
Authorized Project Plan Without Navigation	2,397	1,079,300	244,900	1,324,200

The Authorized Project Plan Without Navigation would have a smaller channel size than the Authorized Project Plan and would require less acreage for deposition of excess excavation material since most of the excavated material would be used to strengthen the existing levee systems. Channelization between Fort Worth and Tennessee Colony Lake would result in adjacent water tables being lowered. Long term vegetative changes would be expected to occur adjacent to the channel and in many areas where induced surface or subsurface drainage would occur. The Reservoir Regulation Channel would lower the frequency of flooding within the levees and would therefore be likely to induce clearing between the levees for crops and/or grazing. The general effect would be a reduction in the number of trees and a less diverse vegetation.

Revegetation in the form of returfing and reforestation would be carried out as shown in Table 4-7.

TABLE 4-7

RETURFING AND REFORESTATION

Project Component	Acres Returfed	Acres Reforested
Reservoir Regulation Channel	2,438	373
Dallas Floodway Extension	1,313	211
West Fork Floodway	2,676	161
Totals	6,427	745

Those environmental effects associated with the conservation pool of Tennessee Colony Lake would be virtually identical to those found in the Authorized Project Plan, except for the eliminated danger of barge spills and the necessity of disposing of maintenance dredged materials within the conservation pool.

Vegetation within the flood control pool would be subject to inundation for longer periods of time and more severe tree and other vegetation kills would be expected to occur than with the Authorized Project Plan. Those trees most subject to damage by flooding, listed in Table 3-13, would be expected to be killed by long periods of inundation. The largest percentage of trees in the area are reported to be Texas sugarberry, green ash, and cedar elm (about 77 percent of woody species present). These three species are relatively water-tolerant, but could be expected to be adversely affected by inundation of more than 45 days. The forested acreage which would have to be cleared for the Tennessee Colony Dam for the Authorized Project Plan Without Navigation would be about 986 acres, as compared to about 961 acres with the Authorized Project Plan. This clearing would result in the loss of about 10,400 woody plants, about 1,800 of which would be in the greater than 10 cm dbh size range.

4.11 Impacts on Fauna. The impacts of the Reservoir Regulation Channel on the fauna in the area between Fort Worth and the headwaters of Tennessee Colony Lake would be those associated with the direct and induced habitat loss or disturbance. At present, there are only a few areas in that reach of the Trinity River that are sufficiently undisturbed so as to have diverse and viable ecological communities. Water quality in this reach is not sufficiently high to support fish, except in the most downstream portion, in tributary streams, and in a few small lakes and ponds removed from the adverse effects of the river. The overall adverse faunal impacts associated with the Authorized Project Plan Without Navigation channelization would be more severe than that associated with the Authorized Project Plan in several respects: (1) More net clearing of woody vegetation would occur, resulting in terrestrial habitat disruption; (2) severe disruption of the existing aquatic fauna would occur; (3) the raised temperature, lowered dissolved oxygen levels, increased turbidity, and wider fluctuations of in-channel flows would decrease the potential of the aquatic habitat; and (4) direct and induced drainage would eliminate many existing small ponds and lakes, thus decreasing aquatic habitat volumes and diversity.

The faunal impacts resulting from the Tennessee Colony Lake with the Authorized Project Plan Without Navigation should be evaluated in terms of the project lake pools, real estate acquisition line, and operational characteristics which differ from those of the Authorized Project Plan.

Increasing the top of the flood pool by seven feet would result in the disruptive periodic flooding of an additional 17,000 acres. Further, the approximately 49,200 acres of flood pool at lower elevations (msl 275 to msl 292) would be subjected to both longer and more frequent periods of inundation. The net result would be more severely adverse impacts on those same animals which would be adversely affected by the Authorized Project Plan. There are no known beneficial faunal impacts as a result of the project differences. The displaced fauna would be forced into adjacent habitats, many of which would not be ecologically suitable, and populations would have to adjust to the natural carrying capacity of the remaining habitat.

Downstream from Tennessee Colony Lake, the increased rate of releases for hydroelectric power generation would be expected to adversely affect the aquatic fauna to a much greater degree than could be anticipated with the Multiple-purpose Channel of the Authorized Project Plan. These downstream diurnal fluctuations in flow would be expected to be dampened out by Lake Livingston.

Severe substrate scouring would occur and benthic populations and diversity would be lowered. Only those fish species capable of adapting to a wide variety of daily flow conditions would be found in the reach from Tennessee Colony Dam to the headwaters of Lake Livingston.

From Lake Livingston downstream to Wallisville Lake, no adverse or beneficial impacts attributable to the Authorized Project Plan Without Navigation would be expected.

4.12 <u>Ground Water Changes</u>. The construction of the Reservoir Regulation Channel would result in a general decline in the flood plain alluvial ground water table. This is in contrast to the changes that would be induced by the Multiple-purpose Channel of the Authorized Project Plan, consisting of rises in the water table over almost the entire flood plain. Vegetated areas close to the river channel where the water table was formerly within 5 feet of the surface would be adversely affected by ground water table declines of up to 12 feet in the Dallas-Fort Worth area and up to 5 feet near the State Highway 34 crossing. Many of the wet-season ponds and abandoned gravel pits would be intermittently drained during low flow conditions. The recharge effects of Tennessee Colony Lake on the Carrizo-Wilcox aquifer and on the flood plain alluvial aquifer downstream from the dam would increase slightly when the lake is at flood control pool level. Recharge effects on the flood plain alluvium downstream from the dam would not extend more than 5 miles.

4.13 Impacts on Historical Structures and Sites. Those historical structures and sites situated downstream from the Tennessee Colony Dam would not be affected by the Authorized Project Plan (Plate 21). There would be no change from the effects described for the Authorized Project Plan on those structures and sites upstream from the Tennessee Colony Dam.

4.14 Impacts on Archeological Sites. The potential for disturbance of archeological sites upstream from Tennessee Colony Lake would be about the same as that for the Authorized Project Plan. Occasional inundation to the flood control pool level would have the potential to affect more sites in the lake area but this would be offset by the avoidance of disruption downstream from Tennessee Colony Dam. The total number of sites that might be affected directly by this project (and considered lost if salvage programs were not performed) is expected to range from 600 to 1,200. Upstream from Tennessee Colony Lake, the potential for post-construction salvage of sites not recorded during salvage programs would be greater with the Authorized Project Plan Without Navigation since high river stages would not be common in the Reservoir Regulation Channel.

4.15 Impacts on Paleontologic Strata. Beneficial and adverse effects on fossil occurrences downstream from Tennessee Colony Dam would be foregone with the Authorized Project Plan Without Navigation. The effects of more frequent inundation in the Tehuacana Creek area would be slightly more adverse on early Tertiary type localities, however, these localities have been well described in geologic literature (Sellards et al., 1932) and would not be considered an irretrievable loss.

4.16 Impacts on Life Quality and Socioeconomic Factors.

4.16.01 Displacement of People. Tennessee Colony Lake in the Authorized Project Plan Without Navigation, because of its larger flood pool, would require the relocation of about 25 more families than the Authorized Project Plan. About 350 of the 1,120 families affected by Tennessee Colony Lake would require assistance under the Uniform Relocation Assistance and Real Property Acquisition Act of 1970.

The relocation of 25 families along the Reservoir Regulation Channel upstream from the Tennessee Colony Lake headwaters, would represent a decrease of 78 families from the total number of families mentioned in Section 3. Those families living downstream from Tennessee Colony Lake would not be affected by channel modification under the Authorized Project Plan Without Navigation and would not require relocation assistance.

4.16.02 Leisure Opportunities and Recreation. Recreation visitation to Tennessee Colony Lake would be approximately the same as described in Section 3. There would be a substantial decrease in the number of recreationists along the channel with the Authorized Project Plan Without Navigation compared to the Authorized Project Plan because of the loss of public access and the loss of the sightseeing attraction attirbuted to navigation lockages. The total recreation visitation with this project would approach 16 million user-days annually.

4.16.03 Community and Population Growth. The Authorized Project Plan Without Navigation would avoid all effects attributable to navigation in the Authorized Project Plan. This would include the permanent growth of communities that would be brought about by the operation and maintenance of navigation facilities and all of the growth that would accrue because of navigation induced development.

The construction of residential developments on the perimeter of natural oxbow lakes and along the natural river channel would continue, or possibly accelerate, because of the flood protection which would be provided by Tennessee Colony Lake.

4.16.04 Aesthetic Values. The Reservoir Regulation Channel upstream of Tennessee Colony Lake would be less aesthetically pleasing than the Multiple-purpose Channel described for the Authorized Project Plan. The aesthetic appeal of Tennessee Colony Lake would remain much the same except for the increased eutrophication and the vegetational damage that would occur within the enlarged flood pool following extended inundation. The increased retention time of the flood waters would destroy or damage vegetation in the flood pool and would correspondingly decrease the aesthetic value of the lake. Changes in aesthetic appearances from what currently exists downstream from Tennessee Colony Dam would mainly depend on non-project related changes.

4.16.05 Impacts on Mineral Resources. With construction of the Authorized Project Plan Without Navigation, no changes in the market traffic pattern of construction aggregates would be expected. The usability of largely undeveloped gravel reserves in the midbasin area would be foregone because of a lack of economical bulk transport.

The Texas Utilities Generating Company, which operates the Big Brown Steam Electric Station near Fairfield, Texas, has indicated that considerably more lignite would be affected by the Authorized Project Plan Without Navigation than by the Authorized Project Plan. As much as 51 million tons of lignite could be affected by this project.

Construction of the Authorized Project Plan Without Navigation would result in an increase of about 20 percent in subordination (reimbursement to owners of oil and gas producing properties), and rehabilitation costs (cost of flood-proofing, providing access, etc. for wells) in the Tennessee Colony Lake area over those of the Authorized Project Plan. This increase would be incurred because of the additional land inundated by the lake at flood control pool level. Subordination and rehabilitation costs incurred by the Multiple-purpose Channel downstream from Tennessee Colony Dam would be avoided. The total net effect on these resources would be slightly more adverse with the Authorized Project Plan Without Navigation.

4.16.06 Secondary Land Use Changes. Induced land use changes surrounding Tennessee Colony Lake with the Authorized Project Plan Without Navigation would be similar to that described for the Authorized Project Plan. A decided decrease in indus rial and commercial land use from that described in Section 3 would be anticipated downstream from Tennessee Colony Lake with this project. Residential development with the Authorized Project Plan Without Navigation may increase over that described for the Authorized Project Plan, as the combination of flood protection and no disruptions to the natural river could provide the incentive to build residences downstream of Tennessee Colony.

SECTION 5 - COORDINATION WITH OTHERS

5.01 Coordination of Planning. Coordination efforts in the Corps of Engineers planning process include coordination with governmental agencies, citizen groups, and the interested public. The following paragraphs are a summary of these activities.

5.01.01 Tennessee Colony Lake Site Selection Public Meeting. A public meeting was held at Fairfield, Texas, on April 20, 1971, to obtain public participation in the siting of the midbasin lake, a component of the project. The objective of the meeting was to obtain the most beneficial siting and included the following considerations: (1) Catfish Creek watershed including Gus Engeling Wildlife Refuge and Sand Pond, (2) Coffield unit of the Texas Department of Corrections, (3) bottomland hardwood forests, (4) lands flooded by the conservation pool, (5) lands intermittently flooded by the flood control pool, (6) relocations, (7) archeological and historical sites, (8) wildlife, (9) fish, (10) mineral resources, (11) foundations, (12) cost, (13) navigation, (14) water quality, and (15) recreation. A total of 1,209 notices was issued. The total attendance was about 240, with representation by Federal, State, and local governmental agencies, industry, citizen groups, and the general public. An analysis prepared by the Corps of Engineers indicated that Tennessee Colony Site No. 2 was preferable to most of the other alternate sites in 9 of 13 categories listed above. All eight proposed damsites were considered equal from the standpoint of recreation and archeological/historical sites. Oral and written statements indicated an almost unanimous preference for the Tennessee Colony Site No. 2 as opposed to the other seven alternate sites. Subsequent design studies indicated the need for a slight adjustment in the dam alignment near the west abutment and the currently recommended site was designated Tennessee Colony Site No. 2A.

5.01.02 Environmental Planning Meetings. Public meetings were held at Arlington, Liberty, and Fairfield, Texas, on December 12, 13, and 14, 1972, respectively. The purposes of the meetings were to obtain information from citizen groups, government agency representatives, industry, and the public on matters of environmental concern, and to inform the public about the various environmental studies in progress. About 18,000 announcements were mailed, including notices to Texas members and members-elect of the United States Congress, Congressional Committees on Public Works, Texas State officials, members and members-elect of Texas State Legislature from districts within the basin, Federal, State, and local governmental agencies, postmasters, the news media, members of citizen groups, and other interested individuals. The attendance and oral and written response is listed below.

Site	Attendance	Oral Statements	Written* Statements	Mailed Statements	Petition Signatures	Resolutions
Arlington, Texas	256	41	32	113	0	0
Liberty, Texas	263	28	30	60	56	13
Fairfield, Texas	321	35	64	13	463	26

*Not including those made orally.

An analysis was made of oral and written statements, resolutions, and petitions to determine areas of interest which were of concern to the public regarding the project. These areas of interest are listed with the number of dispositions in which they were mentioned.

The project would:

Damage the environment	100
Be economically wasteful	57
Destroy a "natural" river	48
Damage Trinity Bay and/or estuaries	44
Destroy natural areas	43
Be ecologically damaging	42
Encourage development	21
Increase pollution	20
Decrease aesthetic and scenic properties	18
Provide unneeded navigation facilities	11
Waste natural resources	11
Increase crime	6
Lower quality of life	6
Lack environmental planning and management	4
Increase need for land use controls	3

The project would provide:

Environmental enhancement	623*
Water supply	618*
Flood control	609*
Recreation	578*
Wildlife preserves	497*
Improved quality of life	493*
Parks and greenways	479*
Economic development	147
Navigation	73
Increased employment	48
Population dispersal	27
Natural areas	23
Public access	14
Scientific areas	6

*Includes 426 signature petition.

Transcripts of the above public meetings are available for examination at the Corps of Engineers Library, 819 Taylor Street, Fort Worth, Texas.

5.01.03 Governmental Agencies. Interagency meetings were held on July 24-25, 1973 and October 30-31, 1974. An effort was made to include those State and Federal agencies whose regulatory responsibilities, coordination efforts, and planning expertise are heavily oriented toward project effects on natural resources. The purpose of the meetings was to inform these agencies of the nature and preliminary results of environmental studies by and for the Corps and to obtain comments and recommendations, especially in regard to reduction of adverse effects.

The following agencies were represented at both meetings:

- Bureau of Outdoor Recreation, U.S. Department of the Interior
- Fish and Wildlife Service, U.S. Department of the Interior
- National Weather Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce
- National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce
- U.S. Environmental Protection Agency
- Division of Planning Coordination, State of Texas
- Texas Parks and Wildlife Department
- Texas Water Development Board
- Texas Water Quality Board
- Trinity River Authority of Texas

5.01.03.01 July 24-25, 1973, Interagency Meeting. Presentations by Corps personnel included a synopsis of the environmental and design studies in progress. Specific subject matter which was discussed included: ground water changes, surface water fluctuations, oxbow formation, physio-chemical and biological considerations in the river and in Trinity Bay, computer model studies, recreational resource plans, Corps policies and responsibilities in regard to lands for fish and wildlife, and wild, scenic, or recreational river designations. As a result of this meeting, additional insight on the scope and nature of the various environmental effects of the project was gained by attendees.

5.01.03.02 October 30-31, 1974, Interagency Meeting. A brief description of the current status of the environmental studies was presented by Corps personnel. Most of the time was allotted to interagency exchange of ideas and information, and the following topics were discussed: project effects on mouth of river flows, Trinity River Authority water quality plan, Trinity River water quality, project effects on Trinity Bay biota, acreages for wildlife conservation, forest clearing, land use planning of cutoff areas (manmade oxbows and islands), channel alignment through Trinity Bay, maintenance dredging and acres required for disposal, 40-County area population projections, off-river alignments, and hydroelectric power.

Coordination was carried out to the extent possible by verbal communications at these meetings. Those agencies represented will be expected to further participate in the planning process by their written and verbal comments on the various aspects of the project during future formal and informal coordination. Areas and scope of responsibility vary with each agency, and whereas only foreknowledge of certain facets of the project might be required in some instances, direct participation and coordination of Corps planning will continue in others.

5.01.04 Citizen Involvement. Throughout the planning period, input will continue to be solicited from conservation, environmental, and other citizen groups, as well as from individuals. This will include personal contacts, telecommunications, letters, public notices, public meetings, workshops, and informal meetings.

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GLOSSARY OF TERMS

ABIOTIC - Nonliving; pertaining to physico-chemical factors only.

ABSORPTION - The process of taking or sucking (in).

ACCLIMATION - Adjustment to environmental change on the part of the individual; the physiological adjustment or increased tolerance shown by an organism to environmental change; nonstandard variation of acclimatization.

ACIDITY - Quality of being acid or sour; having pH less than 7. (see pH)

ADAPTABLE - Capable of undergoing inheritable (and/or nonheritable) structural or functional changes.

ADAPTATION - The result of process of long term evolutionary adjustment of a population to environmental changes.

ADSORPTION - The adherence of substances to the surfaces of bodies with which they are in contact, but not in chemical combination.

AEROBIC - Living, active or occurring only in the presence of oxygen or air.

AFFORESTATION - The process of allowing or encouraging the development of forests; in North America synonomous with reforestation.

AGGRADATION - The process of building up a surface by deposition.

AGRICULTURAL DAMAGES - Damages to growing crops, soil erosion, and deposition of undesirable material, weed infestation, loss of livestock and poultry, damages to buildings, fences, and equipment, and damages to irrigation facilities.

ALFISOLS - Soils usually light colored in the plow layer with deeper layers more clayey and higher in bases than the plow layer. These soils are moderately leached in the upper layers, but usually become more basic with depth. Layers high in carbonates or other salts may occur deep in the soil. Commonly the plow layers are thin and loamy over very clayey and slowly permeable subsoil, making many alfisols very drouthy for plants.

ALGAE - Any of a group of chiefly marine or fresh water chlorophyll-bearing aquatic plants with no true leaves, stems, or roots, ranging from microscopic single cell organisms or colonies to large macroscopic seaweeds, etc.

ALGAL BLOOM - Rapid and flourishing growth of algae.

ALKALI - A soluble mineral layer present in quantities detrimental to agriculture in some soils of basic pH in arid regions; a soluble mineral (salt) obtained from the ashes of plants and consisting largely of potassium or sodium carbonate.

ALKALINITY - A measure of cations balanced by weak acids expressed milliequivalents of neutralized hydrogen ions, in one liter of water.

ALLOCHTHONOUS - Material derived from outside habitat or environment under consideration; e.g. allochthonous detritus of a lake is that derived from surrounding terrestrial environment or from influent streams.

ALLUVIAL SOILS - Soils formed at various locations and transported to their present position by water.

ALLUVIUM - Sand, silt, and clay particles deposited in the flood plain or delta of a stream or other body of flowing water during comparatively recent geologic time.

AMBIENT - Surrounding on all sides.

AMMONIFICATION - Production of ammonia in decomposition of nitrogen-containing compounds such as proteins.

AMPHIBIAN - Any of a class of vertebrate animals, most of which pass through an aquatic larval stage with gills and then through a terrestrial stage with lungs (e.g., salamanders, frogs, and toads).

ANAEROBIC - Capable of living or active in the absence of air or free oxygen.

ANNUAL CHARGES - This figure is made up of two elements: the annual payment required to retire the investment at 3¼ percent over a period of 100 years; and the estimated average annual cost of operation, maintenance, and major replacements.

AQUATIC - Growing, living in, frequenting, or pertaining to marine or fresh water.

AQUATIC HABITAT - A habitat located in water.

AQUIFER - Permeable stratum or zone below the surface of the earth capable of producing water as from a well.

ARABLE LAND - Land fit for cultivation.

ARCHEOLOGICAL SITE - Any place revealing human occupancy, usually during prehistoric times, such as, open camps, caves, rock shelters, mounds, pictographs, bedrock mortar holes, and burial areas.

ASPECT - (Arch.) A grouping of foci which contain a number of culture traits in common.

AVIFAUNA - The total bird world (all species of birds) of a region.

BACKSWAMP - A swampy or marshy depressed area developed on a flood plain with poor drainage due to the natural levees of the river.

BACTERIA - Any of a class of free living, parasitic, or pathogenic microscopic organisms having single celled or noncellular bodies; devoid of conventional nuclei; often living in colonies; colloquial microbes.

B.P. - Before present.

BASELINE PROFILE - Used for a complete survey of the environmental conditions and organisms existing in a region prior to unnatural disturbances.

BASELINE STUDY - See Baseline Profile.

BAY HEAD DELTA - A delta at the head of a bay.

BEDROCK - A general term for the rock, usually solid, that underlies soil or other unconsolidated surface material.

BENTHIC - Of/the bottom of lakes or oceans. Of/organisms which live on the bottom of water bodies.

BENTHOS - Those organisms which live on the bottom of a body of water.

BIOCHEMICAL OXYGEN DEMAND (BOD) - The amount of oxygen required to decompose (oxidize) a given amount of organic compounds to simple, stable substances.

BIOCHEMICAL CYCLING - The movement of chemical elements from the physical environment to organisms in an ecosystem and back to the environment.

BIODEGRADABLE - Can be broken down to simple inorganic substances by the action of decay organisms (bacteria or fungi).

BIOLOGICAL DIVERSITY - The number of kinds of organisms per unit area or volume; the richness of species in a given area.

BIOLOGICAL MAGNIFICATION - The step by step concentration of substances in successive levels of food chains commonly reported only for harmful substances.

BIOLOGICAL PRODUCTIVITY - See Productivity.

BIOTA - All of the named or namable organisms of an area; fauna and flora (= biota) of a region.

BIOTIC - Of/life.

BIOTIC COMMUNITY - See Community; biotic implies plants and animals.

BIOTIC PYRAMID - The set of all food chains or hierarchic arrangements of organisms as eaters and eaten in a prescribed area when tabulated by numbers or by biomasses, usually takes a pyramidal form.

BIOTIC SUCCESSION - See Succession.

BIVALVE - A mollusc having a shell composed to two valves; e.g., a clam.

BLOOM - To flower; of algae, to appear or occur suddenly or in large quantity or degree; see Algal Bloom.

BOG - A quagmire or wet, spongy ground; often a filled in lake; composed primarily of dead plant tissues (peat); principally mosses.

BRACKISH WATER - Water, salty between the concentrations of fresh water and sea water; usually 5-10 parts per thousand.

BROWSE - Shoots, twigs, and leaves of trees and shrubs eaten by cattle or other large herbivores, e.g., deer.

BUFFER - An intermediate region or ecotone between two systems whose presence reduces the effects of one system on the other; a chemical substance which tends to maintain constant pH.

cfs - Cubic feet per second, is a hydrological unit which is the equivalent of 449 gallons per minute.

CHLORINATION - Treatment or combination with chlorine or a chlorine compound, usually for the purpose of killing harmful organisms.

CLIMATE - The average conditions of the weather over a number of years; macroclimate is the climate representative of a relatively large area; microclimate is the climate of a small area, particularly that of the living space of a certain species, group, or community.

CLIMAX - The final, stable community in an ecological succession which is able to reproduce itself indefinitely under existing conditions.

COEFFICIENT OF TRANSMISSIBILITY - The rate of flow in gallons per day through a vertical section of an aquifer whose height is the thickness of the aquifer and whose width is one foot when the hydraulic gradient is 1.00.

CONSERVATION POOL LEVEL - The elevation of a water surface in feet above mean sea level, below which the water is designated for water supply, except that volume designated for sediment storage.

CUESTA - A sloping plain terminated on one side by a steep slope.

DAMAGES TO TRANSPORTATION FACILITIES - Damages to railroads, highways, and county roads.

DAMAGES TO UTILITIES - Damages to electric power lines, telephone and telegraph lines, and pipelines.

DELTA - The alluvial deposit at the mouth of a river.

DENITRIFICATION - Chemical conversion of nitrates to molecular (gaseous) nitrogen (N_2) or to nitrous oxide or to ammonia by bacteria (in soil or water) or by lightning (in air).

DEPENDABLE YIELD - The maximum rate at which water can be withdrawn continuously from the water supply storage of a lake without incurring a shortage during the most critical drought of record.

DETRITUS (ecology) - A mixture of living and dead organic matter washed or dropped into a stream river, or lake.

DIATOMS - Microscopic planktonic or attached single celled or colonial algae which have cases of silica.

DIP - The angle that a structural surface, e.g., a bedding or fault plane, makes with the horizontal, measured perpendicular to the strike of the structure.

DISSOLVED OXYGEN - An amount of gaseous oxygen dissolved in volume of water.

DISTRIBUTION - The geographic range of a species.

DIVERSITY - See Biological Diversity.

DOMINANCE - The degree of influence (usually inferred from the amount of area covered) that a species exerts over a community.

DOMINANT - An organism that controls the habitat at any stage of development; in practice the organism that is most conspicuous and covers the most area.

DOWNDIP - A direction that is downwards and parallel to the dip of a structure or surface.

ECOLOGICAL BALANCE - Range of response normally expressed by an unperturbed ecosystem.

ECOLOGICAL DOMINANCE - Pertains to a species' control, competitiveness, and alteration of conditions for the remainder of the community.

ECOLOGICAL INDICATOR - Use of certain species' tolerances to reflect or infer more general environmental characteristics; see Indicator.

ECOLOGICAL SUCCESSION - See Succession.

ECOLOGY - The study of the interrelationships of organisms with and within their environment.

ECONOMIC REDEVELOPMENT BENEFITS - In areas that answer national criteria for economically depressed areas, this type of benefit is computed by estimating the number of unemployed and underemployed people who would be provided with jobs as a result of the construction and operation of the proposed project; the estimated amount of wages paid to these people provide the total of this type of benefits.

ECOSYSTEM - A community and its (living and nonliving) environment considered collectively; the fundamental unit in ecology. May be quite small, as the ecosystem of one celled plants, in a drop of water, or indefinitely large, as in the grassland ecosystem.

ECOSYSTEM DYNAMICS - Characteristic and measurable processes within an ecosystem such as (1) succession; (2) energy flow and nutrient cycling; (3) community metabolism.

EDAPHIC - Of/the influence of the soil especially on the vegetation growing upon it without reference to climate.

EMERGENT - Aquatic plants, usually rooted, which during part of their life cycle have portions above water.

EN ECHELON - Parallel structural features that are offset like the edges of shingles on a roof when viewed from the side.

ENDANGERED SPECIES - Species that are in danger of becoming extinct.

ENDEMIC - Indigenous or native in a restricted locality; confined naturally to a certain limited area or region.

ENERGY (ECOLOGICAL) - Most commonly, that portion of the visible solar radiation (light) captured by plants and ultimately used for food by the animals in an ecosystem.

ENVIRONMENT - The sum total or the resultant of all the external conditions which act upon an organism.

ENVIRONMENTAL CRITERIA - Standards of physical, chemical, and biological (but sometimes including social, aesthetic, etc.) components that define a given quality of an environment.

ENVIRONMENTAL EFFECT - Resultant of natural or manmade perturbations of the physical, chemical, or biological components making up the environment.

ENVIRONMENTAL INVENTORY - A listing of the components making up an environment - or a listing of types of environments.

ENVIRONMENTAL PARAMETERS - Physical, chemical, or biological components and their interactions which can be stated in quantitative terns; a parameter is what is measured by a statistic.

ENVIRONMENTAL QUALITY - Human (individual or social) considerations of desirable ecological situations.

EPILIMNION - The turbulent superficial layer of a lake between the surface and a horizontal plane marked by the maximum gradient of temperature and density change. Above the hypolimnion.

ESCARPMENT - A steep face terminating high lands abruptly.

ESTUARINE - Of/the mouth region of a river that is affected by tides.

EUPHOTIC - Of the upper layers of water in which sufficient light penetrates to permit growth of green plants.

EURYHALINE - Of/species peculiar to or living in brackish waters of marine or nonmarine origin, and which are resistant to great changes in salinity.

EURYTHERMAL - Of/organisms having the ability of living through a wide range of temperature conditions.

EUTROPHIC - (Literally, "well fed") Of/lakes characterized by the paucity or absence of oxygen in the bottom waters; as a consequence of high primary production and high nutrient content.

EVAPOTRANSPIRATION - The total water loss from the soil, including that by direct evaporation and that by transpiration from the surfaces of plants.

EXOTIC - Of/any non-native or rare species; usually introduced.

FAULT - A surface or zone of rock fracture along which there has been displacement.

FAUNA - The animals of a given region taken collectively; as in the taxonomic sense, the species, or kinds, of animals in a region.

FERRUGINOUS - Pertaining to or containing iron.

FIRST COST - Total cost of project including lands and damages, construction costs, engineering and design, supervision and administration, and cost of future facilities discounted to present worth at estimated time of initiation of construction.

FISH KILL - Pertaining to sudden death of fish population.

FISHERY - Of/fish populations as the basis of an industry, recreational or commercial.

FLOOD CONTROL BENEFITS - The monetary difference between the average annual damages caused by floods before and after construction of a flood control project in a specific geographic area.

FLOOD PLAIN (ecology) - That portion of a river valley which is covered in periods of high (flood) water; ordinarily populated by organisms not greatly harmed by short immersions.

FLUVIAL (ecology) - Applied to plants growing on streams.

FLUVIATILE - Resulting from river action.

FOCUS (Arch.) - One or more sites consistently revealing similar culture traits (similar people living during a limited time span).

FOREST/WOODLAND - An area covered by a growth of trees and/or brush so that more than half of surface has a vegetative canopy above five feet in height.

FLYWAY - Of/the routes taken by migratory birds, usually waterfowl, during migration.

FOOD CHAIN - Animals linked together by food and all dependent, in the long run, on plants.

FOOD WEB - See Food Chain. Implies many cross connections rather than straight line connections.

FORAGE FISH - Fish eaten by other fish.

FOREST - An association dominated by trees; usually defined as woody plants over 10 meters tall.

FRASCH SULFUR - Sulfur mined using a hydraulic method in which superheated water that has been forced into the in-place deposits to dissolve the sulfur is pumped to the surface and treated to recover the sulfur.

GAME - Wild animals usually mammals or birds hunted for sport or food and subject to legal regulations.

GENERAL DESIGN MEMORANDUM - A two-phase report which presents the results of appropriate studies that either reaffirms or reformulates the authorized project for present day conditions (Phase I) and provides the functional design of structures necessary to achieve project objectives (Phase II).

GENUS - A unit of biological classification (taxonomy), including one or several species sharing certain fundamental characteristics, supposedly by common descent.

GLAUCONITIC - Containing glauconite, a mineral consisting of a dull green earthy iron potassium silicate occurring abundantly in greensand.

GRADIENT - A more or less continuous change of some property in space. Gradients of environmental properties are ordinarily reflected in gradients of biota.

GRASSLAND - An area in which grasses are the major plants; trees and shrubs are largely absent.

GREENBELT - A plot of vegetated land separating or surrounding areas of intensive residential or industrial use and devoted to recreation or park uses.

GROUND WATER - Water found underground in porous rock or soil strata.

HABITAT - The environment; usually the natural environment in which a population of plants or animals occurs.

HERBACEOUS - Of/any plant lacking woody tissue in which the leaves and stem fall to ground level during freezing or drying weather.

HERBICIDE - A chemical substance used to kill plants or inhibit plant growth.

HERBIVORE - An organism which eats living plants or plant parts.

HETEROTROPHS - Organisms which must obtain their food from living or dead organic matter.

HILLOCK - A small hill.

HISTORICAL SITE - A site related in some important way to local, State, or National history - such as battlegrounds, places where famous people lived or are buried, important events took place, or an activity contributed meaningfully to the settlement of a region.

HISTORICSL STRUCTURE - An historical structure is considered to be a work of man, consciously created to serve some form of human activity.

HOLOCENE - An epoch of the Quaternary period, from the end of the Pleistocene to the present time.

HUMAN ENVIRONMENT - The sum total of all conditions and influences including (but not limited to) aesthetic, ecological, cultural, social, economic, historical, etc. that affect human life.

HYDRAULIC CONDUCTIVITY - The rate of flow of water through a porous medium such as soil or rock.

HYDRAULIC HEAD - The water level at a point upstream from a given point downstream.

HYDROPHILIC VEGETATION - Water-loving plants.

HYDROPOWER BENEFITS - The difference between the average annual cost of providing hydropower electrical energy and providing the same electrical energy by the next most economical means, generally some type of fossil fuel generating plant.

HYPOLIMNION - The lowermost layer of water in a lake. In certain lakes, the portion (below the zone of warmer water or thermocline) which receives no direct heat from sunlight and no aeration by vertical circulation.

INVESTMENT COST - First cost plus interest during construction. Interest during construction is approximated in planning stages by assuming a straight line average of the interest rate (in this case 3¼ percent) times one-half the estimated construction period.

INVERTEBRATE - Any animal lacking a backbone (i.e., insects, spiders, crustaceans, segmented worms, round and flatworms, molluscs, etc.)

IRRIGATION - To supply agricultural land with water by artificial means.

ISOTHERM - A line on a map connecting points having the same temperature at the same time.

LACUSTRINE - Of/originating in, or inhabiting a lake.

LAGTIME - The delay between some event and its effect.

LAKE - A large body of water contained in a depression of the earth's surface and supplied from drainage of a larger area. Locally may be called a pond.

LAKE TURNOVER - The complete top-to-bottom circulation of water in a lake which occurs when the density of the surface water is the same or slightly greater than that at the lake bottom; most temperate zone lakes circulate in spring and again in fall.

LARVA - An early developmental stage of an animal which changes structurally when it becomes an adult (e.g., a tadpole or caterpillar).

LENTIC - Of/still or slowly flowing water situations (e.g., lakes, ponds, swamps).

LENTICULAR - Having the shape of a double convex lens.

LIFE CYCLE or LIFE HISTORY - The series of changes or stages undergone by an organism from fertilization, birth, or hatching to reproduction of the next generation.

LIMITING FACTOR - An environmental factor (or factors) which limits the distribution and/or abundance of an organism or its population, i.e., the factor which is closest to the physiological limits of tolerance of that organism.

LIMNETIC ZONE - The open water zone of a lake or pond from the surface to the depth of effective light penetration; offshore, from areas shallow enough to support rooted aquatic plants.

LIMNOLOGY - The study of the biological, chemical, and physical features of inland waters.

LITHOLOGIC SEQUENCE - The description of rocks in order of their depth based on such characteristics as color, structure, mineralogic composition and grain size.

LOTIC - Of/rapid water situations, living in waves or currents.

LOWER FORM FAUNA - Invertebrates.

MACROFAUNA - The large (i.e., visible to the naked eye) animals of an area.

MACROPHYTES - Large bodied aquatic plants; nonmicroscopic.

MARINE - Of/the sea or ocean.

MARL - Material consisting chiefly of an intimate mixture of clay and calcium carbonate in varying proportions, formed under either marine or especially fresh water conditions.

MARSH - A tract of low lying soft, wet land, commonly covered (sometimes seasonally) entirely or partially with water; a swamp dominated by grasses or grass-like vegetation.

MEANDER SCAR - Crescent shaped cuts bordering a stream or river which were cut by lateral planation on the outer part of the meander loop.

mg/l - Milligrams per liter - a unit used in quantifying the weight of solute per volume of solvent.

MICACEOUS - Containing mica, any of various colored or transparent mineral silicates crystallizing in monoclinic forms that readily separate into very thin leaves.

MICROMHOS - A unit of specific conductance used as an estimate of dissolved substances present in water.

MIGRATION - A regular movement from one region to another.

MOLLISOLS - Soils that are dark colored in the surface layer, soft, granular, and generally do not set hard when dry. They form under limited leaching in subhumid and semiarid regions. Parent materials are high in bases, especially calcium, in contact with decomposing organic matter in, rather than on, the soil.

MOLLUSC - Any of a phylum of invertebrate animals including oysters, clams, mussels, snails, slugs, squids, octupi, whelks, and other shellfish.

MONOCLINE - A unit of strata that dips or flexes from the horizontal in one direction only.

msl - Mean sea level.

NATIONAL PLANNING ACCOUNTS - The four specific classifications or descriptive categories, national economic development, environmental quality, regional development, and social well being, under which the effects of a proposed action are to be discussed or displayed. These four accounts are set forth by the United States Water Resources Council as germane to the planning of water and related land resources development considerations.

NATIONAL PLANNING OBJECTIVES - The two specific target conditions of national economic development and environmental quality, set forth by the United States Water Resources Council, that are to be emphasized during the planning of water and related land resources actions.

NAVIGATION BENEFITS - From extensive transportation studies in a hydrological/geographic area, the types and amount of transported goods economically suitable for barge traffic are computed; cost to transport these goods by water is estimated and compared to the cost of transporting the same goods by the most economical existing transportation method; the differences in costs (if waterborne is cheaper) are navigation benefits.

NITRIFICATION - A step in the nitrogen cycle technically involving oxidation of nitrogen, e.g., from ammonia (NH_3) to nitrates (NO_3). Soil dwelling (chemosynthetic) bacteria nitrify ammonia in two steps, to nitrite (NO_2) and to nitrate (NO_3) in which form it is most available to plants. Chemical reduction of nitrogen, as to N_2, is denitrification.

NITROGEN FIXATION - A step in the nitrogen cycle involving hydrogenation (reduction) of molecular nitrogen (N_2) to amino or ammonia nitrogen (NH_2 or NH_3) performed by certain nitrogen-fixing (soil) bacteria and blue-green algae.

NONRENEWABLE RESOURCE - A natural, normally nonliving, resource such as a mineral which is present in finite supply and is not renewed by natural system.

NONSTRUCTURAL FLOOD CONTROL BENEFITS - Are the damages prevented by adoption of certain courses of action other than project construction.

NURSERY AREA - An area where animals congregate for giving birth or where the early life history stages develop, e.g., estuaries for shrimp, Scammon's Lagoon, Baja, California, for gray whale).

NUTRIENTS - Chemical elements essential to life. Macronutrients are those of major importance required in relatively large quantities (C, H, O, N, S, and P); micronutrients are also important but required in smaller quantities (Fe, Mo).

NUTRIENT CYCLING - The movement of nutrients from the nonliving (abiotic) through the living (biotic) parts of the environment and back to the abiotic parts.

O&M - Operation and maintenance.

ORGANISM - Any living or recently dead thing.

OUTCROP - That part of a geologic formation or structure that appears at the surface of the earth; also bedrock that is covered only by surficial deposits such as alluvium.

OXYGEN DEPLETION - Removal or exhaustion of oxygen by chemical or biological absorption.

PARAMETER - One of a set of physical properties whose values determine the characteristics of a system.

PERIPHYTON - Community of organisms usually small but densely set, closely attached to stems and leaves of rooted aquatic plants or other surfaces projecting above the bottom.

PESTICIDE - Toxic chemical used for killing pest organisms. Usually widely toxic to many living things (see Herbicide, Insecticide).

PHREATOPHYTE - A plant which derives its water supply from ground water and is more or less independent of rainfall.

PHYTOPLANKTON - Small, mostly microscopic, plants floating in the water column. (See Benthos, Neuston).

PIEZOMETRIC HEAD - The elevation to which the water of a given aquifer will rise in a piezometer (an observation well).

PLANKTON - Small organisms (animals, plants, or microbes) passively floating in water; macroplankton are relatively large (1.0 mm to 1.0 cm); mesoplankton of intermediate size; microplankton are small.

PLANT NUTRIENTS - See Nutrients.

POINT BAR DEPOSIT - Sediment deposited on the inside of a growing meander loop.

POLLUTANT - A residue (usually of human activity) which has an undesirable effect upon the environment (particularly of concern when in excess of the natural capacity of the environment to render it innocuous).

POLLUTION - An undesirable change in atmospheric, land, or water conditions, harmfully affecting the material or aesthetic attributes of the environment.

POOL ELEVATION - The designed water surface elevation of a pool above mean sea level in feet.

POTENTIOMETRIC SURFACE - An imaginary surface representing the static head of ground water and defined by the level to which water will rise in a well.

PREDATOR - An organism, usually an animal, which kills and consumes another organism in whole or in part.

PREDOMINANT - DOMINANT - An organism of outstanding abundance or obvious importance in a community.

PRODUCER - PRODUCER ORGANISM - An organism which can synthesize organic material using inorganic materials and an external energy source (light or chemical). See Autotroph; also Biotic Pyramid.

PRODUCTIVITY - The rate of production of organic matter produced by biological activity in an area or volume, e.g., grams per square meter per day, or other units of weight or energy per area or volume and time.

PROGRADATION - A seaward advance of the shoreline resulting from the near shore deposition of sediments brought to the sea by rivers.

RANGE - The Geographic area of occurrence of a species; the region over which a given form occurs, naturally or after introduction.

RECREATION, FISH AND WILDLIFE BENEFITS - Estimates are made as to the expected visitation to the project by the various types of the recreation public. Unit values (generally about $1 to $1.25 per man-day for general recreation activities, $1.50 per man-day for fishing, and $3 per man-day for hunting) are multiplied by the estimated visitation for the various types of recreation visitation and totaled to obtain benefits.

REDUCTION - A reaction between molecules in which the transfer of an electron is involved (the reduced molecule acquires an electron). Ordinarily involves loss of oxygen and/or addition of hydrogen.

REPTILES - One of the major groups of vertebrate animals, including crocodilians, turtles, lizards, and snakes, having scales or horny plates, true lungs, and a three- or four-chambered heart.

RESERVOIR - An artificially impounded body of water, a manmade lake.

RESPIRATION - (Commonly) breathing; (in biology) the oxidative break-down of food molecules by cells with the release of energy.

RIVERBANK OVERSTORY - Those plants growing along streams whose canopies occupy the greatest heights.

RIVER MILE (R.M.) - Distance in miles along the centerline of a river above a designated point at the mouth of a river.

ROOKERY - The breeding or nesting place of colonies of birds, seals, etc.

RURAL NONAGRICULTURAL DAMAGES - Damages to physical property and loss of production of rural industrial properties such as oil fields, sand and gravel plants, and other property of this type.

SALINITY - The sum concentration of all salts or ionic components; concentration of sodium chloride is, technically, halinity or sodium chlorinity.

SALINITY WEDGE - The movement of subsurface saline water into an aquifer, or in an estuary. Of a body of saline (sea) water under the fresh water.

SALT DOME - A piercement structure with a central salt plug, generally one to two kilometers or more in diameter, which has risen through the enclosing sediments from a mother salt bed.

SALT MARSH - Similar to a fresh (grass dominated) marsh, but adjacent to marine areas covered periodically (tidally or seasonally) with saline water.

SAPROBIC - Of/forms living in foul, badly polluted, or septic waters.

SECONDARY EFFECTS - Those effects not considered to be the direct result of an action but were project induced.

SEDIMENT - Any usually finely dived organic and/or mineral matter deposited by air or water in nonturbulent areas.

SESSILE - Stationary; attached; nonmoving; in botany, nonstalked.

SHELL FISH - Aquatic animals, usually molluscs, having an external shell or exoskeleton.

SHRUB - A woody perennial of smaller height than a tree.

SILTATION - Referring to the deposition of silt sized (smaller than sand sized) particles.

SLOUGH - A wet place of deep mud or mire, or temporary or permanent lake; ordinarily found on or at the edge of the flood plain of a river.

SLUDGE - (Biological) The organic or mixed organic and inorganic deposit accumulating on the bottom of a stream; particle size is that of silt or clay (not sand).

SMSA - Standard Metropolitan Statistical Area consisting of a county with one or more cities of at least 50,000 population, plus any adjacent counties that are metropolitan in character and economically integrated with the central county.

"SPECIAL" CLAYS - Fullers earth, bentonite, ball clay, fireclay, and kaolin.

SPECIES COMPOSITION - Referring to the kinds and numbers of species occupying an area.

SPECIES DIVERSITY - Refers to the number of species or other kinds in an area, and, for purposes of quantification, to their relative abundance as well.

SPECIES DIVERSITY INDEX - An index comparing relative size of populations and number of species.

STANDARD PROJECT FLOOD (SPF) - The SPF for a given project is calculated by relating the record rainstorms for the surrounding weather region to the rainfall runoff area above the project, and using hydrological and hydraulic methods to predict flow elevations and volumes that would pass through the project area. SPF's usually occur less frequently than once in 100 years but can occur any year.

STORM-WASHOVER FANS - Fan-like deposits consisting of sand washed onto the shore during a storm.

STRANDLINE - The line or level at which a body of standing water, as the sea, meets the land (the shoreline), especially a former shoreline.

STRATIFICATION (ecology) - The natural division of plant community into superposed strata or layers; also, division of a water body into two or more depth zones, as in "thermal" or "density stratification."

STRATIGRAPHIC CLASSIFICATION - Classification of stratified rocks and geologic time into rock, time-rock, time and biostratigraphic units.

STRATUM PLAINS - Level or nearly level areas in which the depth of erosion is controlled by level or gently sloping resistant strata.

STRIKE - The direction or trend that a structural surface, e.g., a bedding or fault plane, takes as it intersects the horizontal.

SUBSTRATE (ecology) - The layer on which organisms grow, often used synonomously with surface of ground; also, the substance, usually a protein, attached by an enzyme; often but improperly used as a variant of substratum.

SUCCESSION - The replacement of one community by another; the definition includes the (controversial or hypothetical) possibility of "retrograde" succession.

SUCCESSION, PLANT - The replacement of one kind of plant assemblage by another through time.

SUCCESSION, SECONDARY - Refers to succession which occurs on formerly vegetated areas (i.e., having an already developed soil) after disturbance or clearing.

SUSPENDED SOLIDS - Refers to solid (particulate) materials held in suspension, i.e., in more or less turbulent air or water, and capable of settling out when turbulance ceases.

SWAMP - A flat, wet area usually or periodically covered by standing water and supporting a growth of trees, shrubs, and grasses; in contrast to a bog, the organic soil is thin and readily permeated by roots and nutrients.

TAXONOMY - The study of principles and practice for the orderly classification of organisms.

TERRESTRIAL - Of/land, the continents, and/or dry ground; contrasted to aquatic.

THALWEG - The imaginary line joining the deepest points of a stream valley, whether underwater or not.

THERMOCLINE - A narrow (horizontal) zone of water in lakes and oceans with a steep temperature gradient, separating a warmer surface layer (epilimnion, epithalassa) from a cooler bottom layer (hypolimnion, hypothalassa); as a thermocline is a plane, but a zone is observed, the preference or usual term is metalimnion.

THERMAL STRATIFICATION - The seasonal formation of horizontal layers of water in lakes and oceans (warm surface, cool bottom) of markedly varying temperatures, separated by a zone with a steep temperature gradient.

TIDAL MARSH - Marsh land periodically inundated by tidal oceanic or estuarine water, i.e., salt marsh.

TOXIC - Of/poison.

TRANSECT - A line (or belt) through a community on which are indicated the important characteristics of the individuals of the species observed; sampling along a transect may be plotless or refer to specific plots.

TRANSPIRATION - The loss of water from plants normally as vapor.

TRELLIS DRAINAGE PATTERN - A stream pattern in which master and tributary streams are arranged nearly at right angles with respect to one another.

TRINITY RIVER BASIN WATER RESOURCE NEEDS - Quantified objectives that might be attained by water resource development activities in the Trinity River Basin.

TRINITY RIVER BASIN WATER RESOURCE PLANNING ALTERNATIVES - Possible courses of action, other than the contemplated course, that offer the possibility of accomplishing a specific water resource need of the Trinity River Basin.

TRINITY RIVER BASIN WATER RESOURCES PLANNING OBJECTIVES - Goals whose attainment would alleviate or eliminate water associated problems in the Trinity River Basin.

TRINITY RIVER PROJECT ALTERNATIVES - Possible courses of action, other than the contemplated course, that offer the possibility of accomplishing one or more of the Trinity River Project purposes.

TRINITY RIVER PROJECT PURPOSES - The specific goals that would be attained if the Trinity River Project were constructed. These are: (1) flood control, (2) water supply, (3) navigation, (4) public recreation, (5) fish and wildlife programs, and (6) hydroelectric power.

TROPHIC - Of/nourishment or feeding. See Eutrophic, Biotic Pyramid. (To be carefully distinguished from TROPIC, responding or inclining, and TOPIC, referring to place).

TROPHIC LEVEL - All organisms which secure their food at a common step away from the first level, e.t., (1) plants, (2) herbivores, and (3) carnivores.

TRUNCATE - To cut the top or end from; to terminate abruptly as if cut or broken off.

TURBIDITY - Condition of water resulting from suspended matter; water is turbid when its load of suspended material is conspicuous.

TYPE LOCALITY - The place where a geologic feature was first or originally recognized and described.

UBIQUITOUS - Being found in many widely divergent places; able to thrive under different conditions.

ULTISOLS - Light colored sandy and loamy acid soils of humid regions commonly with yellowish brown or mottled soil below the plow layer which is less clayey. These soils have a low base status accounted for by parent sediments low in bases by leaching. The return of bases to the surface is largely limited to the cycle through tree vegetation. These soils are very deficient in plant nutrients. Its layers are well developed, highly contrasting in color and texture.

UNDERSTORY - Vegetation zone lying between the forest canopy (overstory) layer and the vegetation covering the ground (ground cover).

UPLAND - All types of land forms other than depressions (occupied by lakes, swamps) and those areas in close proximity to rivers, streams, or seas (flood plains, beaches, mud or tide flats, salt marshes).

UPLAND GAME - Term describing huntable animals living in upland areas.

USER DAY - A standard unit of use consisting of a visit by one individual to a recreation development during any reasonable portion or all of a 24-hour period.

VASCULAR - Of/vessels or channels for conveying fluids (as blood or sap); also, tissues supplied with such channels.

VECTOR - An organism that carries a disease, parasite, or infection.

VECTOR CONTROL - Process of controlling a disease, parasite, or infection by control of the carrier.

VEGETATION - Plants in general, or the total assemblage of plants, and their gross appearance as determined by the larges and most common. Flora is used for the list of kinds of plants.

VERTEBRATE - Those animals possessing a spinal column or backbone, i.e., fishes, birds, amphibians, mammals, and reptiles.

VERTISOLS - Clay soils that shrink and develop wide cracks during dry seasons followed by expansion or swelling on rewetting during moist seasons. They have a high capacity for holding plant nutrients and water, but when moist they are slowly permeable to water and air. Commonly they are dark colored from the surface down to as much as 3 to 6 feet. They have gradually changing wavy boundaries between layer' of little contrast except in organic matter content and asso' ed changes in soil color.

WASTE. TER - Water derived from a municipal or industrial waste treatment plant.

WATERFOWL - Birds frequenting water; ordinarily referring to game birds such as ducks and geese.

WATERSHED - An entire drainage basin contributing to the supply of river or lake.

WATER SUPPLY BENEFITS - The difference between the estimated user cost of developing a source of water supply (converted to average annual values), and the estimated cost of developing the next most likely equivalent source of water supply in the absence of the proposed project.

WATER TABLE - The upper limit of that part of the ground which is saturated with water.

WEIR - A device for determining the quantity of water flowing over it from measurements of the depth of water over the crest or sill and known dimensions of the device.

WETLANDS - Land containing high quantities of soil moisture, i.e., where the water table is at or near the surface for most of the year.

WILDLIFE - Undomesticated animals; often hunted or at least noticed by man, and therefore consisting mainly of mammals, birds, and a few lower vertebrates and insects.

WILDLIFE ENHANCEMENT - Manipulation of wildlife habitat regions to promote increases in the amount or quality of living animals.

WILDLIFE HABITAT - The combination of vegetative and physical features which present animals with suitable or maximized living conditions.

WIND ROSE - A diagram showing the frequency and strength of winds from different directions for a given place.

ZOOPLANKTON - Small aquatic animals. See Plankton.

METRIC-ENGLISH CONVERSION TABLE

Length

1 centimeter (cm.) = 0.3937 inch
1 foot (ft.) = 0.3048 meter
1 inch (in.) = 2.54 centimeters
1 kilometer (km.) = 0.621 mile
1 meter (m.) = 39.37 inches   1.094 yards
1 millimeter (mm.) = 0.03937 inch

Areas or surfaces

1 acre = 43,560 square feet = 4,840 square yards.
1 square centimeter (cm^2) = 0.155 square inch
1 square foot (sq.ft.) = 929.030 square centimeters
1 square inch (sq.in.) = 6.452 square centimeters
1 square meter (m^2) = 1.196 square yards
10.764 square feet
1 square yard (sq.yd.) = 0.836 square meter

Capacities or volumes

1 cubic centimeter (cm^3) = 0.061 cubic inch
1 cubic foot (c.ft.) = 7.481 gallons
0.0283 cubic meter
1 cubic inch (c.in.) = 16.387 cubic centimeters
1 cubic meter (m^3) = 1.308 cubic yards
1 cubic yard (cu.yd.) = 0.765 cubic meter
1 gallon (gal.)(U.S.) = 231 cubic inches
3.785 liters
1 liter (l.) = 1.057 liquid quarts
0.908 dry quart
61.025 cubic inches
1 milliliter (ml.) = 0.061 cubic inch
1 quart (qt.)(dry) = 67.201 cubic inches
1.101 liters
1 quart (qt.)(liquid) = 57.75 cubic inches
0.946 liter
1 acre-foot (ac.ft.) = 1.2335 hectare-decimeter

Weights or masses

1 gram (g.) = 0.035 ounce Avoirdupois
1 kilogram (kg.) = 1,000 grams = 2.205 pounds
1 microgram (mg.) = 0.000001 (one millionth) gram
1 millogram (mg.) = 0.001 (one thousandth) gram
1 ounce Avoirdupois (oz. Avdp.) = 28.350 grams
0.911 troy or apothecaries ounce
1 ounce, troy or apothecaries (oz. t. or oz. ap.) = 31.103 grams
1.097 avoirdupois ounces

1 pound Avoirdupois (lb. avdp.) = 453.59237 grams
1.215 trcy or apothecaries pounds

1 ton, gross or long ton (gross tn.) = 2,240 pounds
1.12 net tons
1.016 metric tons

1 ton, etric (t.) = 2,204.623 pounds
0.984 gross tons
1.102 net tons
1,000 kilograms

1 ton, net or short (tn.) = 2,000 lbs.
0.893 gross ton
0.907 metric ton

Flow rates table

1 mgd = 1.55 cfs = 11.59 gallons per second
1 cfs = 448.8 gallons per minute
1 acre foot/year = 892.7 gpd = .62 gallons per minute