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Waterways Experiment Station

Geomorphic Investigation of Shreveport to Daingerfield Navigation Project

by Paul E. Albertson, Joseph B. Dunbar
Geotechnical Laboratory

WES

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Prepared for U.S. Army Engineer District, Vicksburg

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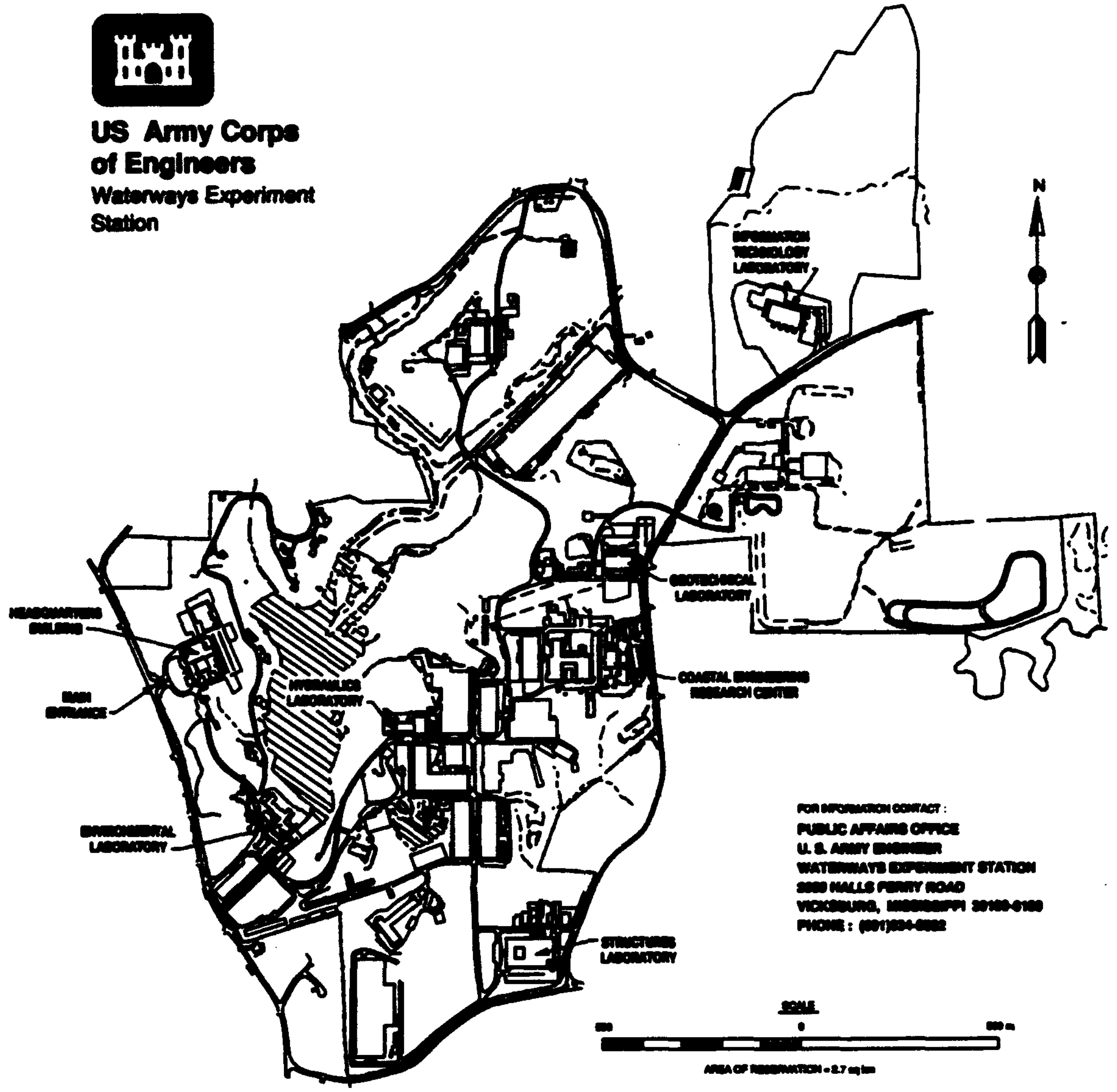

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Preface

The U.S. Army Corps of Engineers, Waterways Experiment Station (WES), was authorized by the U.S. Army Engineer District, Vicksburg (CELMK), to conduct the investigation, "Geomorphic Investigation of Shreveport to Daingerfield Navigation Project," dated 21 May 1991. Mr. Tommy Birchett (CELMK-PD-Q) was the program manager for this study.

This investigation was begun and the report was prepared by Messrs. Paul E. Albertson and Joseph B. Dunbar during the period June 1991 to May 1993. Geomorphic mapping was conducted primarily by Mr. Albertson. Messrs. Albertson and Dunbar are with the Geological Environments Analysis Section (GEAS), Engineering Geology Branch (EGB), Earthquake Engineering and Geosciences Division (EEGD), Geotechnical Laboratory (GL), WES.

Messrs. Shawn Dueitt and Kurt Knessel, contract students, University of Southern Mississippi, Hattiesburg, MS, and Gary Hennington, GEAS, assisted with report illustrations and compilation of the archaeological data.

A general field reconnaissance of the Shreveport to Daingerfield Navigational Project area was conducted by the authors and Mr. Birchett during the period 19 to 22 November 1991. A detailed field reconnaissance, including soil sampling of selected geomorphic environments, was conducted during the period 20 to 31 July 1992 by the authors and Messrs. Knessel and Terrance Wright, Jackson State University, Jackson, MS.

This investigation was performed under the direct supervision of Mr. Joe Gatz, Chief, EGB, Dr. A. G. Franklin, Chief EEGD, and Dr. William F. Marcuson III, Director, GL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

1 Introduction

Background and Study Area

The U.S. Army Engineer District, Vicksburg (CELMK), is currently evaluating the opening of the Shreveport, LA, to Daingerfield, TX, segment of the Red River Waterway for navigation to Daingerfield (Figure 1). The proposed project, authorized by U.S. House of Representatives Document NO. 304 (dated 2 May 1968), would provide for a 9-ft (2.74-m)-deep and 200-ft (60.96-m)-wide channel from the Red River to Lake O' the Pines. The proposed project requires 75 miles (120.7 km) of channel dredging and the construction of three locks and dams. It will traverse Twelvemile Bayou, Caddo Lake, and Big Cypress Bayou, and it will extend into the upper reach of Lake O' the Pines. The study area contains approximately 450 square miles (1,165 square km) and is identified in Figure 1.

Purpose and Scope

The purpose of this investigation is to provide a geomorphic framework for the cultural resources research of the Shreveport to Daingerfield project area. Specific objectives of this investigation are as follows: identify and map the geomorphic features or landforms in the study area on appropriate scale base maps, define the geomorphic processes that are active in the study area, reconstruct to the extent possible the geomorphic development of the study area, and determine the significance of the geomorphic features in terms of locating previously unknown archaeological sites and the potential for discovering buried sites.

The major focus of this investigation is the Big Cypress Bayou Drainage Basin, since this area either has no documented information or contains only limited geomorphic and cultural resources data. The absence of any detailed geomorphic and cultural resources data for this reach of the study area is in sharp contrast to the amount of detailed information that is available for the Red River Valley near Shreveport, LA. Because of the disparity between the levels of data between the upper and lower study reaches, this investigation will concentrate primarily on the Big Cypress Bayou portion of the study area. The Red River Valley segment will be evaluated in general terms as geomorphic influences on the Red River affected the upper study area.

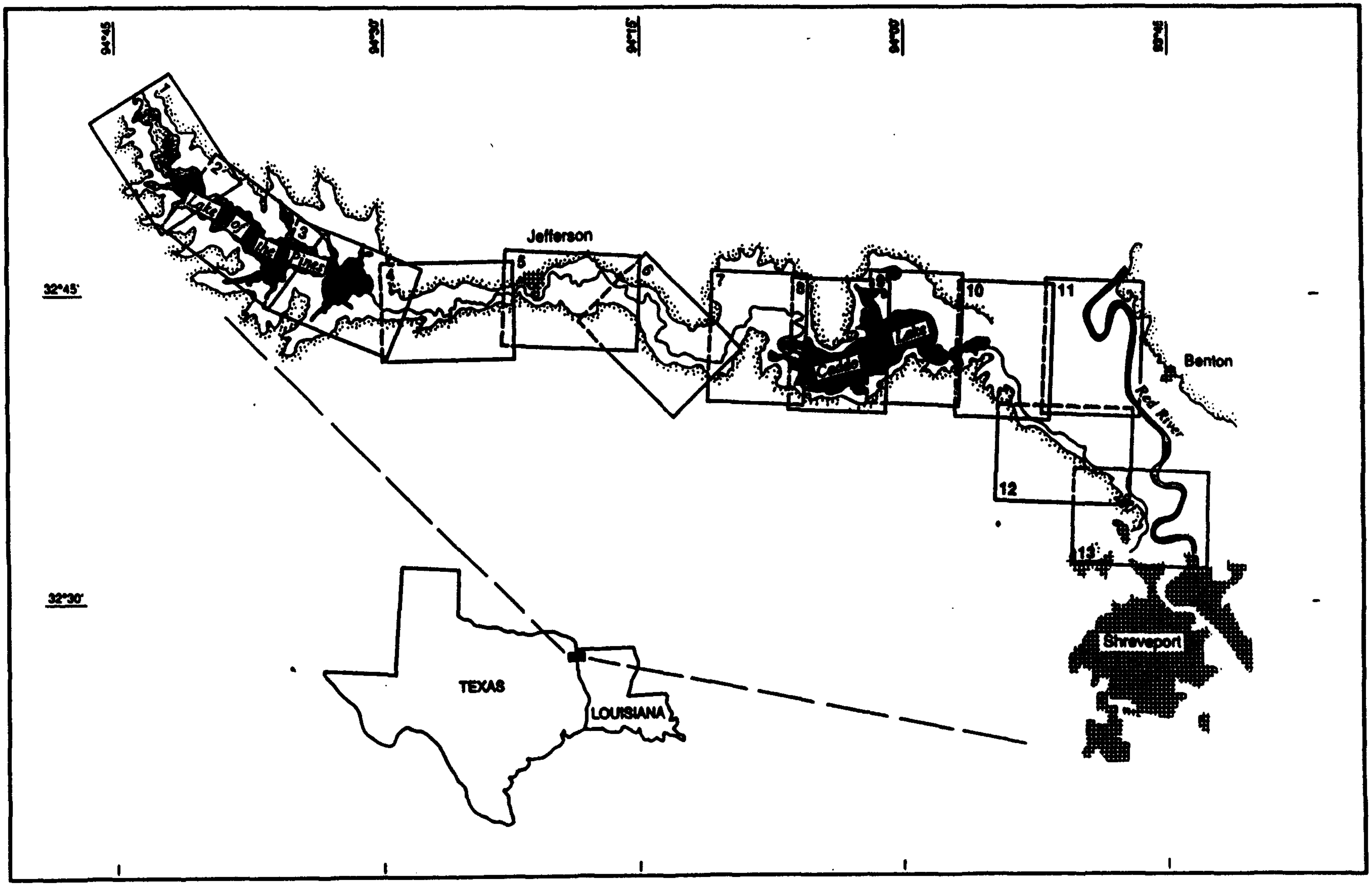


Figure 1. Location and index map to study area

The following study has been conducted in two separate phases. Phase 1 was a preliminary investigation involving geomorphic mapping and a field reconnaissance of the project area, of which this report is an account. Phase 2 built upon the first study by finalizing the geomorphic maps with a detailed field investigation to determine site specific stratigraphic and chronologic characteristics about the different depositional environments within the study area. This investigation involves the following major tasks: data collection and literature review, geomorphic mapping from aerial photography, a field reconnaissance of the project area, soil sampling of selected geomorphic environments, laboratory soil testing, data analysis and reduction, and report preparation.

Previous Investigations

Several studies relate either directly or indirectly to the Shreveport to Daingerfield project area. Geological reconnaissance of the upper Cypress Creek Basins was conducted by Saucier (1967). A regional overview of the chronology and dynamics of the Mississippi and Arkansas Rivers is described by Saucier (1974). Harvey et al. (1987) conducted a geomorphic and hydraulic analysis of the Red River above Shreveport. Both of these reports describe the changes in base level which affected Caddo Lake and Big Cypress Bayou. Changes in base level are attributed to climate changes during the Pleistocene (2 million to 10,000 years) and Holocene (10,000 years to present). Climatic variations in the region are discussed by Delcourt and Delcourt (1985), Hall (1990), and Ferring (1986). Their results indicate the drainage systems in this region experienced significant climatic and geomorphic changes at approximately 14,000, 11,000, 7,500, 5,000, 2,000, and 1,000 years before present (BP).

Site specific studies include work by Klimas (1987) and Albertson (1992). Klimas (1987) evaluates the relationship between Baldcypress and lake level fluctuations caused by construction of Caddo Dam in 1914. Albertson (1992) conducted engineering geology mapping of the project area for sources of construction material and to provide foundation data for engineering structures associated with the proposed navigation project.

An overview of the archaeology of the area is presented by Gibson (1969) and Thurmond (1990). These two reports identify the known cultural resources in the study area. Early historic documents about this area include U.S. Army Corps of Engineers (USACE) reports (1873, 1893, and 1968), Darby's (1816) account of his travels in Louisiana, and Veatch's (1906) report about the geology and groundwater resources of northern Louisiana and southern Arkansas.

2 Procedure

Geomorphic Mapping

The first objective of this study was to map the geomorphic features within the study area. Mapping was done at a scale of 1:24,000 on 13 base maps developed by CELMK for the Shreveport to Daingerfield Map Atlas (USACE 1990). This map atlas was derived from portions of U.S. Geological Survey (USGS) 7-1/2-min topographic quadrangle maps.

The delineation and definition of the geomorphic features was accomplished primarily by analysis of topographic data and aerial photography (i.e. 1:24,000-scale black and white photography flown in 1989, and 1:62,500- and 1:24,000-scale color infrared (IR) photography flown in 1990). In addition to this data, the geomorphic mapping was based upon and guided by previous U.S. Army Engineer Waterways Experiment Station (WES) studies (Albertson 1992, Saucier 1967, Russ 1975, and Smith 1982). These studies served as the foundation for the aerial photographic interpretation and provided detailed information about the subsurface geology. The results of the geomorphic mapping are presented on Plates 1 through 13 (see Figure 1 for index to plates).

Field Studies

Objectives and approach

The purpose of the field studies was to evaluate the results of the geomorphic mapping and conduct soil sampling of selected geomorphic environments. Soil samples were analyzed and tested in the laboratory to determine specific stratigraphic and chronologic properties about the study area. Two separate visits were made to the project area as part of the field work. Site visits consisted of a general reconnaissance and a detailed field investigation.

A general reconnaissance was conducted during the first phase to evaluate the results of the geomorphic mapping and identify locations for later soil borings. During the detailed field investigation, soil sampling was conducted of selected geomorphic environments to obtain sediments for radiocarbon dating and to determine general soil properties about the various geomorphic environments. Radiocarbon dating was used to reconstruct the general chronology of the study area by dating selected stratigraphic horizons and their associated geomorphic features. Pollen analysis of selected sediment samples provided further evidence of the paleoenvironmental record. In addition, soils data were used to define the sedimentological characteristics of the different geomorphic environments to aid in reconstructing the evolution of the study area.

Soils information was obtained from boring data and published literature. Boring data included existing CELMK borings and borings drilled during this study. Published data consisted of county soil survey bulletins from the Soils Conservation Service (1980, 1990, and in preparation). Soil surveys were available for approximately 60 percent of the project area. Soils data were not available for Marion County. Limited soils data for this county were obtained from a field reconnaissance with the Soil Conservation Service (SCS) near Jefferson, TX (SCS unpublished data).

Soil sampling

Soil samples were obtained with a vibracore or a Giddings drilling rig. Twelve borings were drilled in the project area as part of this study. The vibracore sampler works on the principle of soil liquefaction by the sampling equipment in unconsolidated and saturated sediments. Sampling is best in fine-grained sediments (sand, silt, and clay) where the displacement of soil particles allows penetration of the core barrel. The vibracore sampler does not work well in stiff clays. For this type of soil, the Giddings drill rig was used to obtain samples.

Vibracore equipment consists of a 5 horsepower gasoline engine and a 20-ft (6.1-m) flexible hydraulic cable attached to a hydraulic vibrator head. The vibrator head is connected to a 30-ft (9.1-m)-long, 3-in. (7.62-cm)-diam aluminum sampling pipe by an adjustable clamp. A 45-deg cutting edge was added to the sample pipe by sawing the base of the aluminum pipe. This cutting edge was sharpened by filing the aluminum edge to a smooth surface.

Soil sampling by vibracoring consisted of hoisting the sample pipe and the attached vibrator head to a vertical position and vibrating the sample tube to its maximum penetration. A 3-in. (7.62-cm) sample packer was inserted into the upper end of the sample pipe and tightened to prevent sample loss by creating an air-tight seal at the top of the aluminum pipe. The air-tight seal prevents the sample from falling out when hoisting the sample pipe from the ground. Samples were recovered from the ground with a winch and pulley attached to the tripod mast. Sample tubes were cut into 3.28-ft (1.0-m) lengths and sealed for transportation to WES for later laboratory testing and analysis.

In addition to the vibracore borings, three borings were drilled with a trailer-mounted Giddings drill rig. These borings were drilled in stiff floodplain sediments where the vibracore sampler would not penetrate. Three-inch (7.62-cm)-diam standard shelby tube samples were pushed into the ground by hydraulic pressure. Boring advance and cleanout between sample intervals were with a 5-in. (12.7-cm)-diam auger rotated to the desired sample depth. Generally, soil samples were visually inspected and logged onsite. Soil samples were extruded from the shelby tubes in the field by a hydraulic ram attached to the drill rig. Only selected soil samples were sealed in the shelby tubes for later laboratory classification and analysis.

Laboratory Analyses

Sample preparation and testing

Vibracore soil samples were cut into 3.28-ft (1.0-m) lengths and split in half along the longitudinal axis. Sample cores were photographed, one half was sealed in plastic for future reference, and the other half was used for laboratory testing and analysis. Laboratory testing and analyses consisted of preparing detailed boring logs of the soils and sedimentary structure and performing radiometric, radiographic, and biostratigraphic testing of selected samples. These tests were used to characterize important soil and stratigraphic properties about the different geomorphic environments and to aid in the paleoreconstruction of the project area.

Boring logs

Logs of borings drilled during this study are presented in Appendix A. Boring logs in Appendix A contain descriptions of soil type, color (Munsell), texture, soil structure, consistency, and stratigraphic thickness. In addition, locations of samples submitted for radiocarbon dating and pollen analysis are shown on the boring log. Boring locations are identified on the boring logs in Appendix A and are shown on the geomorphic maps in Plates 6, 7, 10, 12, and 13.

Radiocarbon dating

Radiocarbon dating of selected stratigraphic horizons was used to determine the general chronology of the Shreveport to Daingerfield project area. Samples submitted for carbon dating were primarily organic clays from abandoned channels. By dating selected abandoned channels in the study area, it is possible to determine the minimum age of the respective meander belts and estimate the rate of channel migration and abandonment. In addition to dating abandoned channels, lacustrine-backswamp/pointbar sediments from the Twelvemile Bayou area in the Red River Valley were dated to establish the time frame for Soda Lake.

Ten soil samples were sent to Beta Analytic Inc., Coral Gables, FL, for radiocarbon dating. Three of the samples submitted had insufficient carbon for analysis. Test results from the submitted samples are presented in Appendix B. Included in Appendix B is a general description of test procedures and definition of terms. Sample locations are identified on the boring logs in Appendix A and boring locations are identified on geomorphic maps in Plates 1 through 13. A full summary of test results is presented in Table B1 in Appendix B.

Biostratigraphy

A pollen analysis of selected soil samples from the study area was conducted to determine the effects and significance of changing paleoenvironmental conditions during the Pleistocene and Holocene and to assist with the reconstruction of the general chronology for this area. Fourteen sediment samples from five cores were submitted to Dr. Vaughn M. Bryant, Palynology Laboratory, Texas A & M University, College Station, TX, for a general pollen analysis. The pollen report by Dr. Eri Weinstein and Dr. Bryant, Palynology Laboratory, Texas A & M University, is presented in Appendix C. Their report provides an overview of the laboratory procedures, the pollen analyses, and test results.

Radiography

Radiographic techniques permit the inspection of subtle depositional and structural details not evident by ordinary visual examination and logging of soil cores. Nine soil samples were X-rayed to identify important stratigraphic and sedimentological characteristics from various depositional environments which are present in the project area. X-ray techniques are ideally suited for distinguishing sedimentary stratigraphy in lacustrine and backswamp soils that appear to be homogenous.

The main objective of using this technique was to determine the thickness of shallow lacustrine sediments beneath historic Soda Lake in the Red River Valley. X-rays made from lacustrine environments are distinguished from backswamp sediments by the presence of thin sedimentary layering. Organic bioturbation in the backswamp environment generally destroys this layering.

Sample preparation involves placing a 0.4-in. (1-cm)-thick by 10.0-in. (25-cm)-long soil sample onto X-ray film and exposing the sample to radiation. X-rays are absorbed differentially by the soil sample because of variations in sample density, composition, and soil structure. Absorption patterns are registered onto the X-ray film as an image. These images were then examined for structural and sedimentological characteristics.

3 Geology and Geomorphology

Geologic Setting

Geomorphic development of the Big Cypress Bayou drainage basin is the result of geologic processes operating during the last 65 million years. The study area is composed of Tertiary (65 to 2 million years) to Quaternary (2 million years to present) age sediments. Tertiary sediments were deposited by fluvial-deltaic processes similar to processes presently active in Louisiana. During the Quaternary, these Tertiary sediments were uplifted and incised by numerous Pleistocene and younger fluvial systems such as Big Cypress Bayou. This drainage basin reflects the geomorphic processes that have been active during the past 2 million years. These processes are controlled by climatic fluctuations and previous tectonism (i.e. Sabine uplift) .

Geomorphic Surfaces and Environments

Introduction

Geomorphic mapping has identified three major geomorphic surfaces within the study area. These surfaces are differentiated according to their physical characteristics, their apparent age, and by the types of processes that are active on each of these surfaces. These surfaces are identified in Table 1 as the floodplain, terraces, and valley slopes. These three surfaces are further subdivided into depositional environments and/or geologic formations as shown by Table 1 and Figure 2. The approximate age of each surface and the types of geomorphic processes that are active are identified in Table 1.

Valley slopes and tertiary sediments

Surface outcrops of Tertiary sediments in the study area are restricted to the valley slopes and hill slope summits. Tertiary sediments forming the valley slopes were defined by a sharp break in the topography between the nearly flat terraces and floodplain surfaces which border the valley slopes.

Table 1
Geomorphology of the Big Cypress Drainage Basin Project Area

Surface	Landform-Formation	Age	Geomorphic Processes
Floodplain	Point Bar (PB)	H	LA
	Point Bar (PB2)	H-(P?)	LA-VA-BT-SF
	Lacustrine Delta (LD)	H	LA-VA
	Abandoned Course (ACO)	H	VA-LA
	Abandoned Channel (AC)	H	VA-LA
	Undiff. Tributary Alluvium (QAL)	H	VA-LA
Terrace	Abandoned Flood Plain (QTU and QTP)	H-P	E-SF
Valley Slopes	Claiborne Group	T	E-SF
	Sparta (ECS)	T	E-SF
	Weches (ECW)	T	E-SF
	Queen City (ECQ)	T	E-SF
	Reclaw (ECR)	T	E-SF
	Carrizo (ECC)	T	E-SF
	Wilcox Group (EWU)	T	E-SF
	Midway Group (PMU)	T	E-SF

AGE: H = Holocene, P = Pleistocene, T = Tertiary
PROCESS: VA = Vertical Accretion, LA = Lateral Accretion, BT = Bioturbation, SF = Soil Forming Processes, E = Erosion

Geologic formations that make up the valley slopes are identified on the geomorphic maps and in Table 1. These Tertiary formations are fluvial-deltaic, near shore, and marine sedimentary sequences composed of unconsolidated sand, silt, and clay. Boundaries separating the different geologic units are based on the Tyler Sheet (scale: 1:250.000) by Flawn (1965) and from an engineering geology investigation of the Shreveport to Daingerfield project area by Albertson (1992).

The Weches Formation (ECW) caps many of the high hills and "mountains" in the upper reach of the study area (Plates 1 and 2). The Weches is the source of iron ore which developed into the local iron and steel industry in Lone Star, Kellyville, and Jefferson, TX. Approximately 33 percent of the study area (Plates 1, 2, 3, 4, and 5) is covered by the Queen City Sand Formation (ECQ). Beneath the ECQ are the clays of the Reklaw Formation (ECR). Springs emerge where the ECQ/ECR contact is exposed (Plates 4 and 5). Underlying the ECR is the Undifferentiated Wilcox Group (EWU) which consists of interbedded deposits of sand, clays, lignitic silts, and lignite. The EWU makes up 27 percent of the study area and forms the hills and valley slopes in the lower reach of the Big Cypress Bayou and along

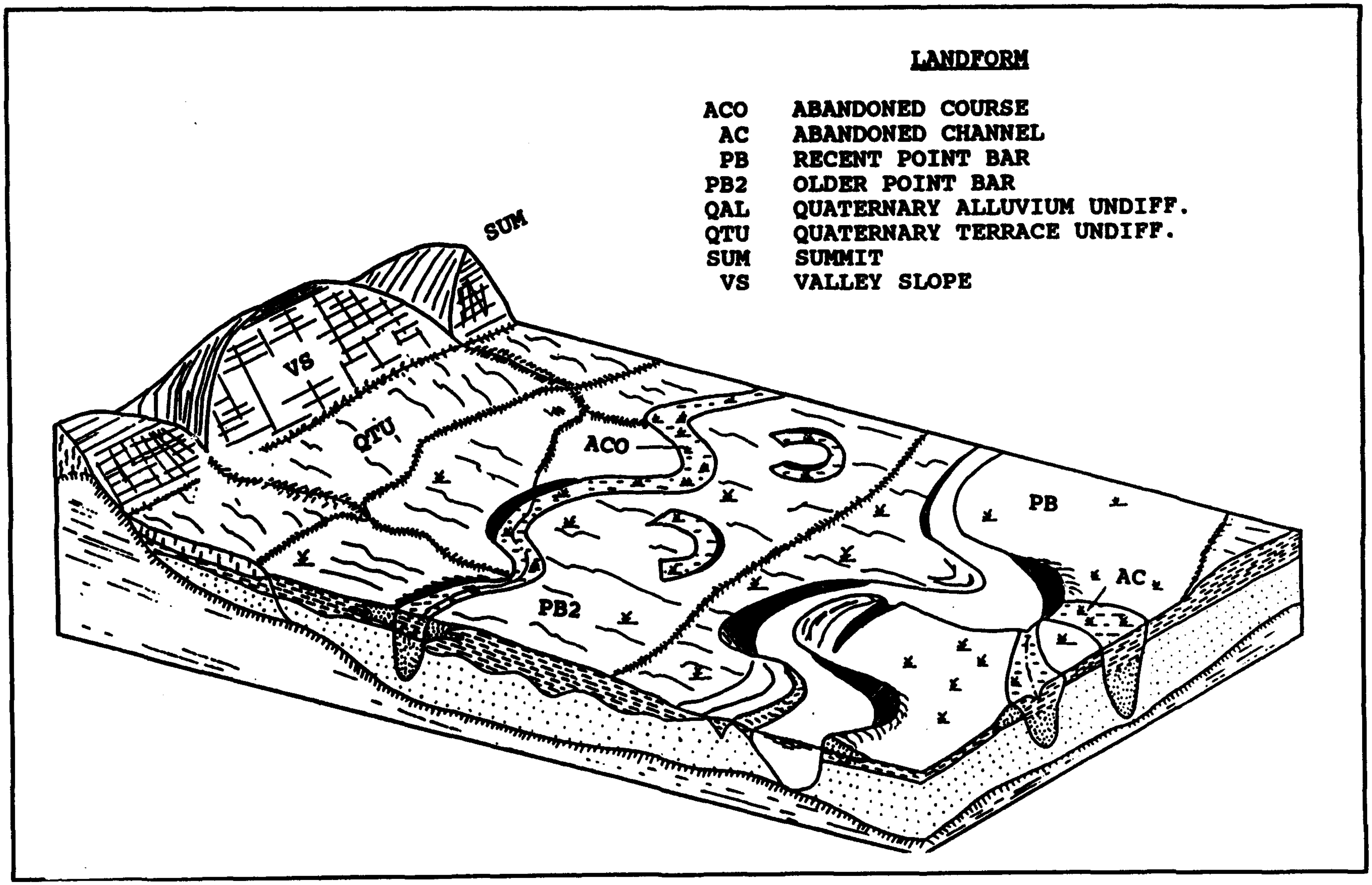


Figure 2. Generalized block diagram of Big Cypress Bayou drainage basin showing major geomorphic environments in study area

Twelvemile Bayou in the Red River (Plates 5, 6, 8, 9, 10, 11, 12, and 13). The oldest unit outcropping in the study area is the Paleocene age Undifferentiated Midway Group (PMU). Black clays of the PMU form the slopes in the vicinity of Mooringsport, LA (Plates 9 and 10). Overlying the Tertiary units in the valleys are Pleistocene and Holocene fluvial sediments.

Terrace (QTU, QTP, and QTD)

A terrace is an abandoned floodplain surface that is elevated above the present river's floodplain. A terrace consists of a relatively flat or gently inclined surface that is bounded on one edge by a steeper descending slope and on the other edge by a steeper ascending slope (Bates and Jackson 1980). Terraces generally border the present floodplain or may be preserved as topographic islands or remnants within the present floodplain. Terrace islands or remnants in the floodplain were not mapped because of the limited accuracy of the topographic data. Terraces are differentiated on the geomorphic maps according to their interpreted age. Terraces identified as QTD are Deweyville terraces along the main Red River Valley (Plates 10 through 11). Deweyville terraces contain oversized fluvial channels and courses as compared to the present system. Deweyville terraces in the Gulf Coast are estimated to have formed between 17,000 and 30,000 years BP (Kolb, Smith, and Silva 1975). Recently, Autin and others (1991) reported that the Deweyville may extend to as early as 10,000 years BP. Oversized meander scars found on the QTD represent the fluvial response of the respective drainage basin to higher rainfall conditions than the present. These terraces are not related to sediment transport by glacial melt water. Pleistocene terraces identified as QTP occur in the Red River Valley following the usage of Smith and Russ (1974). Terraces identified as QTU are undifferentiated Quaternary terraces. Pleistocene terraces in the Big Cypress Bayou drainage basin are mapped as QTU.

Terraces (QTU, QTP, and QTD) mapped in the study area are flat or gently inclined surfaces which occur between the valley slopes and the floodplains of the respective drainage basins. Mapped terraces on the geomorphic maps (Plates 4 through 8) are interpreted to be depositional terraces. In general, the boundary between the terrace and the floodplain was mapped by first defining the limits of the floodplain from hydrologic data. This boundary was then further refined by incorporating soils data from the available county soil survey bulletins, land use interpreted from aerial photography, and from site investigations conducted in the field.

In addition to flood frequency, another important characteristic that distinguishes terrace surfaces from the floodplain and its associated landforms is the development of a mature soil profile(s) by pedogenic processes. The presence or absence of a soil profile reflects the types of geomorphic processes that are active in the area and the age of the soil sequence. Soil forming processes are governed by the physical properties of the soils, the environmental influences of the geomorphic system, and the duration of the geomorphic processes. The absence of a soil profile indicates a soil that has been recently deposited and has not had sufficient time to develop a profile.

Physical properties of the underlying soils and the soil profile are variable because of differences in (a) topography and slope, (b) the types of vegetation which are growing on the surface, (c) the land use characteristics of the area (i.e. crop land versus timber), (d) variations in climate, (e) composition of the underlying parent materials, and (f) the time involved in which the soil has formed. These variations control the different types of geomorphic and pedogenic processes that are involved in soil formation, and they govern the soil profile that will be developed.

Terraces bordering Big Cypress Bayou (Plates 4 through 8) are generally well drained in comparison to the floodplain. Flood frequency on terrace surfaces is between 100 to 500 years. Lack of flooding on the terrace surfaces, as compared to the floodplain, results in soil forming or pedogenic processes becoming dominant. In areas where flooding is more frequent, soil forming processes are less dominant as sedimentation rates increase.

Floodplain

A working definition of a floodplain is important to this study as the terrace boundaries are determined by the limits of the present floodplain. The definition of a floodplain can have many meanings. Fairbridge (1968) identified the problem of defining a floodplain and described it as follows:

> "To define a flood plain depends somewhat on the goals in mind. As a topographic category, it is quite flat and lies adjacent to a stream; geomorphologically, it is a landform composed primarily of unconsolidated depositional material derived from sediments being transported by the related stream; hydrologically, it is perhaps best-defined as a landform subject to periodic flooding by the parent stream. A combination of these perhaps comprises the essential criteria for defining the flood plain."

Based on this definition, a floodplain must contain three basic parts. It must contain elements of topography, geomorphology, and hydrology as part of the definition.

Flood frequency must be incorporated as part of any definition for a floodplain. Consequently, it is that area of the river valley which is subject to inundation by the annual flood or the highest discharge during the year. The question then becomes, "What is the average annual flood?" To resolve this problem, average annual flood has been expressed by flood frequency and a probability distribution or by a recurrence interval. The hydrologic part of the definition for a floodplain becomes a function of flood frequency. Leopold, Wolman, and Miller (1964) suggest that a flood frequency of 1 to 2 years should be used as the basis for defining the river's floodplain.

The definition of a <u>floodplain</u> as used in this study is that area of the floodplain that is subject to inundation by a flood with a recurrence interval of 2 years. Within this area are sediments deposited by the main stream and its tributaries. These sediments are differentiated according to the landforms which they comprise. The primary landforms are identified in Table 1 and are illustrated in Figure 2. These landforms will be individually described as follows.

The procedure that was used to establish the general limits of the floodplain of the Big Cypress Basin and its tributaries is based on the interpretation of flood frequency data from stream gaging stations in the project area. Flood frequency data were provided by the Hydraulics Branch, LMK. The limits of the 2-year flood were determined for selected locations on the floodplain as shown by Figures 3 and 4. Topographic profiles containing the various flood stages are presented in Appendix D. The extent of the present floodplain in the project area was estimated from the lateral limits of the 2-year flood stage. The accuracy of the topographic data is limited to the nearest 5-ft (1.5-m) contour interval which was obtained from the USGS 7-1/2-min base maps of the project area. Additional criteria were evaluated before the final floodplain limits were established. These criteria are described in more detail in the next section.

Floodplain Geomorphic Environments

Point bar (PB and PB2)

Point bar deposits are lateral accretion deposits formed as a river migrates across its floodplain. River channels migrate across their floodplain by eroding the outside or concave bank and depositing a sand bar on the inside or convex bank (Figure 2). With time, the convex bar grows in size and the point bar is developed. Associated with the point bar are a series of arcuate ridges and swales. The ridges are formed by lateral channel movement and are relic sandy lateral bars separated by low-lying swales. The swales are locations where fine-grained sediments accumulate.

Point bar deposits are as thick as the total depth of the river that formed them. These deposits fine upward from the maximum size of the river's bed load (coarse sand and/or fine gravel) to fine-grained soils (clay) at the surface. The basal or coarse-grained portion of the point bar sequence (i.e. point bar substratum) is deposited primarily by lateral accretion, while the fine-grained or upper portion of the point bar sequence (i.e., point bar topstratum) is deposited by overbank vertical accretion.

Point bar deposits in the Red River Valley and the Big Cypress Bayou basin are the dominant and the most dynamic environment within the project area. Point bar limits were defined primarily from interpretation of the color IR photography and topographic data. The boundaries for the present meander belt are identified on the geomorphic maps as PB and define the active portion of the present floodplain. Older point bar deposits are identified as PB2 and were mapped only in the Big Cypress Bayou Basin (i.e. Plates 4 through 7). PB2 deposits are adjacent to the present meander belt and are well removed

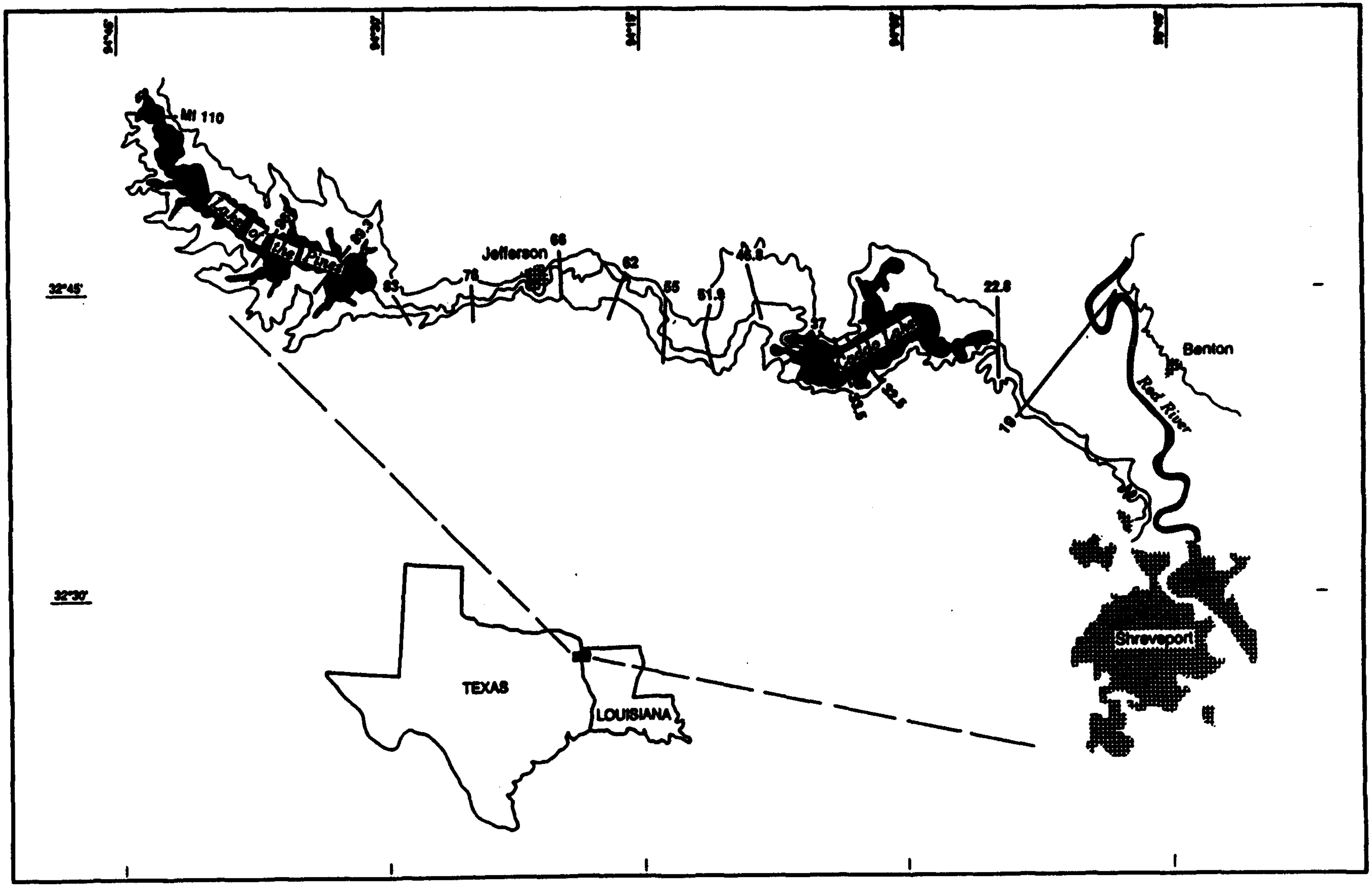


Figure 3. Locations of topographic profiles; see Figure 4 for flood frequency and elevation data and Appendix D for individual profiles

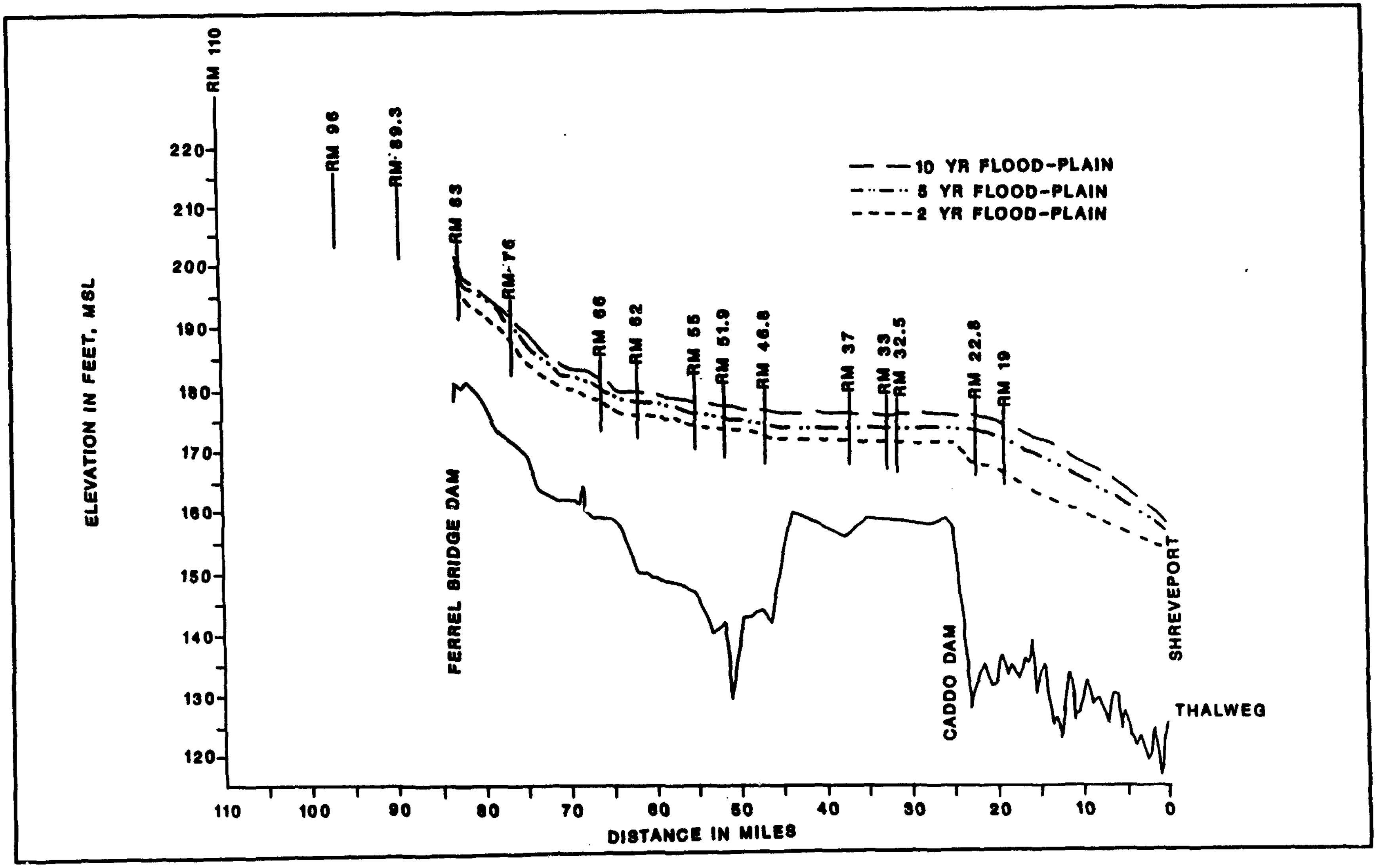


Figure 4. Flood frequency at selected locations in study area; see Figure 3 for locations of topographic profiles and Appendix D for individual profiles

from the zone of active lateral accretion. The PB2 surface is receiving sediment primarily by vertical accretion. This surface is covered by well developed pine forests.

Primary characteristics of the PB or active point environment are the well developed ridge and swale topography and its proximity to the main channel. In the Red River Valley, ridge and swale topography is especially well developed. Major swales are identified on the geomorphic maps for both the upper and lower reaches of the study area. Another primary characteristic of the PB environment is the well developed sandy point bars along the main channel. Sandy point bars are easily recognized on aerial photography and on topographic maps.

PB2 deposits are generally well drained and covered by mature trees as compared to the active point bar. The principal geomorphic processes are vertical accretion of new sediment from annual flooding, pedogenesis (soil formation), and bioturbation. Bioturbation is the churning and stirring of the underlying sediment by vegetation and organisms (Bates and Jackson 1980). These processes combine to produce a characteristic soil profile and lithology which is different from the active point bar. In general, soil profiles are better developed in older point bar deposits than in the active point bar setting. Classification of soils by the SCS in the Big Cypress Basin indicates Inceptisols and Alfisols are the major soil groups for the PB2 surface, while Entisols are associated with the younger PB environment.

General relationships between landforms defined by this study and SCS soil series are presented in Appendix E. Each of these different soil series has a unique soil profile characterized by diagnostic physical or chemical properties. The diversity of the soil series for the different landforms reflects, in part, differences in mapping conventions between the various counties and differences in soil type due to geography and variations associated with the soil forming variables (i.e. time, parent material, climate, biological activity, etc.). Because of the great variety of soil series associated with the different landforms, specific or exact relationships between soil series and landform type are not possible. Rather, general soil properties and characteristics can be differentiated for the various landforms.

Point bar deposits in the Big Cypress Bayou basin are approximately 25 to 30 ft (7.5 to 9.0 m) thick. Soil types defined by borings drilled as part of this study and from boring data evaluated by Albertson (1992) identify a typical point bar sequence as grading upward from poorly graded, or uniform sands at the base, to silty sands, silts, and clays near ground surface. These deposits are usually variable horizontally, especially where ridge and swale topography is well developed or relic chutes (high water channel across the point bar neck) are present. In the Red River Valley, point bar thickness is generally two to three times greater than point bars along its tributaries (Smith and Russ 1974). Except for differences in thickness and areal extent, point bar deposits occurring in the Red River Valley are generally similar to those in the Big Cypress Bayou basin. The major difference is due to scale between the two respective fluvial systems and occurs in vertical accretion or top-stratum thickness. Red River point bar deposits contain a much thicker topstratum.

Boring data indicates that point bar deposits are separated into two distinct units based on soil types; a thin predominantly fine-grained upper unit or point bar topstratum (silt and clay) deposited by vertical accretion, and a thick, coarse-grained lower unit or point bar substratum (silty sand and sand) deposited by lateral accretion. The thickness of the point bar topstratum in the Big Cypress Bayou Basin reach is variable, ranging from less than 3 ft (1 m) to approximately 10 ft (3 m). For the Red River Valley, topstratum thickness is approximately two times as great, averaging approximately 20 ft (7 m) in thickness (Smith and Russ 1974). (Knowledge about top-stratum thickness is helpful in understanding and evaluating buried archaeological sites.) The substratum, in comparison to the topstratum, is much thicker, forming almost the entire thickness for this environment. In the Big Cypress Bayou basin, topstratum thickness is much greater in the PB2 environment than in the PB unit.

Natural levee

Natural levee deposits were not mapped as a separate environment on the geomorphic maps because this environment is present throughout the floodplain to some extent and mapping this environment would detract from the topographic information on the base maps. However, natural levee deposits are described in this report as a separate environment because it is an important geomorphic process in the study area, especially as it affects cultural resources.

Natural levee deposits form by vertical accretion when the river overtops its banks during flood stage and sediment suspended in the flood flow is deposited immediately adjacent to the channel. The resulting landform is a low, wedge-shaped ridge with the greatest thickness adjacent to the river. Natural levee thickness decreases away from the river until it eventually merges with other floodplain deposits.

Natural levee deposits in the upper project area are less than 5 ft thick and are about 100 to 200 ft (30.5 to 61 m) wide. These limits are below the contour accuracy of the 7-1/2-min map scale used in the geomorphic mapping. Natural levee limits are not readily identified on the available aerial photography except for the main Red River Valley where the scale of the fluvial landforms are much larger. In comparison, natural levees along the Red River may range several miles in width. A reconnaissance investigation in the upper Big Cypress basin identified silt and sand as the predominant soil types associated with natural levee deposits.

Natural levee deposits generally contain a low organic content because oxidation has reduced organic materials to a highly decomposed state. Soils are typically brown to reddish brown. Small calcareous nodules are frequently associated with these deposits as a result of groundwater movement through the permeable levee soils. Natural levee soils are generally well drained, have low water contents, and a stiff to very stiff consistency.

Abandoned course (ACO)

An abandoned course is a river channel that is abandoned in favor of a more efficient course (Figure 2). A course must contain a minimum of two meander loops for the channel to be classified as an abandoned course on the geomorphic maps. Abandoned courses are abundant throughout the project area and are identified as ACO on the geomorphic maps in Plates 1 through 13.

An abandoned course forms when the river's flow path is diverted to a new position on the river's floodplain. This event usually is a gradual process and begins by a break or a "crevasse" in the river's natural levee during flood stage. The crevasse forms a temporary or crevasse channel that may, over time, develop into a more permanent channel. Eventually, the new channel diverts the majority of flow and the old channel progressively fills. Final abandonment begins as coarse sediment fills the abandoned channel segment immediately down stream from the point of diversion. Complete filling of the abandoned course is a slow process that occurs first by lateral accretion and then later by overbank deposition and vertical accretion. The complete filling process may take several hundred to several thousand years to complete. In some instances, complete filling may not occur as relict and upland drainage preserves partial stream flow through the course.

Abandoned courses and associated abandoned channels collectively form a meander belt on the floodplain of the river. Meander belt deposits consist of a several mile wide, massive point bar sequence, divided by various abandoned channels and courses which collectively form the meander belt. The frequency and location of the meander belt segments are useful for determining the Holocene chronology of floodplain development.

Abandoned courses in the Red River Valley are identified on the geomorphic maps with a general meander belt classification developed by Saucier and Snead (1989) for the Red River (Figure 5, modified from Saucier 1974). This classification divides the Red River into five major meander belts. Meander belt 1 is the youngest, while belt 5 is the oldest. Abandoned courses in the Red River associated with the most recent meander belt are not numbered on the geomorphic maps to avoid symbol crowding. The oldest meander belt that is present in the Red River study area is meander belt 5, estimated to be 4,000 to 5,500 years BP. This meander belt corresponds to the Twelvemile Bayou abandoned course (Plates 10 and 12).

Meander belts are not identified above the headwaters of Caddo Lake, because abandoned course segments are too discontinuous to differentiate. Furthermore, the valley width does not readily permit the development of multiple meander belts.

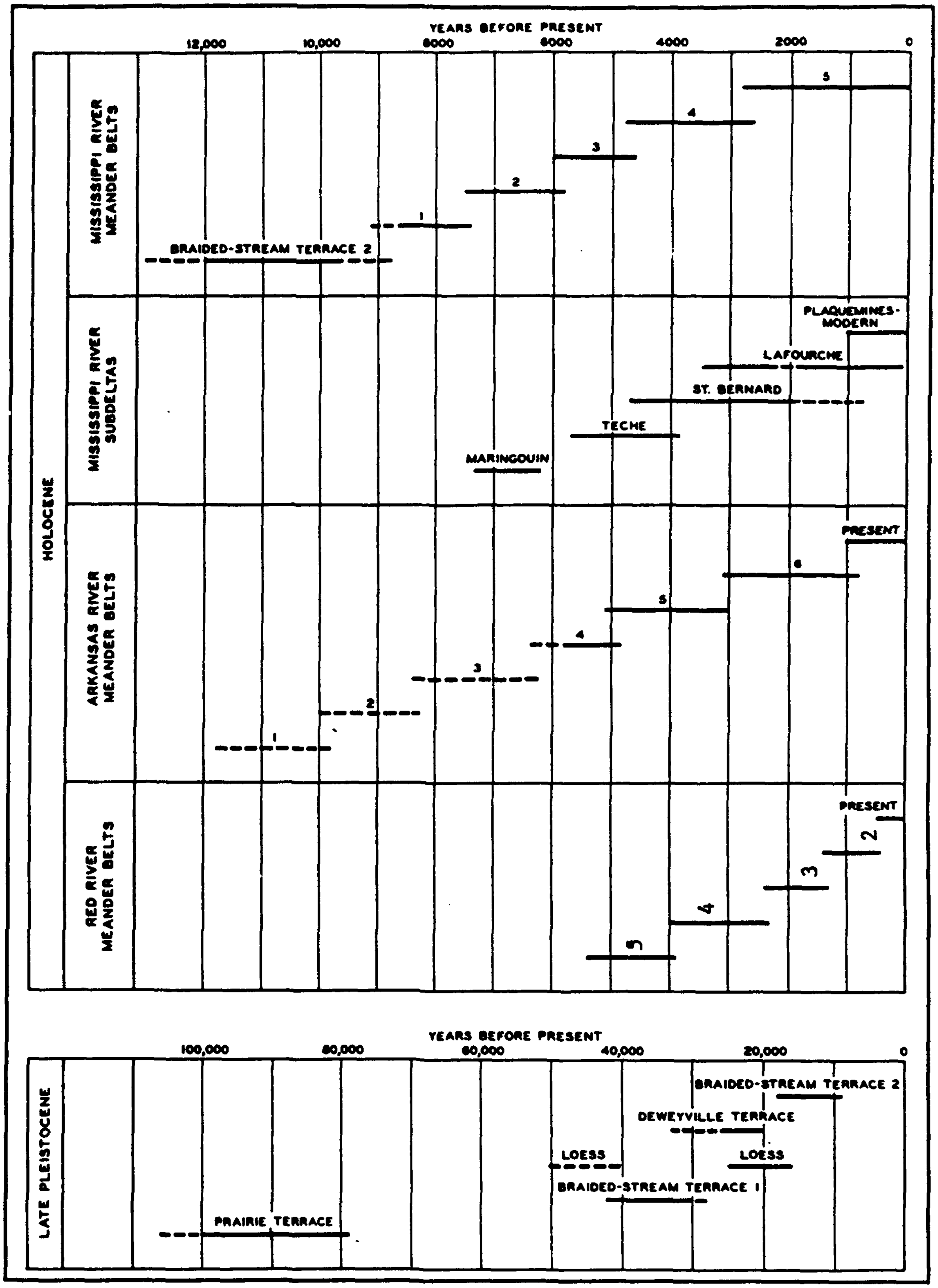


Figure 5. Chronology of late Pleistocene and Holocene landforms and deposits (modified from Saucier 1974)

Abandoned channel (AC)

Abandoned channels are relict channel loops that are abandoned when the river cuts across its point bar (Figure 2). The cutoff produces an oxbow lake. The process by which the river abandons the loop occurs either gradually as a neck cutoff or during a single flood event as a chute cutoff. A chute is a high water channel across the point bar of the channel. Abandoned channels mapped by this study may be either well defined classic "oxbow" loops or loop segments. Abandoned channels are abundant throughout the project area. These features are mapped in the Red River Valley (Plates 10 through 13), in the Big Cypress Bayou reach (Plates 4 through 8), and in the main tributaries to these systems. Abandoned channels are not always individually labeled on the geomorphic maps because these features are so numerous.

Channel filling is a gradual process. It occurs initially by lateral accretion, when the channel is still connected to the main course. After the main channel has migrated away from the abandoned segment, then vertical accretion dominates. During times of high water flow, suspended sediment is transported to the abandoned channel. Above Caddo Lake, abandoned channels associated with the present meander belt (PB) are generally hydraulically connected to the main channel, are younger in age than abandoned channels in the mature point bar (PB2) environment, and are still in the process of filling. In contrast, abandoned channels in the PB2 environment are filled or almost completely filled. Abandoned channels that are not filled continue to receive sediment by overbank deposition during the peak flood season which may occur for only a brief time each year.

As part of this study, several abandoned channels were sampled to provide stratigraphic and chronologic information about the channel. The major goal of the field work during this study was to obtain samples to determine general stratigraphy and date selected abandoned channels. Field work was confined primarily to the Big Cypress Bayou reach between the headwaters of Caddo Lake and Jefferson, TX. Eight vibracores were drilled in five different abandoned channels (Plates 6 and 7).

It is important to understand that even with radiometric dating techniques, an exact age is still not possible, since radiocarbon dating provides only a chronology of the filling history, not when the channel was active and receiving full river flow. Furthermore, there are risks associated with dating channel fill deposits, because older, eroded materials (i.e. logs) may become incorporated into the younger channel fill sequence. Ideally, dating is best where only the vertical accretion component of the channel fill is sampled. The vertical accretion component incorporates the latter stages of the abandonment process when trees, roots, and other organic sediments are concentrated in the filling cycle. Dating of individual abandoned channels provides general data to estimate the age of the respective abandoned course (or meander belt) from its individual components. Additionally, age relationships may also be interpreted from the position and orientation of the abandoned channels on the floodplain with respect to other nearby abandoned channels and courses or other primary geomorphic surfaces.

Vibracore drilling was moderately successful as four cores penetrated well into the basal substratum sands. Boring data indicate abandoned channels are characterized by a thin clay topstratum which is underlain by a thick sandy substratum (Appendix A, borings V1, V2, V3, and V4). Generally absent from abandoned channel sediments in the Big Cypress Bayou reach are organic rich horizons. Three samples submitted for testing contained insufficient carbon. Consequently, radiometric dating was limited by the available organic content of these sediments. Radiocarbon test results as previously noted are presented in Appendix B and are summarized in Table B1.

The absence of datable carbon in floodplain sediments in the Big Cypress Bayou reach is an important geomorphic characteristic. An absence of carbon indicates that geomorphic processes active during the Holocene and Late Pleistocene were not favorable for the preservation of organic sediments. Rather, oxidation of organic sediments is typical for the study area above the headwaters of Caddo Lake. Pollen data from vibracore borings evaluated during this study supports degradation of organic sediments as pollen density is low in samples selected for analysis (Appendix C). Environmental conditions did not favor preservation of organics that were deposited in fluvial sediments. Climate and sedimentation rates promoted organic decay.

Lacustrine (L)

Lacustrine or lake deposits were mapped only within the main Red River Valley (Plates 10 through 13). Lacustrine deposits were formed by historic Soda Lake situated below Caddo Dam. This historic lake is presently drained. Lake limits are dashed on the geomorphic maps, as the exact boundaries for the historic lake are unknown. Lacustrine deposits were mapped on the geomorphic maps as overlying other floodplain environments (i.e. lacustrine overlying point bar (L/PB), lacustrine overlying backswamp (L/BS), etc.).

Lacustrine deposits are fine-grained sediments deposited from suspension on the shallow lake bottom. Lake deposition is generally well removed from the locus of active sediment discharge into the lake. During this phase, deposition is dominated by slow vertical subaqueous accretion of suspended sediment which drops out of suspension because of reduced energy conditions. Sediment transport in suspension is mainly by wave and currents away from the locus of active fluvial discharge. Lacustrine deposits are usually associated with and overlain by lacustrine delta deposits.

A major goal of this study was to separate and determine the thickness of lacustrine deposition in the former lake bed of Soda Lake. A shallow boring was drilled in a field that was once beneath Soda Lake to provide stratigraphic information about the former lacustrine deposits (Plates 12 and 13; Appendix A, boring ST12).

Stratigraphically lacustrine deposits are distinguishable from backswamp (also point bar topstratum) deposits by the presence of sedimentary layering in x-rays in homogenous clay sequences. Because bioturbation from vegetation and burrowing organisms disturbs the sedimentary layering in backswamp deposits, these two environments are distinguishable by x-ray techniques. X-ray data from boring ST12 indicates that lake sediments at this location are approximately 3.2 ft (1 m) thick (Appendix A, boring ST12). This value seems reasonable as it agrees with a report to the Chief of Engineers of 3 to 4 ft (0.91 to 1.22 m) of sediment being deposited because of the Red River Raft (USACE 1873). Depending on location and distance with respect to sediment source areas and preraft floodplain topography, lake deposits may occur at even much greater thickness, perhaps as much as 5 to 10 ft (1.52 to 3.05 m). With only one boring, it is not possible to provide a better range estimate.

Lacustrine delta (LD) and lacustrine delta distributary channels (LDC)

Lacustrine delta (LD) deposits occur primarily at the head waters of Caddo Lake and Lake O' the Pines from backwater flooding caused by the development of these lakes. Lacustrine delta deposits are mapped in the headwaters area of Lake O' the Pines and Caddo Lake as shown on Plates 1, 7, and 8. Lacustrine delta deposits mapped on the geomorphic maps represent the growth of both lacustrine delta and natural levees associated with an advancing fluvial system into a drowned river valley. For reasons already mentioned, natural levee deposits were not mapped as a separate environment.

Lake O' the Pines was formed by construction of Ferrels Bridge Dam during the 1950's. Caddo and Soda Lakes were formed by natural damming on the Red River. The exact mechanism by which these lakes formed is unclear. Historic, geomorphic, and archaeological data indicate these lakes probably developed because of a massive log jam in the lower Red River valley. Data evaluated during this study indicate these lakes may have formed during late prehistoric time, and possibly the lakes may be as much as 500 years old based on a radiocarbon date of 510 ±60 years in boring ST12. The formation and origin of Caddo and Soda Lakes will be described in more detail in the next section of this report.

Lacustrine delta distributary channels (LDC) are formed at the river's mouth. Channels advance into the lake by lateral accretion of coarse sandy sediments to the channel mouth and form bay mouth bars. The individual lacustrine delta channels form a complex network of diverging channels that distribute flow away from the main channel. These distributary channels are separated by coarse sand bars which collectively form the lacustrine delta. Evolution of the branching distributaries is short lived as the lateral constraints imposed by the lake boundaries promote rapid filling, abandonment of the numerous distributaries, and continued lakeward advancement of the trunk channel. Continued overbank deposition of new sediment along the trunk channel results in natural levee growth. These natural levees in turn merge and interfinger with smaller marginal interdistributary lakes and/or other older flood plain remnents.

Lacustrine delta deposits as mapped on the geomorphic maps consist of the entire vertical and lateral accretion sedimentary sequence. This environment is the result of lacustrine, distributary channel and delta mouth bar, and natural levee processes described previously. At the headwaters of Caddo Lake, a lacustrine delta complex has been mapped (Plates 7 and 8). Big Cypress Bayou upon entering the Clinton Lake area (Plate 7) extends due east to approximately the middle of the lake where it forms a delta complex. At this location, Government Ditch was dredged. The delta complex contains two lacustrine delta distributary channels. One distributary channel extends nearly due south where it again branches into another delta complex. The other distributary channel continues eastward where it meanders along the eastern boundary of Caddo Lake and merges with a submerged abandoned course.

Topographic and hydrographic data shown on the base map support classifying Big Cypress Bayou as a lacustrine delta complex. Channel widths of the lacustrine delta distributary channels are half as wide as the channel upstream and downstream of the complex. The downstream portion of the channel is interpreted to be the submerged abandoned course of the former floodplain.

The general thickness and composition of lacustrine delta deposits are illustrated by boring V4 (Plate 7 and Appendix A). At this location, vibracore sampling was in an abandoned channel partially filled by lacustrine delta deposits. Lacustrine delta deposits in boring V4 are sandy and approximately 9 ft (2.74 m) thick. Lacustrine delta thickness at this location represents the lateral accretion component of the filling cycle.

Development of lacustrine delta growth and lacustrine filling in the headwaters area (i.e. Clinton Lake, Carters Lake and Chute, Black Lake, etc.) have been dependent upon the lake level. Construction of Caddo Dam in the early 1900's established the lake level at approximately 169 ft (51.5 m) mean sea level (MSL). The lake level has been slightly higher before Caddo Dam, when the Red River Raft was in existence and drainage from Caddo Lake was controlled by changing base level (Kidder 1914, Leverett 1913, and Janes 1914). Leverett (1913) reports geologic evidence for the lake level reaching 180 ft (54.9 m) MSL. During prehistoric and early historic times, the headwaters area probably experienced both fluvial and fluvial-deltaic growth, depending upon lake level stages. From the geomorphic mapping, lacustrine delta development has not been widespread because the lake itself is considered to be relatively young. It is estimated that Caddo and Soda Lakes are less than 500 years old. Valley drowning in the headwaters area has submerged older floodplain deposits beneath Clinton Lake and flooded the nearby abandoned channels (i.e. Old Horse Slough and Carters Chute, Plate 7) associated with the PB2 surface.

Raft distributary channels (RD)

Raft distributary channels are considered comparable to crevasse channels. These channels form as a break or crevasse in the natural levees and transport floodwaters to low lying areas bordering the floodplain. These channels are well developed on the Red River floodplain (Plates 10 through 13) and were formed because of the Red River Raft. The Raft is described in more detail in the next section of this study.

Backswamp (BS)

Backswamp (BS) deposits in the project area are located in poorly drained forested areas bordering the point bar environments. This environment is approximately 1 percent of the study area. Backswamps are common in the Red River valley and have been covered with lacustrine deposits. The dynamics of the Big Cypress Bayou with its narrow valley and high sand content are not conducive to backswamp formation.

Backswamp deposits form by periodic flooding and vertical accretion of new sediment. The primary geomorphic process occurring in this environment are vertical accretion of new sediment by annual flooding, pedogenisis, and bioturbation. These processes combine to form a characteristic soil profile and lithology. In general, soil types are predominantly gray to dark gray clay interbedded with silt and decayed roots and wood fragments.

4 Geomorphic Chronology

Introduction

The third objective of this study was to define the geomorphic chronology of the project area to the extent possible with the known data. The chronology is based on the available soils and geological data, results of the geomorphic mapping, boring and laboratory data produced during this study, and finally, the radiocarbon data from abandoned channels. The geomorphic history of the area is defined by the distribution and extent of the underlying geologic units, the floodplain sediments which overlie these formations, and the soils that have formed and modified these different landscape elements.

Pleistocene

Geomorphic setting and terrace levels

The Red River and Big Cypress Bayou were formed during the Pleistocene, a period of active continental glaciation in North America. The Red River and Big Cypress Bayou were not directly affected by continental glaciation during the Pleistocene. Neither of these fluvial systems directly received glacial meltwater or related sediments. Instead, geomorphic processes operating in the study area were controlled by climatic variations associated with Pleistocene glaciation. Climatic changes influenced the base level on the Red River and its tributaries. Since the outlet for the Red River during the latter part of the Pleistocene was by way of the Mississippi River Valley, direct effects of glaciation (i.e. glacial melt water, glacial sediment, and sea level changes) would have influenced the Red River's discharge to the Mississippi River and its link to the Gulf of Mexico.

The end result of this complex interchange between Pleistocene climate changes and associated base level response has been the creation and incision of a well defined drainage basin into the underlying Tertiary sediments. At the beginning of the Holocene, the Red River alluvial valley and its larger tributaries had developed a series of descending stepped terraces, formed as a result of aggrading and degrading fluvial cycles, and a well defined flood plain with associated environments of deposition.

Within the boundaries of the study area, the highest and oldest mapped terrace (Plates 10 through 13) is the Prairie Terrace (QTP), deposited approximately 115,000 to 130,000 years before the present (BP) during the Sangamon Interglacial Period (Harrelson 1990, and Harrelson and Smith 1988 (Figure 5)). The next oldest terrace mapped in the study area is the Deweyville (QTD), a lower Red River terrace (Plates 10 through 13) that is situated stratigraphically below the Prairie (Smith and Russ 1974). This terrace is estimated to have been deposited between 14,000 and 30,000 years BP. Oversized abandoned channels are characteristic of the Deweyville. These oversized channels are indicative of a much wetter climate and a higher stream discharge.

Upstream from the head waters of Caddo Lake (Plates 5 and 6), several oversized abandoned channels were mapped. These channels are associated with the older point bar surface (PB2), possibly a lower terrace surface, adjacent to the floodplain. Because of limited topographic and flood frequency data, this surface was included as part of the floodplain. Abandoned channels contained on this surface are much larger in comparison to abandoned channel segments closer to and associated with the main channel. These larger abandoned channel segments may represent a Deweyville equivalent in the Big Cypress Bayou drainage basin. Unfortunately, vibracoring of sediments from one of these channels (Plate 6, borings V2 and V3) was unsuccessful in recovering sufficient organic materials to radiocarbon date the filling history.

In another abandoned channel (i.e. vibracore V4, Plate 7) associated with the PB2 surface, radiocarbon dates from this channel indicate a Late Pleistocene age approximately 15,000 to 16,000 years BP when filling began. Dates from vibracore V4 should be interpreted with caution as these dates were obtained near the basal portion of the channel fill sequence. Dates from this fill sequence may possibly represent older eroded organic sediments, rather than in situ, contemporaneous fill sequences. Ideally, dates from channel fill sequences should record the fine-grained filling history as opposed to the lateral migration component which may include older eroded materials. In addition to the limited radiocarbon data, two other kinds of evidence, soils and pollen data, suggest that these channels may be older than Holocene.

Soils data

The first kind of evidence occurs in the soils which form the PB2 surface. A series of soil borings were drilled by the SCS (unpublished data) between Highway 43 and the abandoned channel in which vibracores V2 and V3 were drilled (Plate 6 for location). SCS borings define characteristics which are common for older mature soils. Soils at this location contain both argillic and fragipan horizons.

Argillic horizons are a diagnostic soil horizon representing a certain thickness (i.e. 7.5 to 15 cm) and an increased accumulation of clay (i.e. 3 to 8 percent) as compared to the overlying soils or the underlying parent material (Birkeland 1984). Clay content and thickness in argillic horizons are variable because of geographic differences in the soil forming variables (i.e. time, climate, slope, and composition of the underlying parent materials and overlying soils, etc.). Evidence for translocated clay particles from the overlying horizon must be present for a soil to contain an argillic horizon.

Fragipan horizons are soil horizons of high bulk density relative to the overlying soil horizons (Birkeland 1984). More detailed information and primary characteristics of fragipan soils are presented by Birkeland (1984). In summary, fragipan soil horizons are brittle, range in thickness from 15 to 200 cm, and are common in loamy material in climates characterized by water moving through the soil at some time during the year. Fragipan horizons are low in organic matter and generally noncalcareous. The cementing or binding agent is believed to be silicate clay minerals. There are no other chemical or mineralogical associations related to fragipan soils. The exact mechanism and conditions by which these soils form are unknown.

The geomorphic importance associated with argillic and fragipan soil horizons in the PB2 surface is that these soil horizons represent a stable surface and require a certain amount of time to develop. Exactly how much time is needed to develop either of these characteristics is unknown as it relates to the complex interchange between the different soil forming variables. Fragipan soils are often associated with the Pleistocene. Climatic changes are cited as possible mechanisms involved in their formation. However, Birkeland (1984) cautions that fragipan horizons have been documented in the literature as forming entirely during the Holocene. The geomorphic significance of fragipan horizons in terms of this study is that the PB2 surface has been stable enough for pedogenic processes to imprint and alter the underlying fluvial deposits.

Pollen data

The second kind of evidence which may help date the PB2 surface is derived from vibracore borings and results of the pollen analysis (Appendix C). A composite pollen diagram of selected pollen types as a function of their percent and depth is presented in Figure 6. All the cores except V7 in Figure 6 are derived from the PB2 surface. Because of the limited organics obtained during this study, cores with pollen suites from individual abandoned channels representative of different Holocene time intervals isn't possible. Rather, a combined or composite pollen diagram of selected species is presented in Figure 6 to develop relationships which may help define floodplain chronology. The pollen diagram includes pollen from three cores (V3, V4, and V7) ranging from the late Pleistocene to the present as defined by limited radiocarbon data and boring stratigraphy.

Four general categories of pollen types are summarized by Figure 6. These categories include grasslands, hardwoods (mainly oak and hickory), pine (excludes cool weather northern pine species), and total trees (includes all tree types). The time range represented by the pollen diagram is approximately 16,000 years. Radiocarbon dates are available from samples near

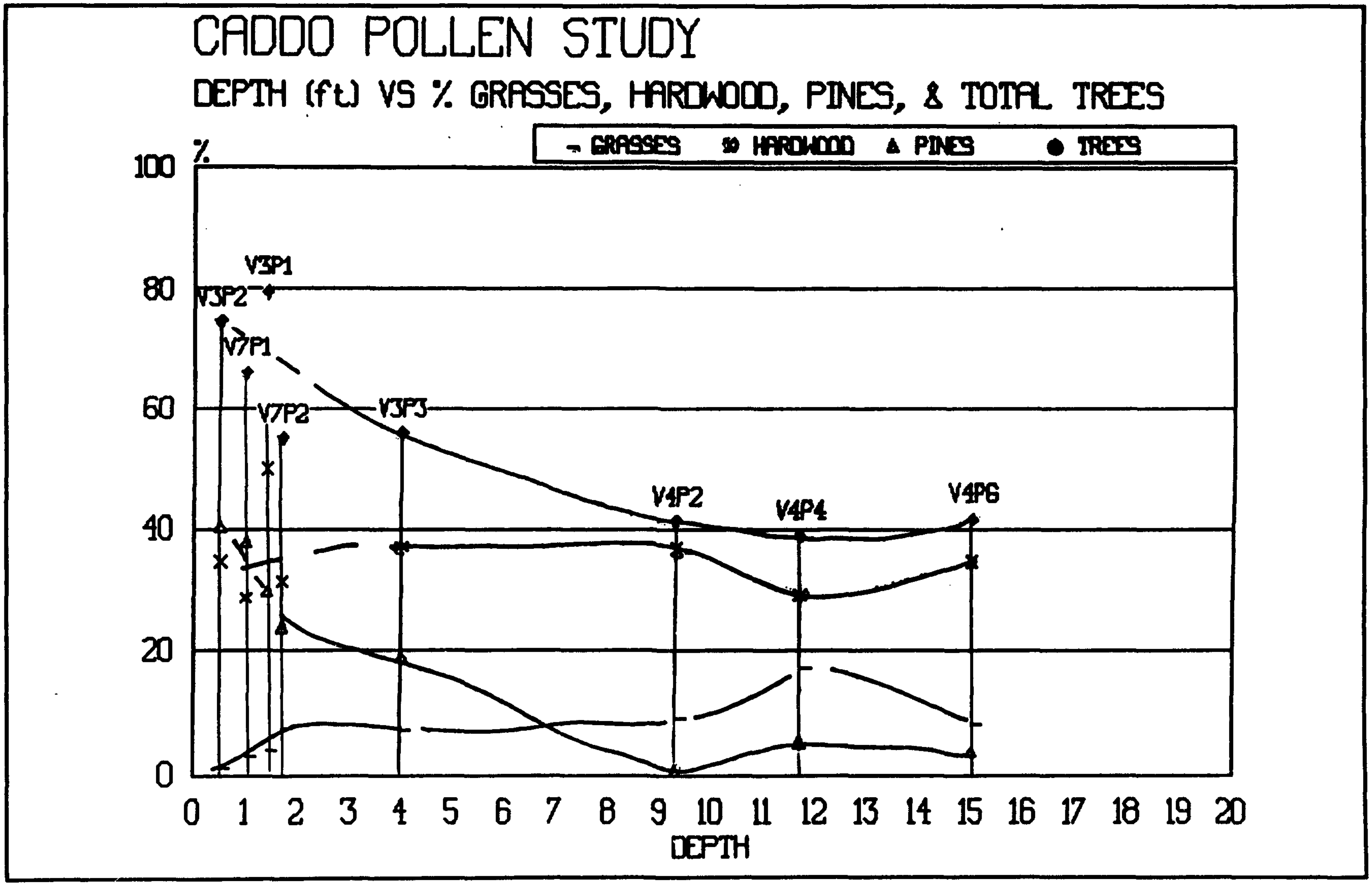


Figure 6. Pollen diagram from vibracores in headwaters of Caddo Lake

the base of V4 (16,810 to 15,180 years BP) and near the surface in V3 (105 years BP) and V7 (900 BP). The relationship among the various pollen categories indicates that total trees have increased overall, while grasslands have declined. Hardwoods have remained relatively stable, while pine is steadily increasing near surface.

The general significance of these categories is best summarized by Collins and Bousman (unpublished paper 1991) as follows:

> "The modern distribution of plant communities in Northeastern Texas is conditioned most clearly by the distribution of rainfall and temperature, but other factors, such as soil, have a significant affect as well. In general the modern plant communities consist of pine forests in far East Texas. As one travels from east to west oaks and hickory begin to replace pine, then hickory declines in frequency, and finally oak is displaced by more and more grass until in the west grasslands dominate the landscape. While these plant communities are seen as climax communities for the area in which they are mapped, it is generally believed that the distributions are controlled by climatic patterns and that significant changes in regional climatic patterns influence the distributions of these plant communities in a predictable fashion."

If the pollen data obtained from the headwaters of Caddo Lake is sufficiently "continuous and representative" of the last 15,000 years, then climate changes have not produced sharp vegetation shifts in the study area. The percentage of hardwoods has remained relatively stable. The overall increase in pine and total trees suggests that the study area is currently receiving higher temperature and rainfall rates than compared to the late Pleistocene. The data in Figure 6 suggest that extreme changes in vegetation, where one climax community was replaced by another representing a several-order magnitude shift along the vegetation gradient, did not occur as a result of changing climate. Instead, vegetation changes were less severe with movement occurring as gradual shifts along the east to west pine-hickory-oak-grasses gradient described by Collins and Bousman (unpublished paper 1991). Pollen data obtained during this study indicates the shift was primarily confined to the pine and hickory-oak communities. Pollen data from vibracore V4 (14.7 to 15 ft) indicates some boreal tree species (i.e. birch and spruce) were present in the study area during the late Pleistocene (Appendix C, sample V4-P6). Pine dominance in the southeastern United States occurred by the middle Holocene as determined from a regional pollen database as shown by Figures 7a through 7e (from Delcourt and Delcourt 1983).

It must be stressed that the pollen data obtained during this study do not completely represent Holocene climate change. Rather, the pollen data (Figure 6 and Appendix C) may only represent the present and the late Pleistocene, with no intermediate data points from early to middle Holocene. It is highly likely that the data do not completely reflect events associated with the early and middle Holocene periods. Bryant and Holloway (1985) have noted that for east Texas in general there is a limited fossil pollen record from the Holocene for reasons previously cited. Where pollen data do exist for eastern

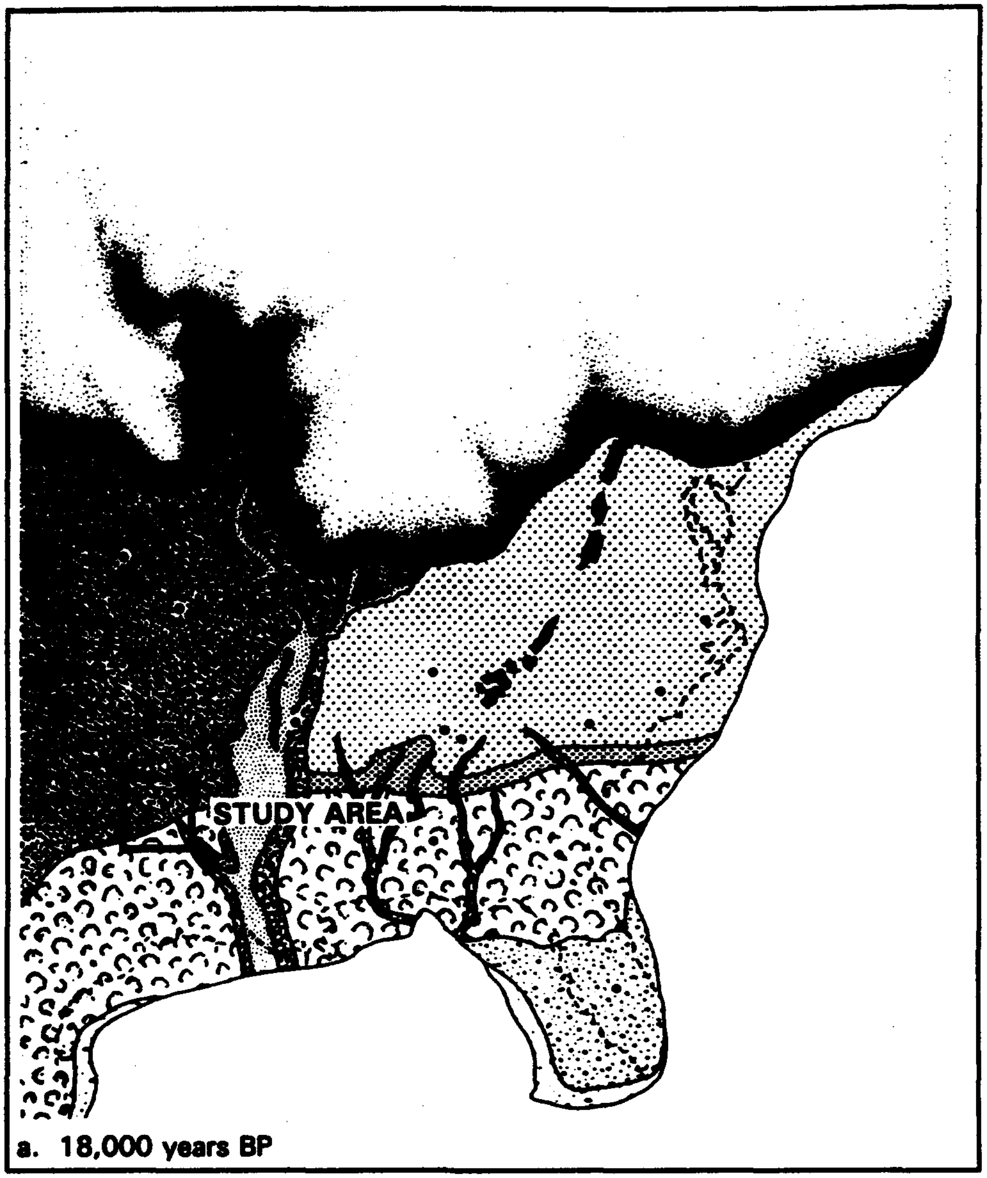


Figure 7. Paleovegetation maps; see Figure 7e for legend (from Delcourt and Delcourt 1983) (Sheet 1 of 5)

and central Texas, some characteristics are known about the early Holocene. Collins and Bousman (unpublished paper 1991) have compiled radiocarbon and pollen data from two Texas sites, Weakly Bog (near Dallas) and Boriack Bog (near Austin), which are shown in Figure 8. Their diagram shows the general distribution of grasses and arboreal (trees) pollens for the past 16,000 years. Their diagram illustrates the complex relationship between grasslands and trees during the late Pleistocene and Holocene periods. As grasslands increased in dominance, trees declined accordingly, and vice versa. The authors note that the data from these two Texas sites indicate that grasslands were dominant during the middle Holocene when drought conditions were documented for other parts of Texas. It is highly possible that the

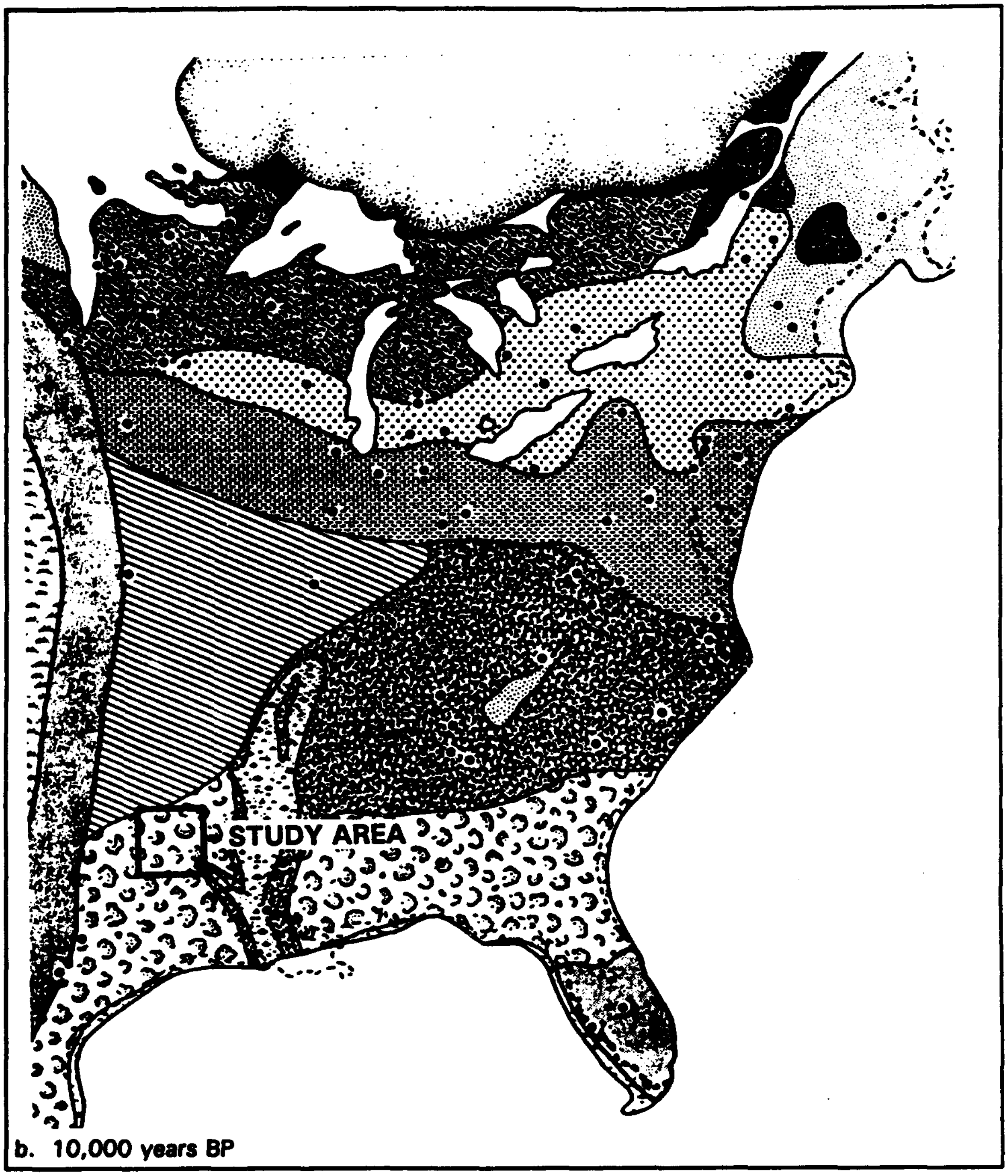


Figure 7. (Sheet 2 of 5)

middle Holocene pollen record is absent in the Caddo area partly because of the middle Holocene drought or "Hypsotherm."

Summary

Pollen data are available from two cores from the PB2 surface which represent extreme ends in a 15,000-year time interval. If the Pleistocene age at

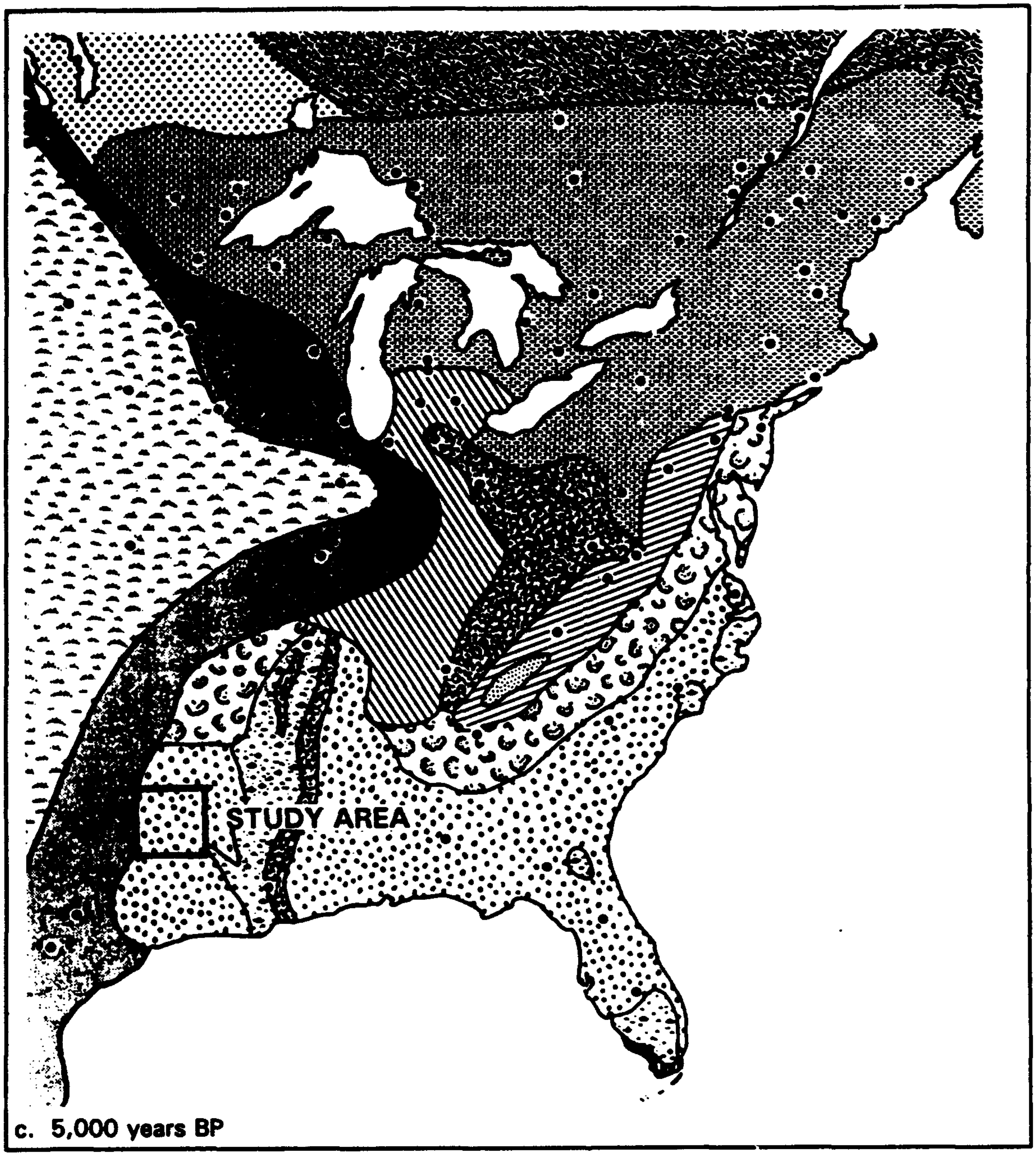


Figure 7. (Sheet 3 of 5)

one end of this time interval is correct (i.e. based on in situ abandoned channel sediments and not older, eroded, and transported organic deposits), then the PB2 surface may contain Pleistocene floodplain remnants. Pollen data from Texas and other locations in the southeastern United States show that climate changes have caused major shifts in vegetation patterns during the past 16,000 years. Exactly what changes have occurred during the early and late Holocene are unknown as organic sediments are not abundant in the subsurface from the headwaters of Caddo Lake. Absence of organic sediments may relate in part to middle Holocene drought conditions that were present in

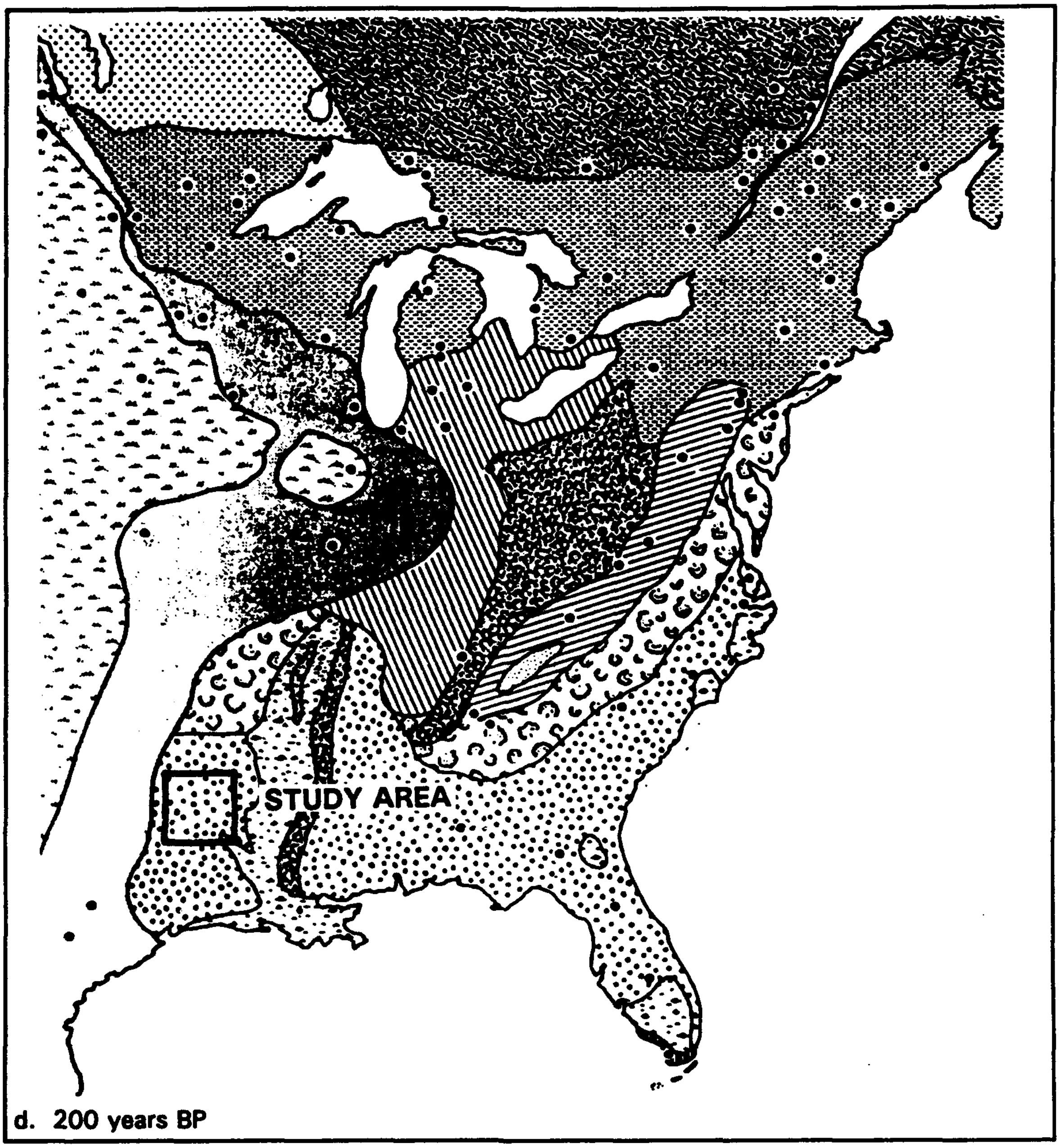
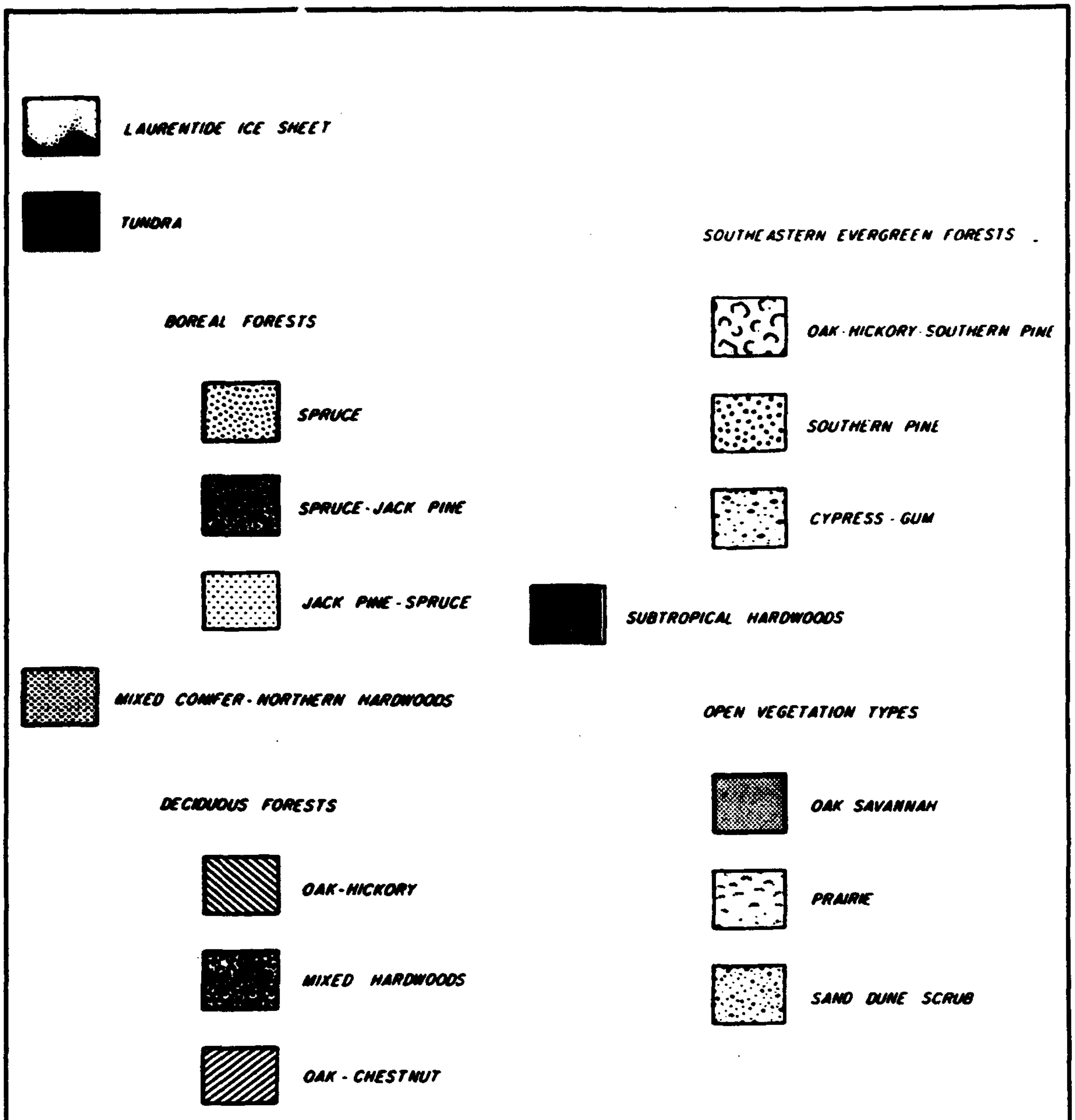


Figure 7. (Sheet 4 of 5)

central and eastern Texas during this time. Soils data and size, shape, and meander amplitude of certain meander loops near the headwaters of Caddo Lake indicate that this surface has the potential to be much older than Holocene.

The exact age range for the PB2 surface in the headwaters area of Caddo lake is unknown. Geomorphic evidence indicates that this surface has been stable and possibly may extend at some locations well into the late Pleistocene. In terms of its archaeological significance, the PB2 surface has been stable enough that it may contain paleoindian sites. In the final analysis,



e. Legend for Paleovegetation map

Figure 7. (Sheet 5 of 5)

archaeological evidence may represent the best means to further define the age of this geomorphic surface.

Holocene

At the beginning of the Holocene, the Mississippi River changed from a braided to a meandering system (Saucier 1974). Braided stream conditions were the result of the large influx of sediment from the melting glaciers that

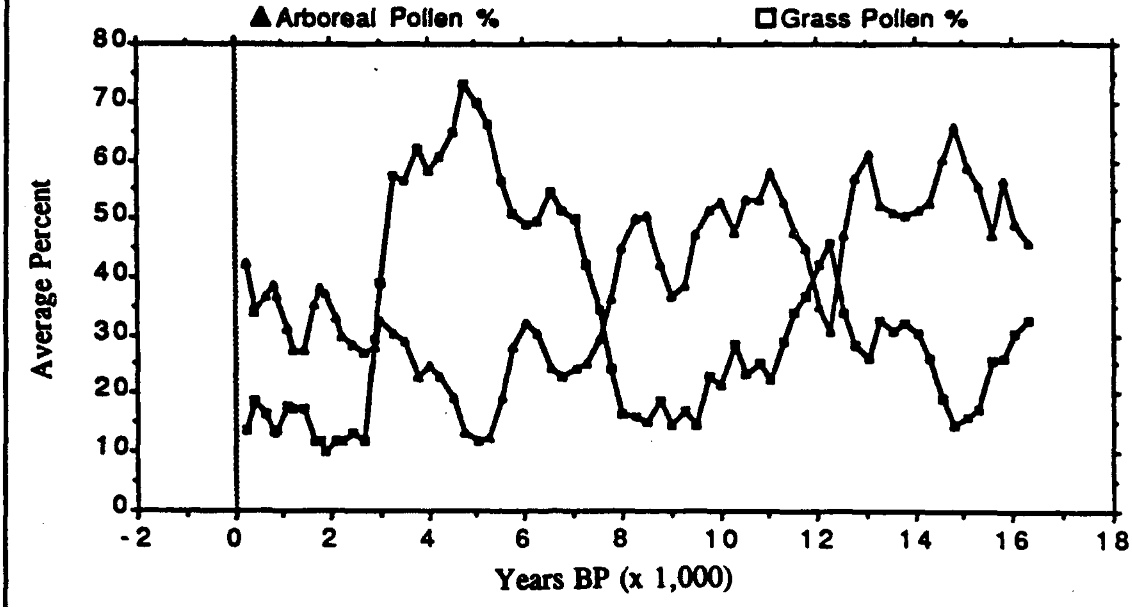


Figure 8. Summary pollen analysis from two eastern Texas sites: Weakly Bog, near Dallas, and Boriack Bog, near Austin (from Collins and Bousman, unpublished paper 1991)

had covered much of North America. Numerous, interconnected, or anastomosing stream courses in the Mississippi River Valley carried the glacial melt water and sediment gulfward. With the beginning of a meandering system, the Mississippi River began building a series of meander belt courses across its alluvial valley. As sea level reached its present level approximately 5,000 years ago, the Mississippi River began building a series of delta complexes seaward across coastal Louisiana (Figure 5).

The Red River was not directly affected by continental glaciation, since it did not directly transport glacial sediment and meltwater. Because glacial outwash and sediment were not transported by the Red River or its tributaries, the Red River was probably a meandering system during the Pleistocene. Climate changes were the primary geomorphic forces that affected the Red River valley and its tributaries.

Course shifts by the Mississippi River would have affected the Red River and its tributaries. Major course shifts would have influenced the location of the mouth of the Red River and its discharge to the Mississippi River. Major changes in the discharge location would have affected overall river distance and gradient and ultimately base levels. These changes would cause either stream aggradation or incision along the length of the Red River floodplain and its tributaries.

During the Holocene, the Mississippi River built five meander belt courses in its alluvial valley (Figure 5, modified from Saucier 1974, and Saucier and Snead 1989). In the Red River valley, six remanent meander belts are preserved (Smith and Russ 1974, Russ 1975, Saucier 1974, Saucier and Snead 1989). The most recent Red River course to the Mississippi River may have formed some time between 500 and 1,000 years ago through Moncla Gap (Russ 1975). Pearson (1986) suggests this change may have occurred even earlier, perhaps as early as 1,800 years ago based on archaeological data. This last course shift may have been partly responsible for the formation of the Red River Raft. The raft was a series of log jams approximately 100 miles in length which were present in the lower Red River valley during historic time.

The natural damming of the Red River by a series of log jams along portions of its lower valley may have been triggered by the migration of the Red River's mouth to Moncla Gap, a new position on the floodplain of the Mississippi River, and also by changing climate. Hall (1990) indicates that approximately 1,000 years ago a regional climate change occurred from moist to dry in the southern Great Plains. The response by the Red River to this climate change may have led to channel incision which helped to promote increased bank erosion. Similar changes have been noted for the central Great Plains (Martin 1992). Floodplain incision, bank erosion, and valley-wide lateral migration may have introduced a large influx of sediment and trees into the lower Red River Valley to form the Red River Raft.

Historic

By the early 1800's, the lower Red River was blocked by a series of logjams known as the "Great Raft." The Red River Raft was a nearly 100-mile-long series of log jams which had accumulated on the point bars of the river and formed numerous interconnected river channels in the upper Red River valley (Guardia 1933). An account of rafting is described by Timothy Flint (1833) as follows (Smith 1982):

> "About thirty leagues (i.e., 70 miles) above Natchitoches, commences the great raft, which is... a broad, swampy expansion of alluvion of the river to the width of twenty or thirty miles. The river, spreading here into vast number of channels, frequently shallow courses, has been for ages clogging with a compact mass of timber and fallen trees, wafted from the upper region. Between these masses, the river has a channel, sometimes lost in a lake, and found by following the outlet of that lake back to the parent channel. The river is blocked up by this immense mass of timber for a length on its meanders, of between sixty and seventy miles. There are places where the water can be seen in motion under the logs. In other places the whole width of the river may be crossed on horseback, and boats only make their way, in passing these places, by following the inlet of a lake and coasting it to its outlet, and thus finding the channel again. Weeds, flowering shrubs, and small

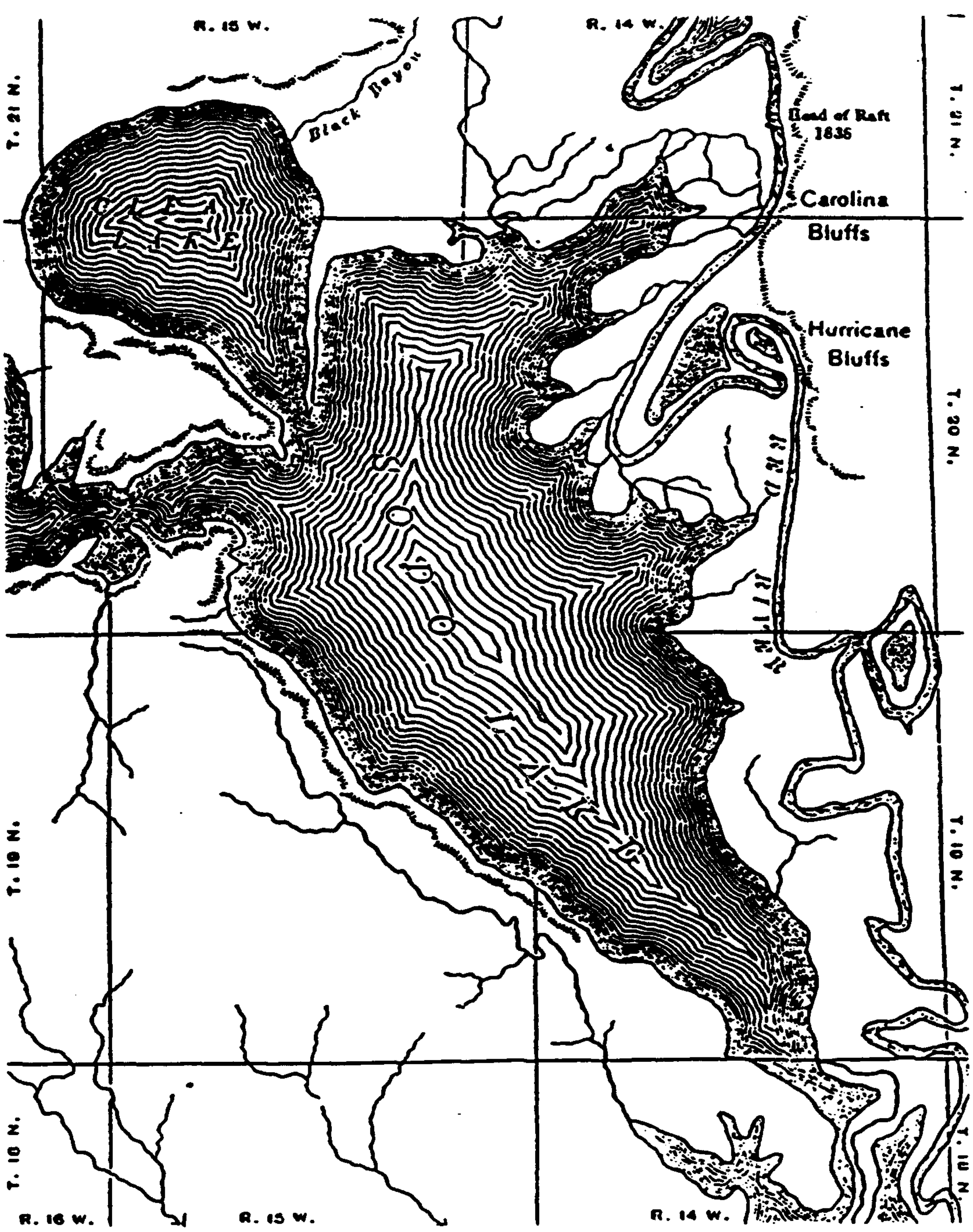
> willows have taken root upon the surface of this timber, and flourish above the waters. But in all these places the course of the river, its outlines and its bends, are distinctly marked by a margin of forest trees which grow here on the banks in the same manner as they do where the channel is open."

As described in the previous summary by Flint (1833), the Red River Raft led to the formation of numerous valley margin lakes within the Red River valley and alluvial valleys of its tributaries. The raft was an important mechanism for the formation of the large lakes that covered much of the study area during historic time. This study will not examine in detail the history of the raft other than its significance to lake formation as it is beyond the scope of this investigation. Further information about the raft is available from numerous historic accounts and papers (Darby 1816, Flint 1833, Veatch 1906, Caldwell 1941, and Mills 1978).

Soda Lake covered much of the lower study area by the early 1800's as shown by Figure 9a (from Veatch 1906). Soda Lake was connected to Caddo Lake by way of Willow Pass (See Figure 9b for location of Willow Pass.). It is judged that the maximum lake limits for Soda Lake were established during historic time, near the levels indicated by Figure 9a. Beneath the limits of Soda Lake, lacustrine deposits buried the former floodplain of the Red River. The thickness of these lacustrine sediments was identified at one location (Plates 12 and 13, boring ST-12) and was about 3.2 ft (0.98 m). Lacustrine deposits may be even thicker, depending on distance from sediment source areas.

Lake limits for Caddo Lake, or Ferry Lake as it was known in the early part of this century, were determined by Leverett (1913). He examined geomorphic evidence for ancient shorelines in the bluffs surrounding the lake. His study concluded that the mean high water stage for Caddo Lake was approximately 4 ft (1.22 m) higher than the present level (i.e. 169 ft (51.51 m) MSL) which is regulated by Caddo dam. Relict shoreline evidence indicated that lake levels may have reached a maximum of approximately 180 ft (54.86 m). These fluctuations are due perhaps to seasonal variations.

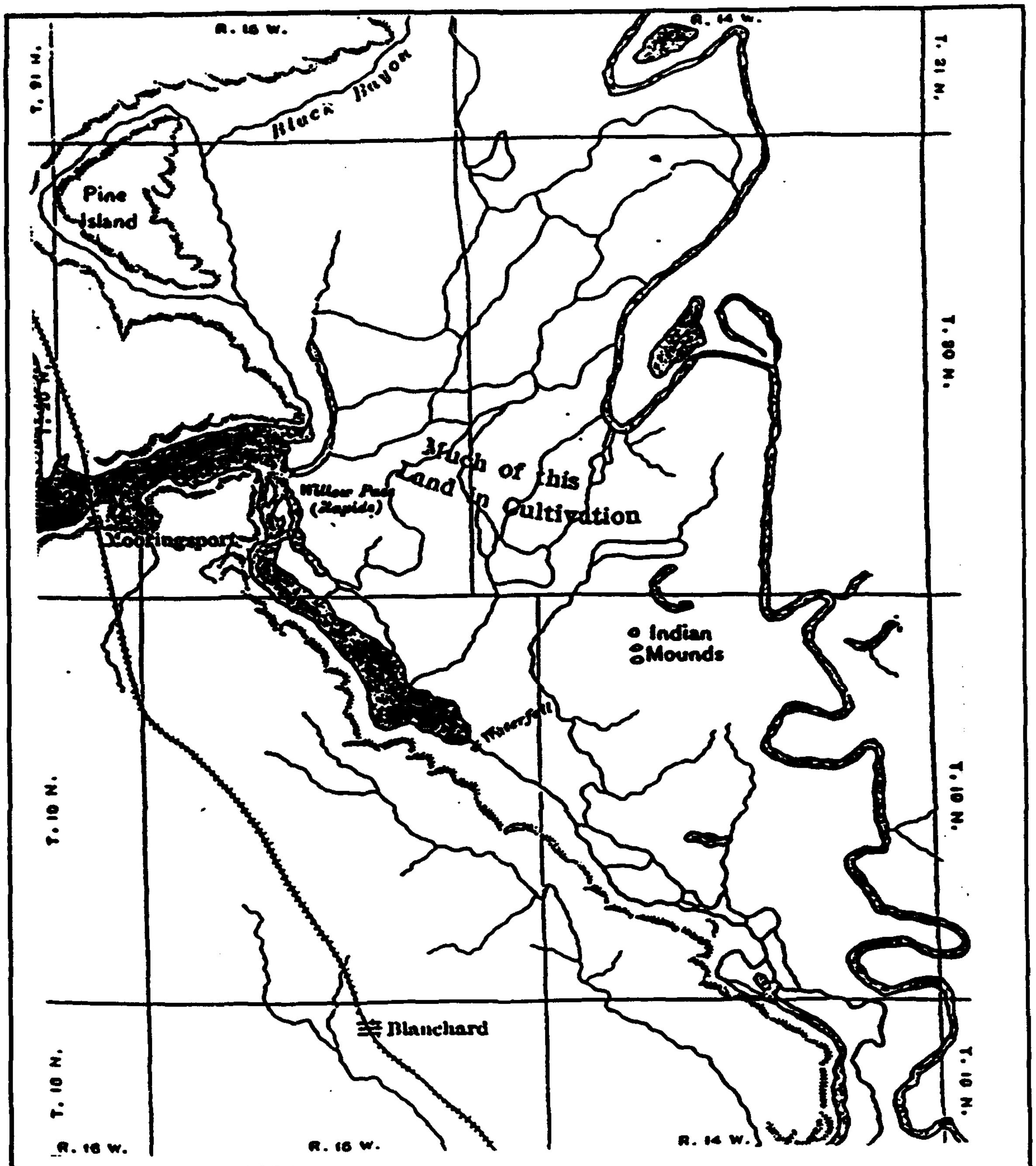
Complete removal of the Great Raft was accomplished by the USACE by 1873 for navigation purposes. Removal was conducted intermittently, depending on congressional funding and the national interest at the time, and took approximately 40 years to complete. Removal of the Great Raft caused the Red River to degrade its channel headward and drained the large lakes such as Soda Lake that had formed behind the raft. Fluvial downcutting of the present Red River floodplain did not reach Caddo Lake but completely drained Soda Lake (Figure 9b). After draining Soda Lake, the channel of Twelvemile Bayou began degrading headward. Kidder (1914) reported approximately a 14-ft (4.27-m) maximum falls on Twelvemile Bayou. The rate of headward erosion along Twelvemile Bayou was estimated at approximately 1,400 to 2,000 ft (426.73 to 609.61 m) per year based on data reported by Oliver (1908), Kidder (1914), and Leverett (1913). Leverett (1913) estimated that by



a. Area covered in 1838 and 1839

Figure 9. Location and limits of Soda Lake (Veatch 1906) (Continued)

the middle 1930's the falls would have advanced to the present location of Caddo Dam. The Corps built Caddo Dam in 1914 to prevent complete draining of Caddo Lake. A control structure and weir were later added in 1974.



b. Area covered in 1901

Figure 9. (Concluded)

Origin of Caddo and Soda Lakes

Origins for Caddo and Soda Lakes are important questions that need to be addressed by this study, particularly as they affect or impact the distribution of cultural components. Debate on the specific origins for these lakes has occurred since the early 1900's (Veatch 1906, Kidder 1914, Leverett 1913, Janes 1914, Fisk 1940, Russ 1975, and Bagur 1992a and 1992b).

A seismic origin has been attributed to the formation of these lakes by Indian legend. However, there is no geomorphic evidence in the form of active faults or recorded historic earthquake activity for this part of the United States. Borings drilled as part of the foundation for Caddo Dam reveals no stratigraphic or sedimentological evidence of earthquake induced sand boils (USACE 1893). If there were a seismic source associated with these lakes, then evidence in the historical seismicity, present day tectonism, or geomorphic record would be present. No such evidence exists.

The New Madrid area is the location for the largest historic earthquakes that have occurred in North America. These earthquakes occurred during the winters of 1811 and 1812. Isoseissmal data (Stearns and Wilson 1972) interpreted for this earthquake indicate the source area is too far distant from the study area to cause damage of the type necessary to produce lakes by vertical crustal movements. Origins for these lakes can be explained by natural fluvial processes.

Fisk (1940) proposed that valley margin lakes may have formed from "natural levee damming" by the main course as it migrated against the valley wall and intersected the valley mouths of the tributary streams. The process of natural levee growth would then build a dam across the tributary course and block access to the drainage. For Caddo Lake to form by this mechanism, it would require the Red River to occupy the Black Bayou course along the western valley wall and then to build a sediment dam in Willow Pass. Black Bayou is considered to be one of the earliest meander belts of the Red River (Saucier and Snead 1989). Assuming Black Bayou did form Caddo Lake, then the lake would have formed 4 to 5 thousand years ago. Geomorphic evidence, historic accounts, and the available archaeological data do not support the present lake complex as being this old.

Veatch (1906) argues the origin for the lakes must include the raft as the mechanism which dams the river, rather than strictly by natural sedimentation and base level changes. Perhaps the best evidence of a raft origin for the lakes is demonstrated by the events following removal of the raft. Removal resulted in valley-wide degradation of the Red River's floodplain, draining of Soda Lake, and caused down cutting of a new channel along Twelvemile Bayou to a lower base level. Leverett (1913) estimated that if Caddo Dam had not been built, Caddo Lake would have been drained by the 1930's.

Ultimately, the origin for the lakes is due, in part, to changes in base level between the Mississippi and Red Rivers because of shifting meander belts and climatic changes. Geomorphic evidence (i.e. lacustrine delta development in the Caddo Lake headwaters) and historic data evaluated during this study suggest that the present lakes are relatively young (less than 500 years before the present).

A more accurate age date is not possible with the available data. A more precise determination of the lake age would require numerous borings from beneath Caddo Lake and the former lake floor of Soda Lake to obtain additional stratigraphic and radiocarbon data. Archaeological data in the next section of this report provide additional evidence for the age of the lake complex based on the distribution of cultural components.

Caddo Lake represents a shallow, 3- to 5-mile-wide (4.83- to 8.05-km), drainage basin lake with a narrow valley at its confluence to the Red River. The entrance into Caddo Lake from Twelvemile Bayou is a natural setting for the location of Caddo Dam, since the valley is so narrow at this location. Prehistoric formation of Caddo Lake would have flooded the existing floodplain of Big Cypress Bayou. This former floodplain would have contained a well-defined main channel, abandoned courses and channels, and associated environments of deposition. The available historic and prehistoric data examined during this study suggests that existing archaeological sites would have been impacted by the lake formation, if there were any present.

5 Significance of Geomorphology to Cultural Resources

Introduction

Objectives

The last and most important objective of this study was to determine the archaeological significance of the geomorphic features, especially in terms of locating previously undiscovered sites. The major goals of this objective are as follows: identify and define the principal archaeological site/landform associations and classify the landforms according to their site potential; provide guidance for locating sites that are of specific ages or cultural components; and identify areas that have high potential for site destruction or preservation by natural geomorphic processes.

The approach that was used to define the relationships between known archaeological sites and geomorphic features involved identifying the known archaeological sites, evaluating the geomorphic site data from the recorded sites, and identifying important characteristics that relate the archaeological sites to the geomorphic features. These characteristics were then evaluated to predict the locations of undiscovered sites according to their geomorphic context.

It is important to emphasize that the primary purpose of this analysis is to show general relationships between the various landforms that comprise the study area and the archaeological sites contained within this area. This study is not meant to be an archaeological analysis.

Procedure

Archaeological site data were obtained from the Environmental Resources Branch (PD-Q), CELMK. Site data consisted of published reports for Texas (Gibson 1969, Peter and Stiles-Hanson 1990, and Thurmond 1990) and the archaeological site records from the Louisiana Computerized Archaeological

Database (LA-CAD) for Caddo Parish in Louisiana. The Louisiana site data is part of the database maintained by the Division of Archaeology of the Louisiana Department of Culture, Recreation, and Tourism.

There are 92 known archaeological sites in the project area. Ten sites are historic sites and were not used for determining archaeological and landform relationships. For the remaining 82 sites, important archaeological and geomorphic characteristics were derived from the site descriptions and the geomorphic maps. Characteristics that were compiled from the geomorphic maps and site descriptions include site number and quadrangle map, river mile location, site drainage basin, site elevation, site type, kinds of artifacts (i.e. lithic scatter, ceramics, historic debris, etc.), cultural component(s), and landform type. The catalogue of all known sites is presented in Appendix F. Because of their sensitivity, the locations for the known archaeological sites are not individually identified in Appendix F or on the geomorphic maps.

The accuracy of the known site locations is often open to debate. Every effort was made in this study to use only sites that are judged to be located correctly. However, known sites were not field checked for their location. Site locations were plotted on base maps and compared to the site descriptions. If there was a doubt about the site location, then the site was not used in this study. The site catalogue is utilized with a full understanding that it may contain inaccurate site locations and site information. Ideally, a field verified archaeological site database is preferred and is recommended.

Archaeological site definition

An archaeological site is defined by Willey and Phillips (1958) as the smallest unit of space that marks the location of a single unit of settlement and is usually covered with artifacts or components indicating former occupation. The physical limits of a site may vary from a few square meters to many square kilometers. An archaeological site for purposes of this study is simply a location where artifacts have been found. The definition of a site as used in this study does not differentiate on whether settlement has occurred as in the definition by Willey and Phillips. There are no restrictions placed on the usage of the term "archaeological site" in this study. A site can be a location where settlement has occurred, or it can be a location that was occupied only once and artifacts were left.

The reason for adopting a nonrestrictive definition is due to the nature of the archaeological site data. The archaeological data from the project area consist of site reports that are more than 50 years old to recent reports. The site data vary from brief descriptions to detailed reports. Often times the site locations and other kinds of important information in the site descriptions are missing or the data are wrong. In addition, it is possible for a single large site to be represented in the record as multiple sites that were recorded at different times by different individuals or organizations.

The primary objective of using the archaeological site data is to show the general relationships between the prehistoric sites and the landforms. It will be left to the archaeologists to interpret information about the site beyond its geomorphic characteristics, eliminate sites where duplicate listings occur, combine sites on the individual landforms that contain duplicate sites, or remove sites that are judged to be located inaccurately. It is important to emphasize that the site catalogue has not been field checked and it probably contains some erroneous data. Basic trends are defined about the landforms by the archaeological site data in this section of the report. Illustrations have been prepared from the catalogue in Appendix F, specifically about site-landform distributions.

Characteristics of an archaeological site

The artifacts that make up the archaeological site have by their distribution and position within the site certain temporal and spatial qualities. These qualities are defined by the geographic, stratigraphic, and the ethnographic characteristics of the artifacts (Gould 1987).

The stratigraphic and geographic characteristics describe physical qualities about the site itself. The geographic characteristics describe the spatial context between the artifacts and their relationships to other artifacts and their environment. The stratigraphic characteristics define the temporal or chronological order of the artifacts and relate these characteristics to the site occupation. Defining the geomorphic setting of the site is an important first step in evaluating the geographic and stratigraphic characteristics of the site.

This study describes mainly the geographic (environmental or geomorphic) characteristics of the known archaeological sites. The identification of the site geomorphology is important to understanding the overall site archaeology, since the different landforms are dominated by certain types of geomorphic processes. These different kinds of processes will affect or control the distribution of the archaeological sites and the associated artifacts.

Stratigraphic or chronological characteristics of individual archaeological sites are not fully addressed by this study. The geomorphic analysis provided by this investigation will provide a general stratigraphic or chronological framework to evaluate the individual sites. A more detailed evaluation of individual sites will require the acquisition and analysis of further soil borings on the landforms upon which the individual sites are located. These soil borings will identify important sedimentological and soil forming characteristics and may provide datable materials for further determining chronologic boundaries.

The last major criteria of an archaeological site are the ethnographic characteristics. These characteristics are determined by the archaeologist. The ethnographic characteristics of the artifacts and the site are concerned with the human qualities of the site. Ethnographic characteristics relate the human occupation to their associated activities and to the different types of cultures.

However, before the ethnographic characteristics can be fully understood, the geographic and stratigraphic characteristics must be fully defined and evaluated.

Distribution of Known Archaeological Sites

Drainage basin

The known prehistoric archaeological sites (total of 82 sites) were evaluated according to drainage basin reach as shown by Figure 10. Sites are generally evenly distributed except for the Big Cypress Bayou reach of the study area. The distribution suggests that a detailed cultural resource survey has not been conducted for this reach. The Big Cypress Bayou reach accounts for approximately 25 percent of the land area contained in the study area. The largest concentration of sites are associated with and border Lake O' the Pines and Caddo Lake. This concentration is more a function of the number and quality of surveys performed in this area rather than a preference by the different cultural components.

Landforms

The distribution of prehistoric sites as a function of the different landforms in the study area on which the sites are located is presented in Figure 11. Approximately 60 percent of the known prehistoric sites are located above the floodplain on terraces or valley slopes. The remaining 40 percent of the sites are associated with the floodplain of the various fluvial systems which form the study area. Three sites are located within or beneath Lake O' the Pines and Caddo Lake.

The majority of floodplain sites are located upon the natural levees or point bars adjacent to abandoned channels and courses. Geomorphic mapping did not identify natural levee limits in the study area, since this environment is so widespread. Instead, the underlying fluvial environment was mapped as the principal landform type. Known prehistoric sites are primarily located upon point bars adjacent to the present channel or on the PB2 surface. The majority of floodplain sites are derived from Twelvemile Bayou and the Red River valley as shown by the site catalogue in Appendix F. As indicated by Figure 10, there are not many sites identified in the Big Cypress Bayou reach. Lack of sites on the PB2 surface in this river reach may be due, in part, to site burial by vertical accretion of sediment and/or the absence of detailed surveys in this area.

Lake shorelines

Sites associated with lake shorelines may provide additional evidence for the age of Caddo and Soda Lakes. Locations of the known Caddo

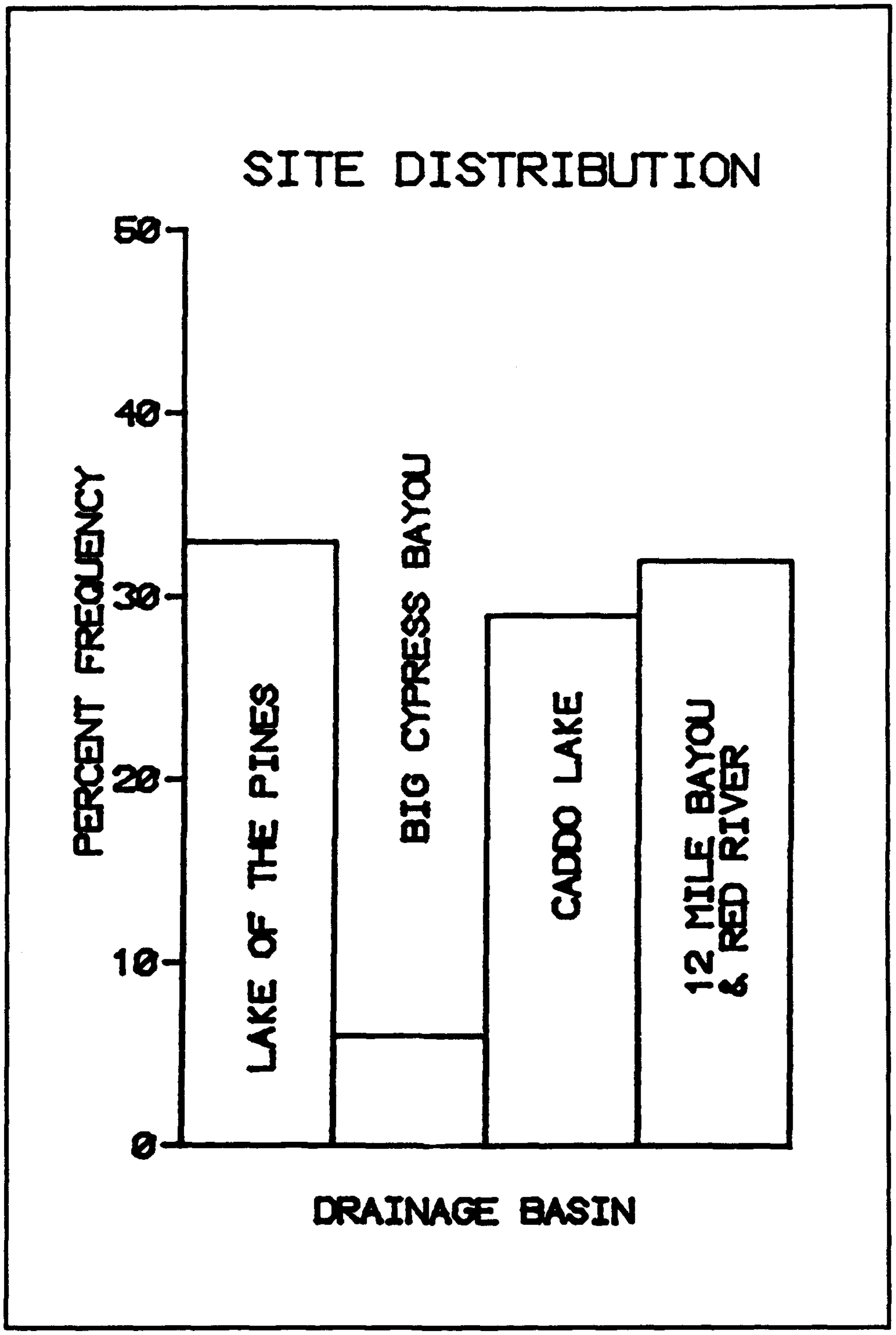


Figure 10. Distribution of archaeological sites based on drainage basin. Total number of reported prehistoric sites in study area is 82

archaeological sites are compared to the historic lake limits for Caddo and Soda Lakes in Figure 12. Only Caddo Indian sites were selected for the comparison, since the Caddo culture is within the time limits interpreted for the lake development. The Caddo culture ranges from approximately 200 BC

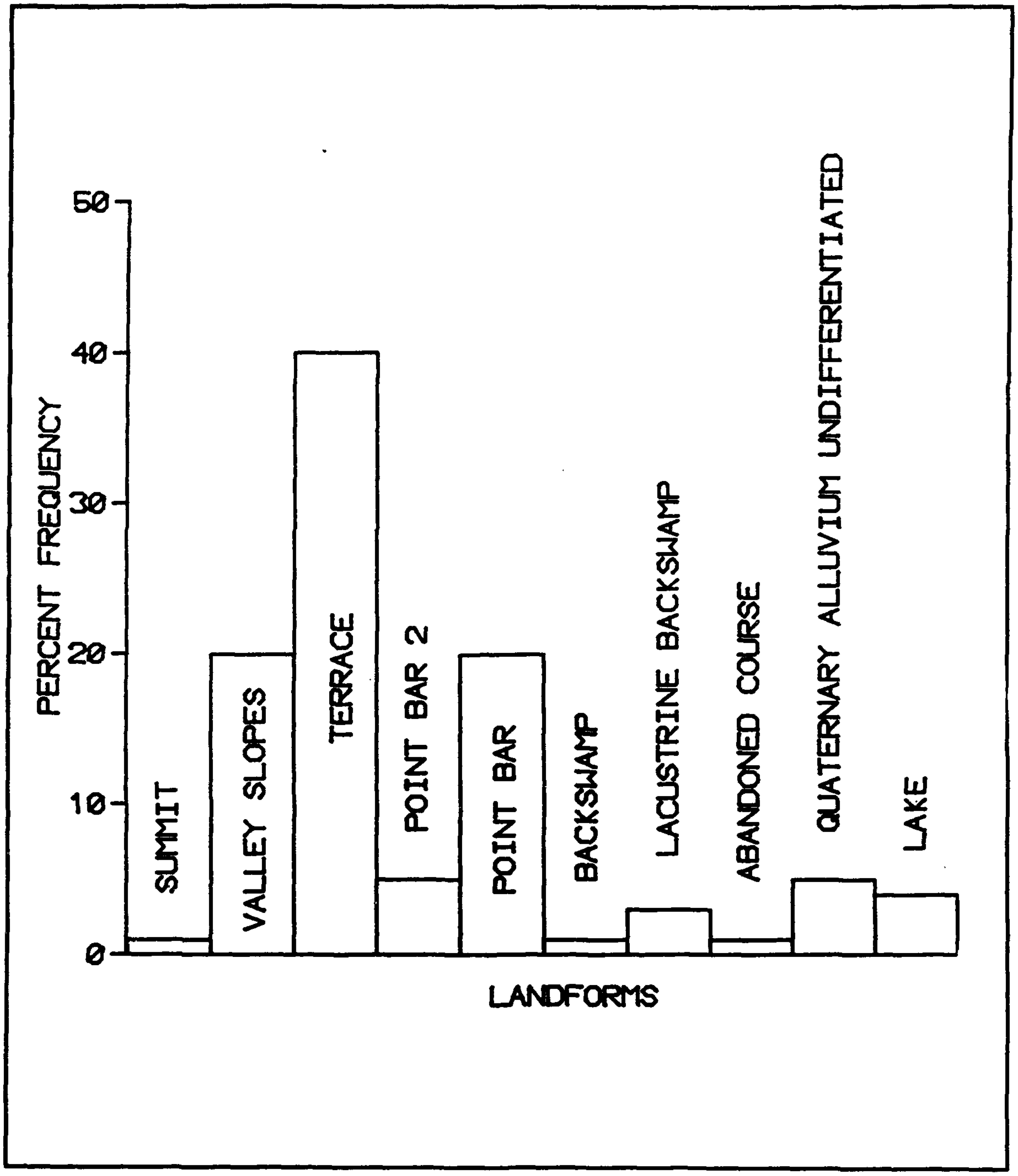


Figure 11. Distribution of all known archaeological sites based on landform

to 1700 AD. Archaic sites were not used in the comparison, since these sites predate the earliest possible formation of the lake. Archaic sites in the southeastern United States generally range from approximately 10,000 years ago to 200 BC. Historic lake limits are based on the work by Kidder (1914) for Caddo Lake and the 1838-39 lake limits identified by Veatch (1906) in Figure 9a for Soda Lake. The site distribution identified by Figure 12 indicates that a correlation may exist between Caddo sites and the historic lake shorelines.

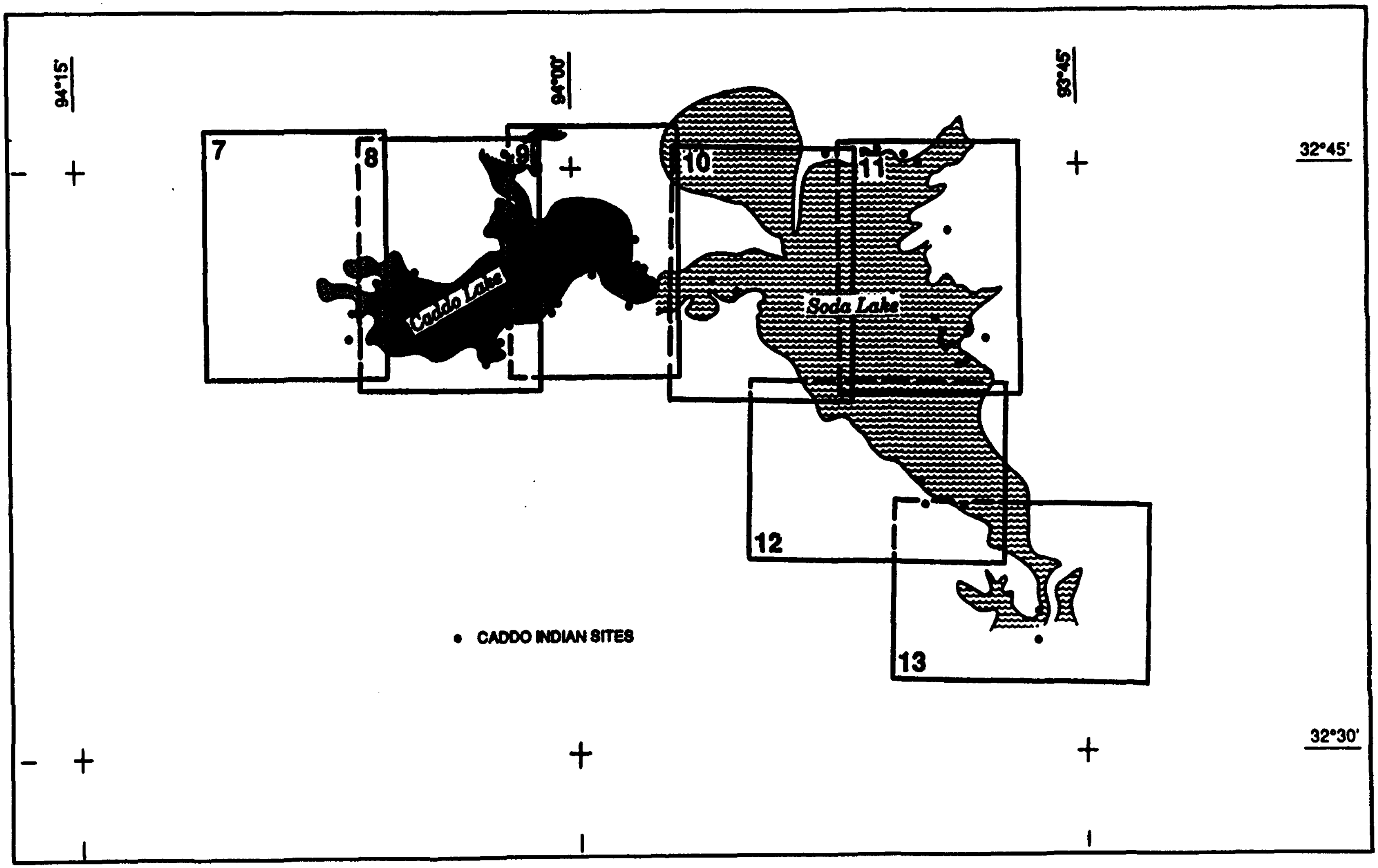


Figure 12. Distribution of Caddo archaeological sites along the historic shoreline of Caddo and Soda Lakes. Historic lake limits are from Kidder (1914) for Caddo Lake and from Veatch (1906) for Soda Lake (Figure 9a)

Lake limits for Soda Lake in Figure 12 were transferred to the geomorphic base maps and the archaeological sites located according to their position to the 1838-39 shoreline. Lake limits in Figures 9a and 12 are believed to be near their maximum at this time, since Captain H. M. Shreve, tasked with removing the raft, had only cleared to Shreveport by 1838 (Mills 1978). Sites in Soda Lake and adjacent to the Red River in Figure 12 (area of Plate 11) may not have been submerged, since these sites are associated with natural levees of an abandoned channel complex. This area would have been higher ground and may not have been flooded except possibly during seasonal flooding. The shoreline distribution of archaeological sites around Caddo Lake suggests that the lake complex was established during Caddo time.

An alternative explanation to the shoreline distribution is that the lake margin sites are not related to the lake complex but relate to the previous floodplain surface. Flooding inundated the study area because of the Red River Raft and drowned the existing prehistoric sites that were present. Lake margin sites are therefore not related to the lake complex but relate to the previous floodplain. The absence of sites in the lake is due to lacustrine sedimentation and burial of the existing floodplain and associated sites.

Closer examination of this latter explanation may, in fact, be partly true as early Caddo sites would have been inundated by the formation of the lake complex. Available data suggest that the lake complex is less than 500 years old. Consequently, sites associated with the Caddo culture between 200 BC and approximately 1200 to 1500 years AD, prior to lake formation, would have been flooded by the advent of the raft, providing there were sites at these locations. LMK has calculated that it would require 2.45 years to fill Caddo Lake to the present level, assuming total damming of the river, normal rainfall, and a dry lake bed (Cool 1992). Assuming similar conditions for the entire Caddo-Soda lake complex, it probably would have taken less than 10 years to form. This estimate is highly improbable, since a sudden complete blockage of river flow would have been unlikely. Rather, the blockage would have begun on the lower Red River and taken several decades to migrate upstream. The entire process may have taken 50 to 100 years to complete. The exact time required to form the lake complex may never be known, but the filling framework was short enough that prehistoric settlements were more than likely forced to move to higher ground and settlements began forming along the lake shoreline. It is highly probable that lake formation flooded prehistoric sites that were present beneath the historic limits of Caddo and Soda Lakes.

Elevation, flood frequency, and site location

The distribution of the known archaeological sites as a function of elevation, flood frequency, and their approximate river mile location above Shreveport is shown in Figure 13. Tributary sites distant from the central axis of the valley profile are not shown (i.e. Red River sites in the northern part of the study area). Only sites within the main valley of the study area are identified

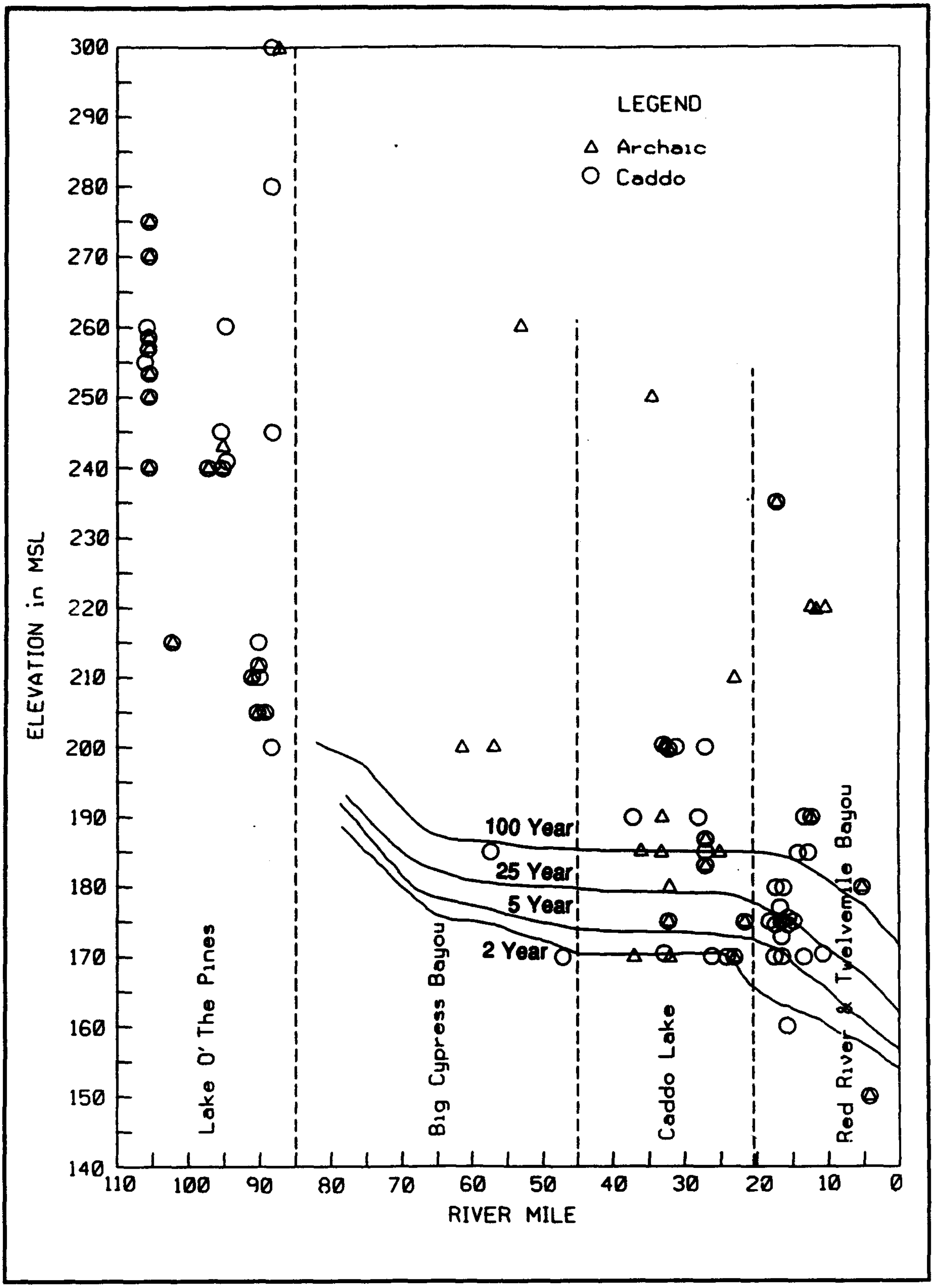


Figure 13. Distribution of archaeological sites in project area as a function of elevation, flood frequency, cultural component, and distance above Shreveport, LA

in Figure 13. The vast majority of sites are located above the minimum pool level or the 2-year flood frequency.

Archaeological sites are not uniformly distributed throughout the project area as shown by Figure 13. There are fewer sites identified for the Big Cypress Bayou segment. Higher site concentrations along adjacent drainage segments are attributed to a higher intensity of cultural resource surveys in these areas.

Distribution of cultural components

Available archaeological site data for the purpose of this study were divided into three cultural component types: Archaic, Caddo, or Historic. Historic sites were not evaluated in this study since prehistoric sites are the primary focus of this investigation and because other factors may govern the distribution and occurrence of historic sites. Historic sites are best defined and evaluated by conducting a detailed historic assessment and inventory of the study area. A historic site assessment and inventory is beyond the scope of this study.

The distribution by cultural components in Figure 13 indicates that sites generally contain multiple occupations. Sites that identified multiple occupations were considered to be both an Archaic and a Caddo site.

Archaic sites are located primarily on terrace surfaces and valley slopes as shown by Figure 14a. Approximately 80 percent of the known Archaic sites are located upon these surfaces. The remaining sites are located primarily on the floodplain. Lack of sites upon the floodplain may be due in part to site burial by vertical accretion or because the landform age is to recent.

A positive correlation has already been determined to exist between historic Caddo and Soda Lake shorelines and Caddo sites. The distribution of Caddo sites according to other landforms is presented in Figure 14b. Caddo sites are concentrated primarily on valley slopes, terraces, and point bars adjacent to the present floodplain. These three landforms account for approximately 75 percent of the known Caddo sites.

Prediction of Site Occurrence

The distribution of the known archaeological sites as identified in the preceding illustrations indicates that sites are not random, but are clearly associated with specific landforms in the project area. Geomorphic relationships identified for the known sites can be used to locate and interpret previously undiscovered sites and guide the subsequent archaeological analysis of the individual sites and the entire study area. Geomorphic relationships identified by this study should help to improve the efficiency of later cultural resource investigations in the project area and maximize the results obtained.

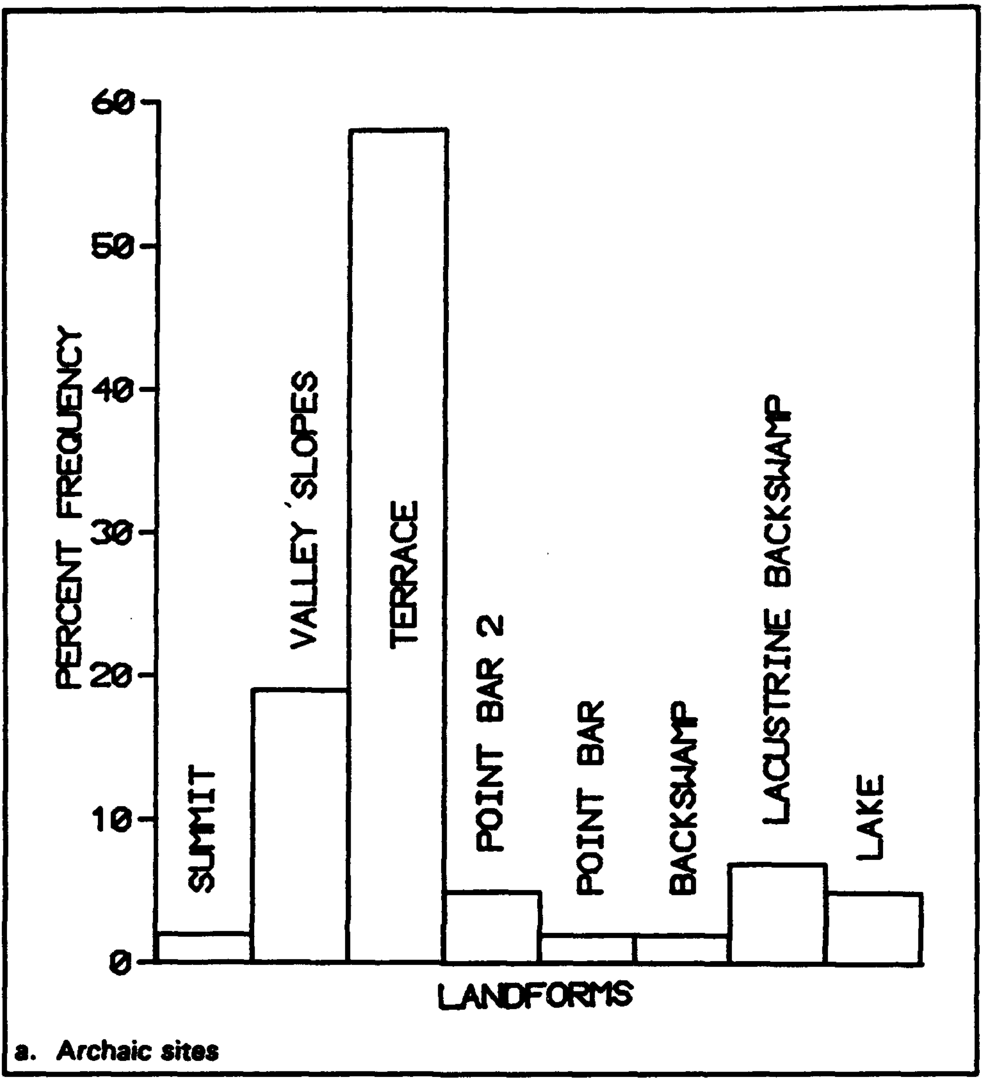
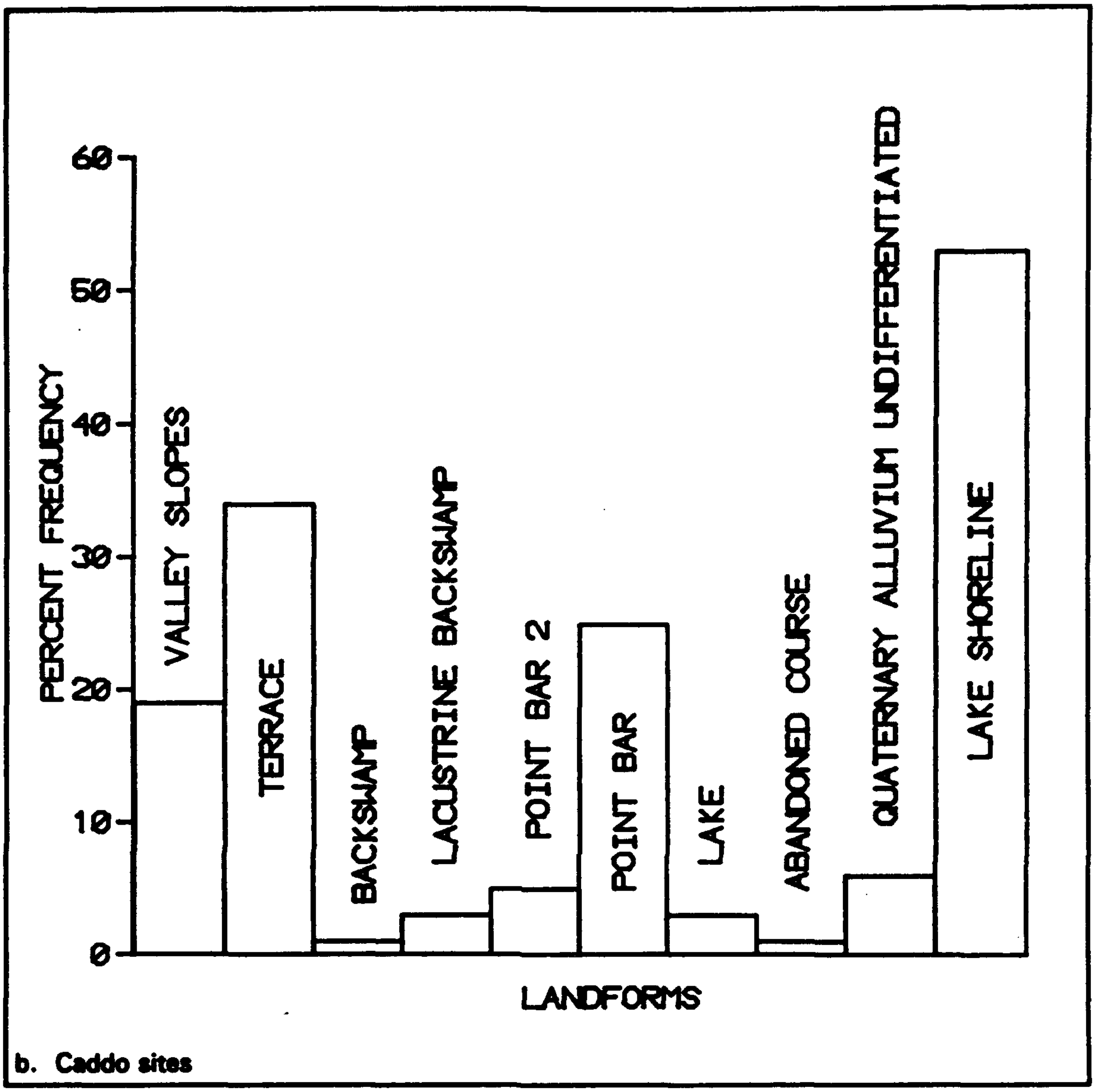


Figure 14. Distribution of Archaic and Caddo archaeological sites by landform (Continued)

In addition to locating undiscovered sites, geomorphic relationships will aid the archaeologist in defining the ethnographic site characteristics.

Terraces have the highest site potential of all the landforms identified by this study. Forty percent of all the known Caddo and Archaic sites are located upon terraces (Figure 11). In addition to the terraces, Caddo sites are concentrated along the natural levees of point bars within the present floodplain and along the shorelines for historic Caddo and Soda Lakes.

Artifacts are most likely to be encountered on terraces and the natural levees of abandoned channels associated with the present floodplain course (i.e. PB surface). Artifacts may be located either on these landform surfaces or as part of the sediments that form these landforms.



b. Caddo sites

Figure 14. (Concluded)

Lack of sites upon the older point bar (PB2) surface may be due to vertical accretion of sediment and/or the lack of adequate cultural resource investigation on this surface. The PB2 surface in the Big Cypress Bayou segment is probably the least surveyed part of the study area. Geomorphic data indicates that possibly some abandoned channels and courses comprising this surface may possibly have formed during the early Holocene or late Pleistocene. Archaeological site data may provide additional evidence to the age of the various floodplain components.

Site Preservation and Destruction

Introduction

In the Shreveport to Daingerfield project area, a number of processes are or have been at work either preserving or destroying the evidence of prehistoric groups. Most evident of these processes are the result of historic man, such as cultivation of the soil, timbering, construction of roads, buildings, and dams, and removal of the Red River Raft. However, natural processes have also played a key role in the preservation or destruction of the archeological record. Some geomorphic processes, such as lacustrine sedimentation or fluvial sedimentation, may serve to preserve the record through burial. Erosional processes may destroy sites by redistribution or destruction of the surfaces where sites occur. In the following paragraphs, the archeological significance of several processes are discussed, including fluvial sedimentation, chemical weathering, fluvial scouring, and wave attack from fluctuating lake levels.

Fluvial sedimentation and site preservation

An understanding of fluvial sedimentation rates is important in evaluating artifact decay and preservation characteristics. Knowledge about sedimentation rates is also important in understanding the stratigraphic or chronological significance of the archaeological record. Rapid sedimentation will promote the preservation and superposition of artifacts and features that result from serial occupation of sites (Figure 15 (Ferring 1986)). In contrast, slow sedimentation rates will result in the accumulation of archaeological debris as mixed assemblages and increase the potential for artifact decay by chemical and physical causes.

It is therefore important to understand, at least in general terms, local sedimentation rates to address the potential for site preservation and the types of sites that will be preserved. Sedimentation rates in the project area were interpreted from geomorphic evidence and are based on field observations and laboratory analysis of the available data.

Geomorphic Evidence and Archaeological Significance of Sedimentation Rates

Geomorphic evidence and sedimentation model

Geomorphic mapping and laboratory data were the principal means of determining sedimentation rates in the study area. The various types of evidence used to determine sedimentation rates are presented in Figure 16

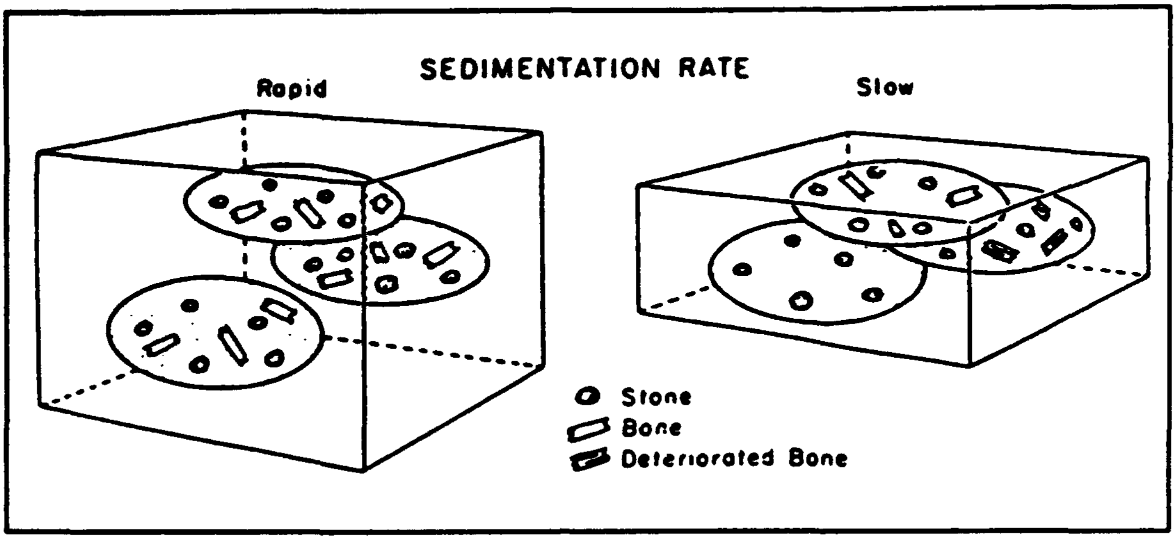


Figure 15. Sedimentation model contrasted between settings with rapid and slow accumulation rates. With rapid sedimentation rates, note better preservation and superposition of artifacts (from Ferring 1986)

(Ferring 1986). Types of evidence include sedimentary structure, soil profile development, bioturbation, and fossil preservation. The types of evidence shown by Figure 16 and a general knowledge of the different processes operating within each landform make it possible to estimate sedimentation rates for the landforms identified in Table 2.

Sedimentation rates in the study area must be considered in terms of the present day and when Caddo Lake was formed. Erosion and sediment transport are occurring throughout the project area. Sediment deposition is judged to be high in the lake and headwaters area of Caddo Lake and Lake O' the Pines. Sedimentation rates on the Red River floodplain are also considered to be high, estimated at approximately 3 ft (1 m) per 1,000 years (Smith 1982). In addition, sedimentation rates are higher here because the Red River Raft accelerated the aggrading of the Red River floodplain by adding 3 to 4 ft (0.91 to 1.22 m) of lacustrine sediment during the past 500 years. In contrast, the lowest sedimentation rates occur on the terraces and areas removed from semiannual flooding. Valley slopes and summits are mainly locations of weathering and erosional processes. Sedimentation rates on terraces are intermediate between rates on summits and hill slopes and the higher rates on the floodplain.

The site preservation and destruction characteristics of the different landforms, as a function of sedimentation, are evaluated for different types of archaeological artifacts in Table 2. The artifacts examined in Table 2 are animal bones, shell, charcoal, ceramics, crystalline lithics, and granular lithics. The different landforms were evaluated according to their ability to enhance preservation or accelerate decay. The interpretations made in Table 2 are based on the deterioration of archaeological sites primarily by chemical weathering in a humid environment with the main preservation influence by burial from fluvial sedimentation as indicated by the model in Figure 14.

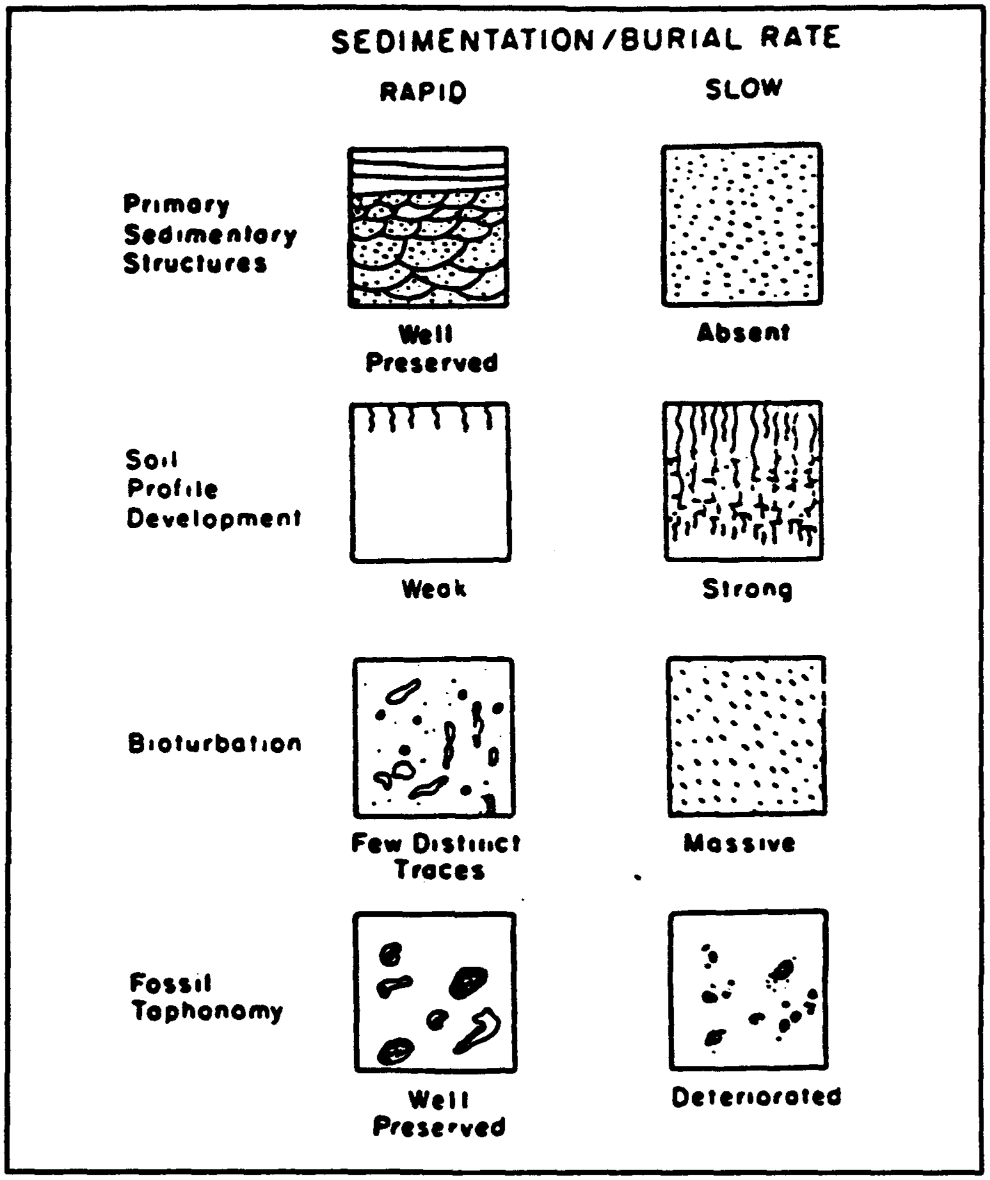


Figure 16. Geomorphic evidence of sedimentation rates (from Ferring 1986)

Discussion

Preservation and destruction qualities of landforms are site dependent and are based on a number of interdependent variables. These variables include soil pH, soil moisture, wet aerobic or anaerobic environments, types of micro-organisms and macro-organisms present, sediment movement, and soil [illegible]. The relationships between these variables are very complex. They can vary slightly and result in different decay properties for the different artifact types. Hamilton (1987), Steele (1987), and Vaughn (1987) describe the effects that each of these variables has on artifact deterioration in archaeological sites. The majority of artifacts identified in the archaeological site

Table 2
Geomorphology of the Big Cypress Drainage Basin Project Area

					Archaeological Artifacts[4]					
Surface	Landform - Formation	Age[1]	Geomorphic Process[2]	Rate[3]	AB	SH	CH	CE	CL	GL
Floodplain	Point bar (PB)	H	LA	M-R	B	B	B	B	N	N
	Point bar (PB2)	H-P	LA-VA-BT-SF	M	B	B	B	B	N	B
	Lacustrine delta (LD)	H	LA-VA	M-R	E	E	A	E	N	N
	Abandoned course (ACO)	H-P	VA-LA	M	E	E	A	E	N	N
	Abandoned channel (AC)	H	VA-LA	M	E	E	A	E	N	N
	Tributary alluvium (QAL)	H	VA-LA	M-R	A	A	A	A	N	N
	Lake shoreline	H	E-WW	*none*	A	A	A	A	A	A
Terrace	Abandoned floodplain (QTD and QTU)	H-P	SF	L	A	A	A	A	N	N
Valley slopes	Tertiary geology Clairborne, Wilcox, and Midway groups	T	E-SF	L	A	A	A	A	N	N

[1] Age: H = Holocene, P = Pleistocene, T = Tertiary.

[2] Geomorphic process: VA = Vertical accretion, LA = Lateral accretion, SF = Soil forming processes (Pedogenesis), BT = Bioturbation (organic mixing by vegetation an organisms), E = Erosion, WW = Wave wash.

[3] Rate of deposition: Low, M = Medium, R = Rapid.

[4] Archaeological artifact: AB = animal bones, SH = shell, CH = charcoal, CE = ceramics, CL = crystalline lithics, GL = granular lithics, A = accelerates decay, E = enhances preservation, B = both; may accelerate decay or enhance preservation, N = neutral or no effect.

descriptions (Appendix F) are lithics. These artifacts are least affected by chemical and physical weathering as shown by Table 2.

Chemical weathering promotes the decay of bone, shell, charcoal, and pottery. Stone artifacts are not affected. With increasing sedimentation and burial, artifact preservation is greatly enhanced as burial reduces the rate at which chemical weathering occurs. Archaeological sites are most threatened on the summits and on the side slopes where sedimentation rates are very low or where erosion is the dominant process.

Archaeological sites are more likely to be protected adjacent to or near the main channel where maximum sedimentation and burial occurs. Sites that are in close proximity to the main channel and not in the direct path of lateral migration by the river are buried by vertical accretion. Vertical accretion is presently an important mechanism for sedimentation in the lakes and headwaters portion of the project area. In the headwaters area, the former floodplain has been buried by lacustrine and lacustrine delta sedimentation.

Other factors to be considered in a discussion of artifact preservation and decay for geomorphic systems include flooding effects, groundwater movements, fluvial scouring, and wave wash. Lake or reservoir flooding can accelerate artifact decay by altering the chemical and physical processes normally operating. Artifacts may be affected by groundwater movements and associated chemical reactions between the groundwater. Terraces are especially affected by groundwater movements as they are composed primarily of unconsolidated sediments and are hydraulically connected to the main channel. The consequences of lake and reservoir flooding have been to increase the probability of fluvial scouring to areas above the normal floodplain and to increase the frequency and magnitude of changes to the groundwater levels in terrace soils. Other indirect and potentially adverse effects of reservoir flooding on archaeological sites include wave wash (wind and boat traffic) and riverbank caving following a rapid pool drawdown.

There are no strict rules governing archaeological site preservation or destruction as a function of the respective landforms and associated geomorphic processes. Various trends or generalizations have been identified above which can be used as guidelines in evaluating the archaeological significance of the different landforms. Specific areas or individual archaeological sites should be examined and evaluated on the merits of each site.

6 Summary and Conclusions

Geomorphology

Geomorphic mapping has identified three primary landform surfaces (i.e. valley slopes, terraces, and the floodplain) which are further subdivided according to environments of deposition or underlying parent geology. Bordering the floodplain of the different fluvial systems in the study area are topographically higher abandoned floodplain surfaces or terraces and valley slopes composed of Tertiary age sediments. Two Pleistocene age terraces were identified and mapped in the main Red River Valley. In the Big Cypress Bayou reach, terraces were not differentiated by age on the geomorphic maps. The major floodplain environments of deposition are point bar, lacustrine, lacustrine delta, abandoned channel, abandoned course, backswamp, and undifferentiated tributary alluvium. Natural levees were not identified or mapped as a separate environment of deposition because of the mapping scale and the abundance of this environment in the project area.

The development of the Big Cypress Bayou drainage basin began during the late Tertiary and early Pleistocene. Fluvial downcutting and lateral migration by the various stream courses have created a well-defined alluvial valley and floodplain. Terraces are situated along the valley walls, midway between the Tertiary uplands and the floodplain of the Big Cypress Bayou drainage basin. Geomorphic data indicate that the PB2 surface may extend in age from approximately 1,000 years before the present to possibly the late Pleistocene. Data collected during this study possibly indicate that the Big Cypress Bayou floodplain above Caddo Lake may contain early Holocene to late Pleistocene age abandoned channels.

Formation of the Red River Raft during the late prehistoric and early historic time blocked riverflow on the Red River and created a series of large valley margin lakes. Caddo and Soda lake were formed as a result of the raft and these lakes covered much of the present day study area. Historic and geomorphic data indicate the lakes were formed less than 500 years ago.

Archaeological Significance

Historic archaeological sites were not evaluated by this study. The majority of prehistoric archaeological sites are located on terraces and valley slopes adjacent to Big Cypress Bayou.

A general correlation exists between Caddo sites and historic shorelines for Caddo and Soda Lakes. Sites are generally absent from the area beneath historic Soda Lake. It is probable that sites may be buried beneath lacustrine sediments within the historic lake limits. Maximum thickness of lacustrine deposits in the study area is unknown. Lacustrine sediments are estimated to range from 3 ft (0.91 m) to a maximum of 10 ft (3.05 m) based on similar sites reported for the Red River valley (Smith 1982).

In addition to lake shorelines, Caddo sites generally correlate with point bar (PB) deposits associated with the present meander belt. These sites are located upon natural levees of abandoned channels and courses connected to the present meander belt.

Archaic sites are concentrated mainly on valley slopes and terraces. Absence of Archaic sites within the floodplain suggests that these surfaces may be buried by vertical accretion of sediment and/or the landforms which comprise the floodplain may be younger at some locations. The ages and the general meander belt chronology for the Red River Valley has been tentatively developed by Saucier (1974). Exact age limits for specific floodplain components however are less certain and will require evaluation on a case-by-case basis.

The potential for archaeological sites at the surface and in the subsurface in the Big Cypress Bayou area is considered to be very favorable. Surface and buried sites are highly probable for both the PB2 and terrace surfaces. Favorable locations on either of these surfaces occur in close proximity to abandoned channels and courses.

Field and laboratory data obtained by this study show that organics are not readily preserved in the project area. Degradation of organic sediments suggests that easily weathered archaeological artifacts are not readily preserved unless rapid burial has occurred.

Existing data suggest that in the headwaters of Caddo Lake, the different floodplain components may span the entire Holocene and possibly extend into the late Pleistocene. Exact chronological boundaries are not possible with the limited data presently available. The archaeological record may provide the best evidence to determine more specific chronological boundaries and ages for the various floodplain features.

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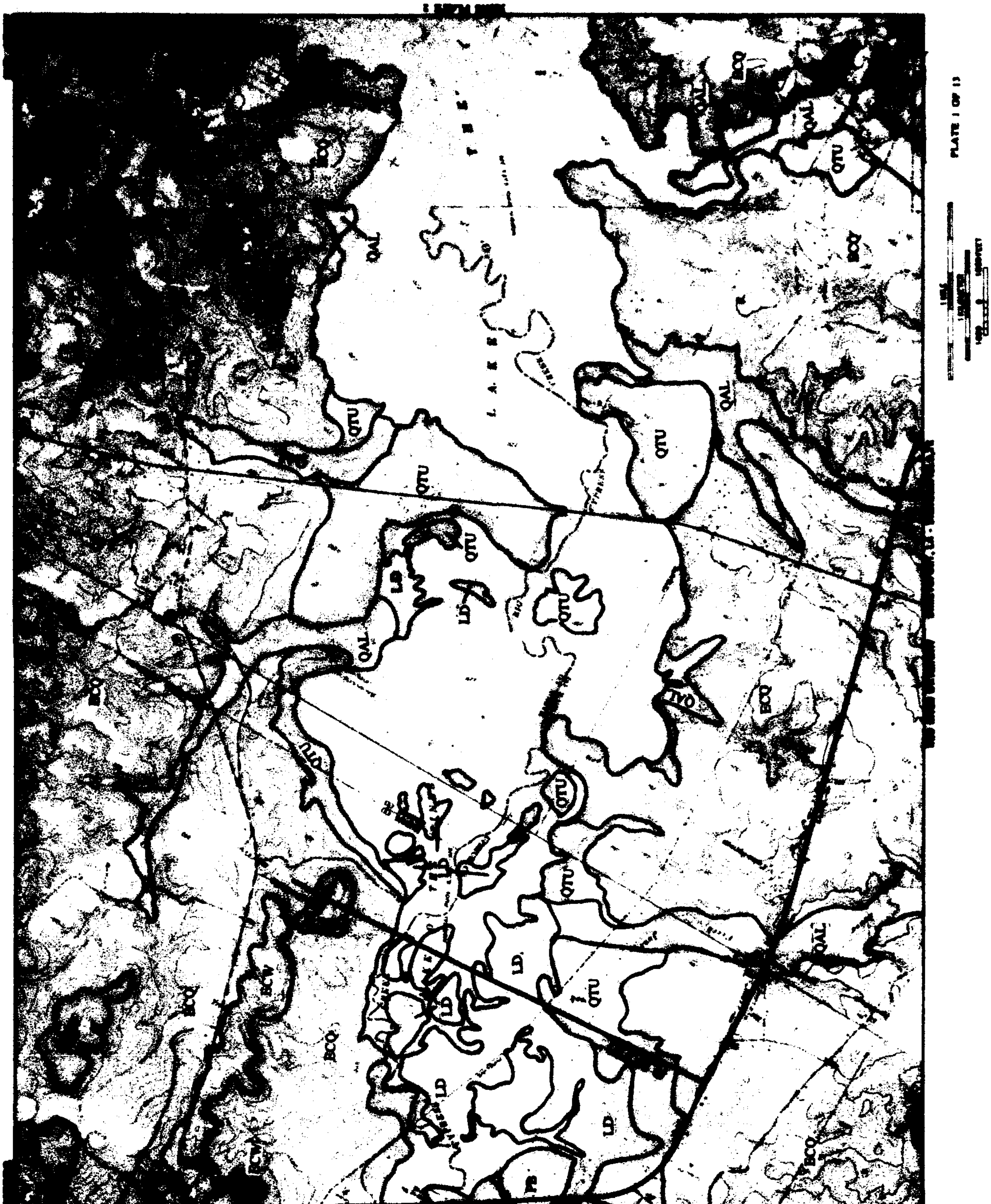

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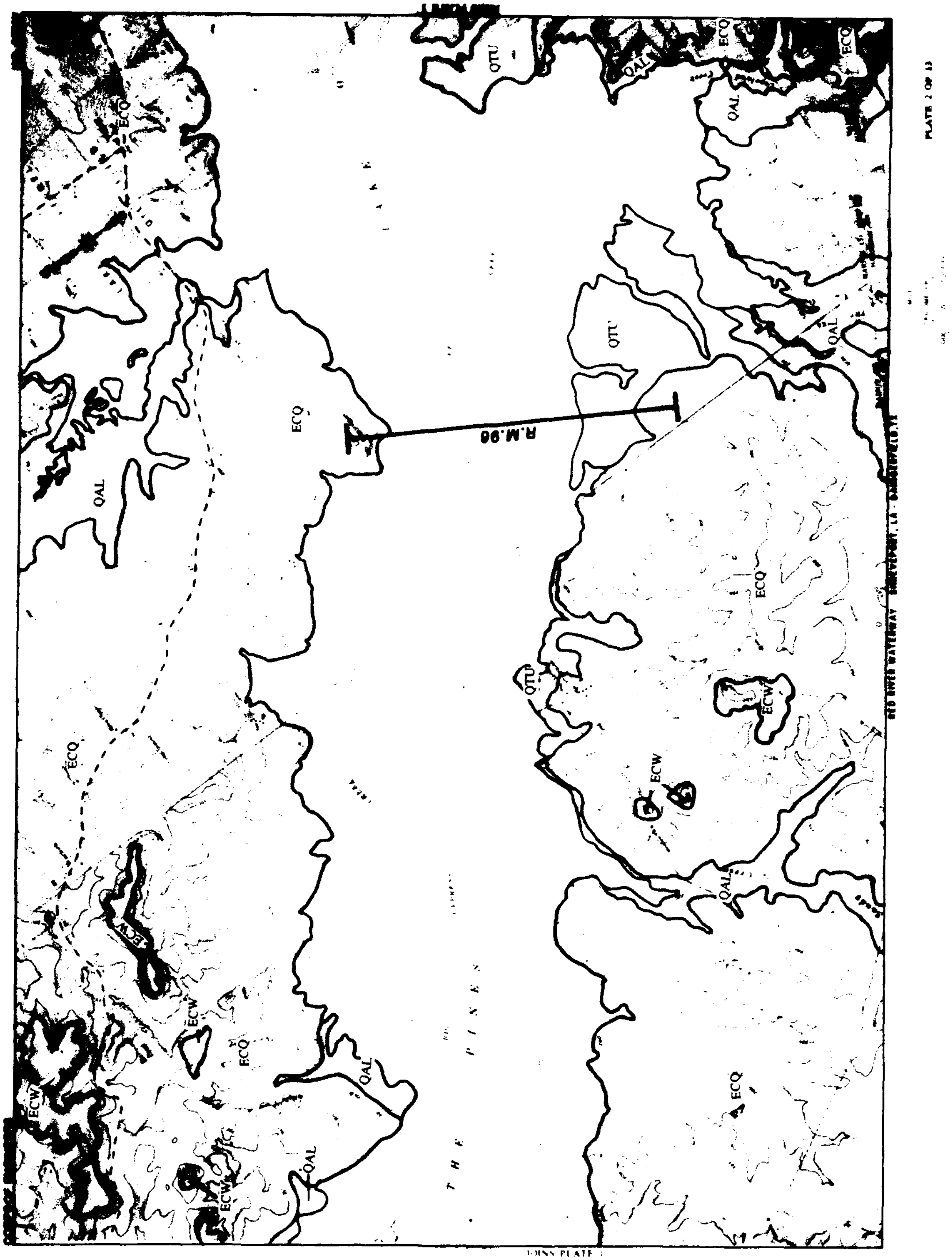
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PLATE 2 OF 13
RED RIVER WATERWAY SHREVEPORT, LA

Plate 2

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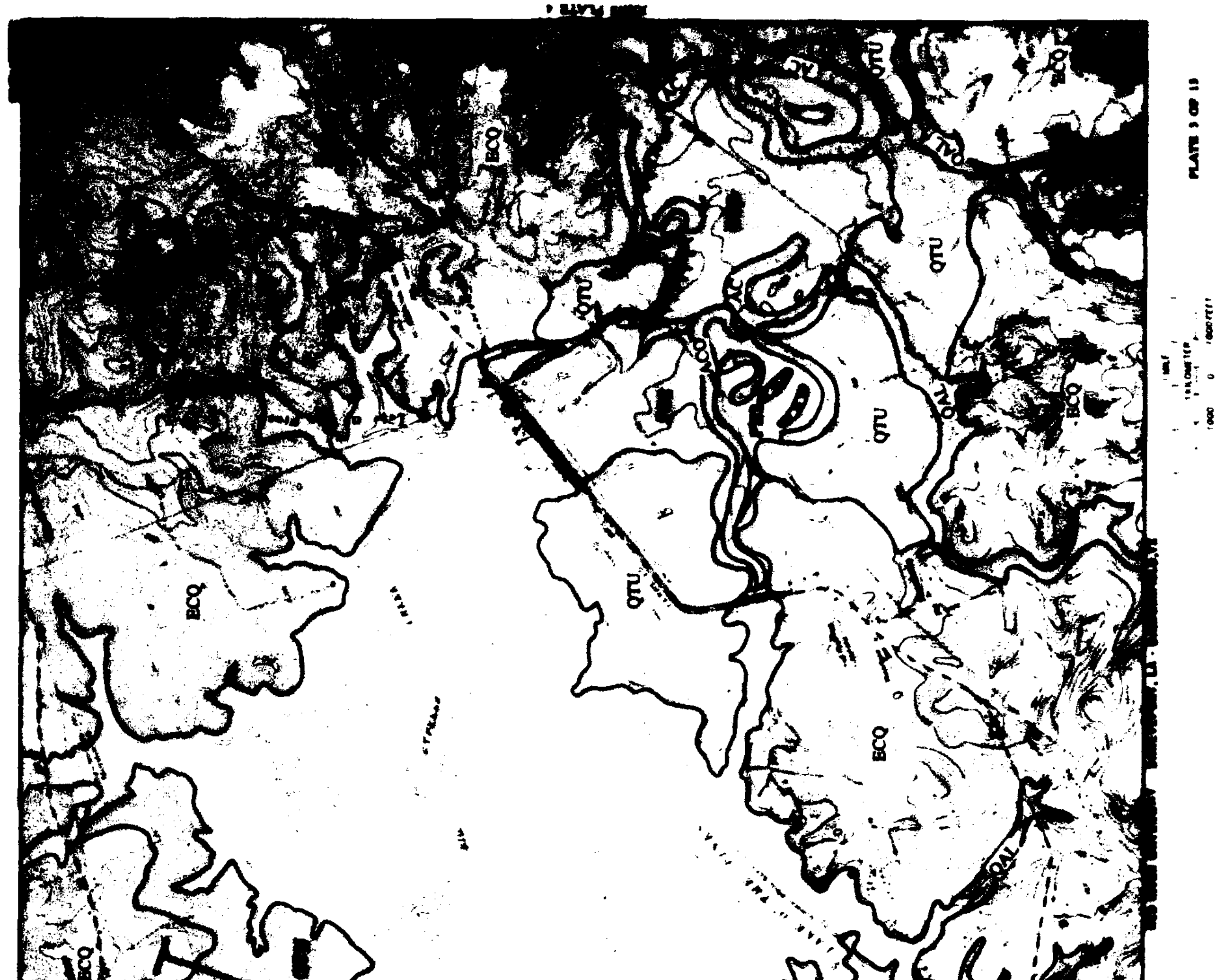

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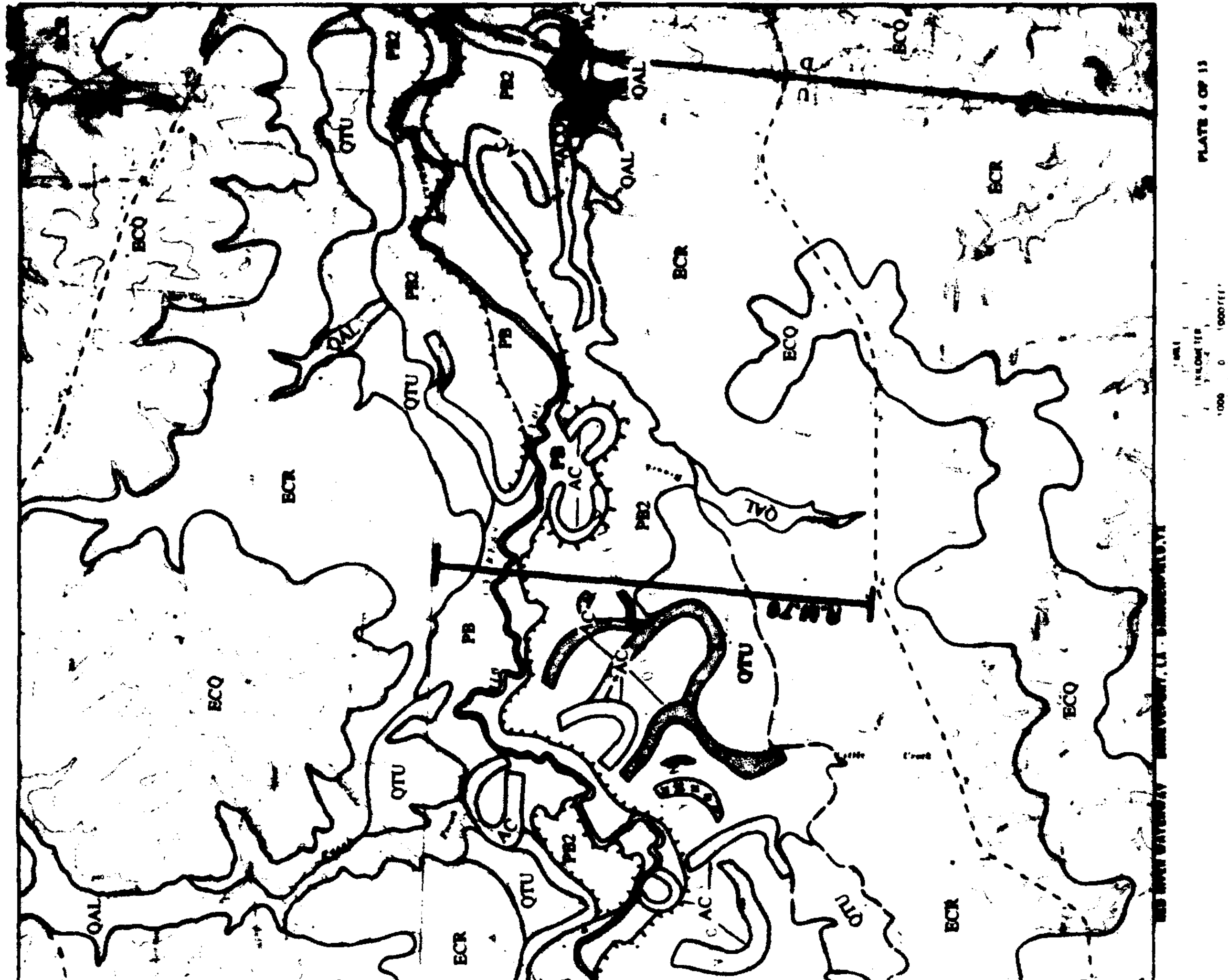
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Plate 4

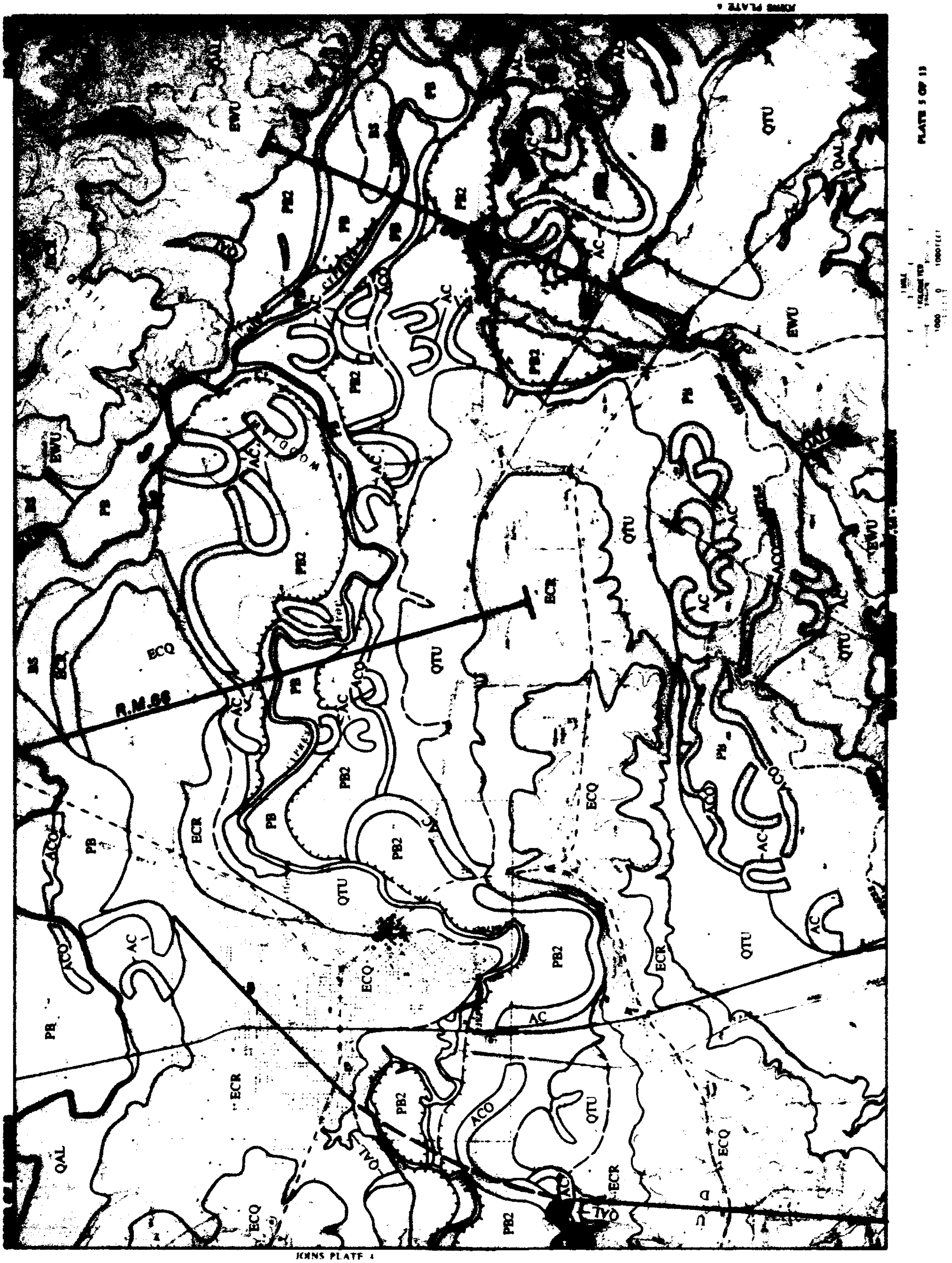
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Plate 5


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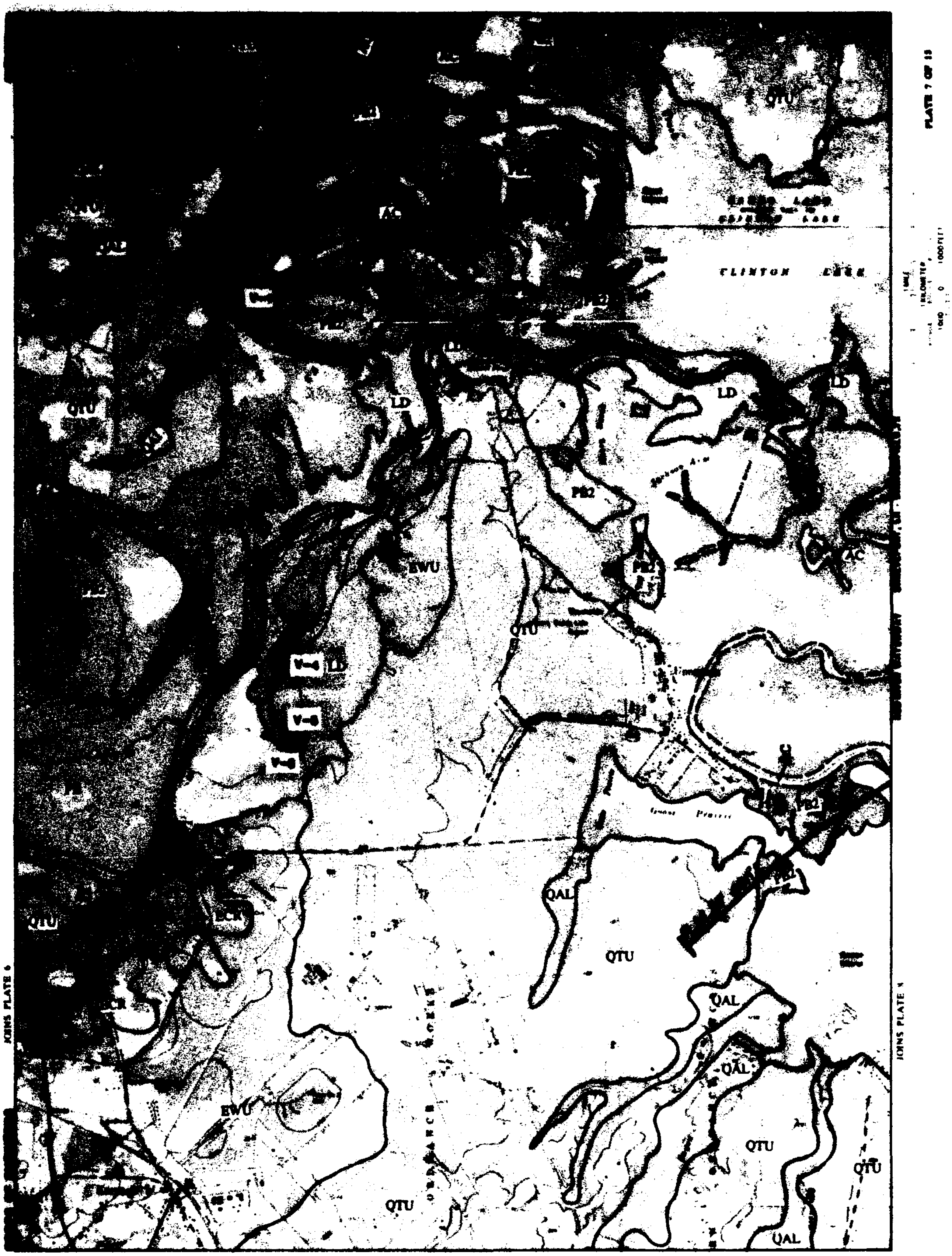

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PLATE 7 OF 13

Plate 7

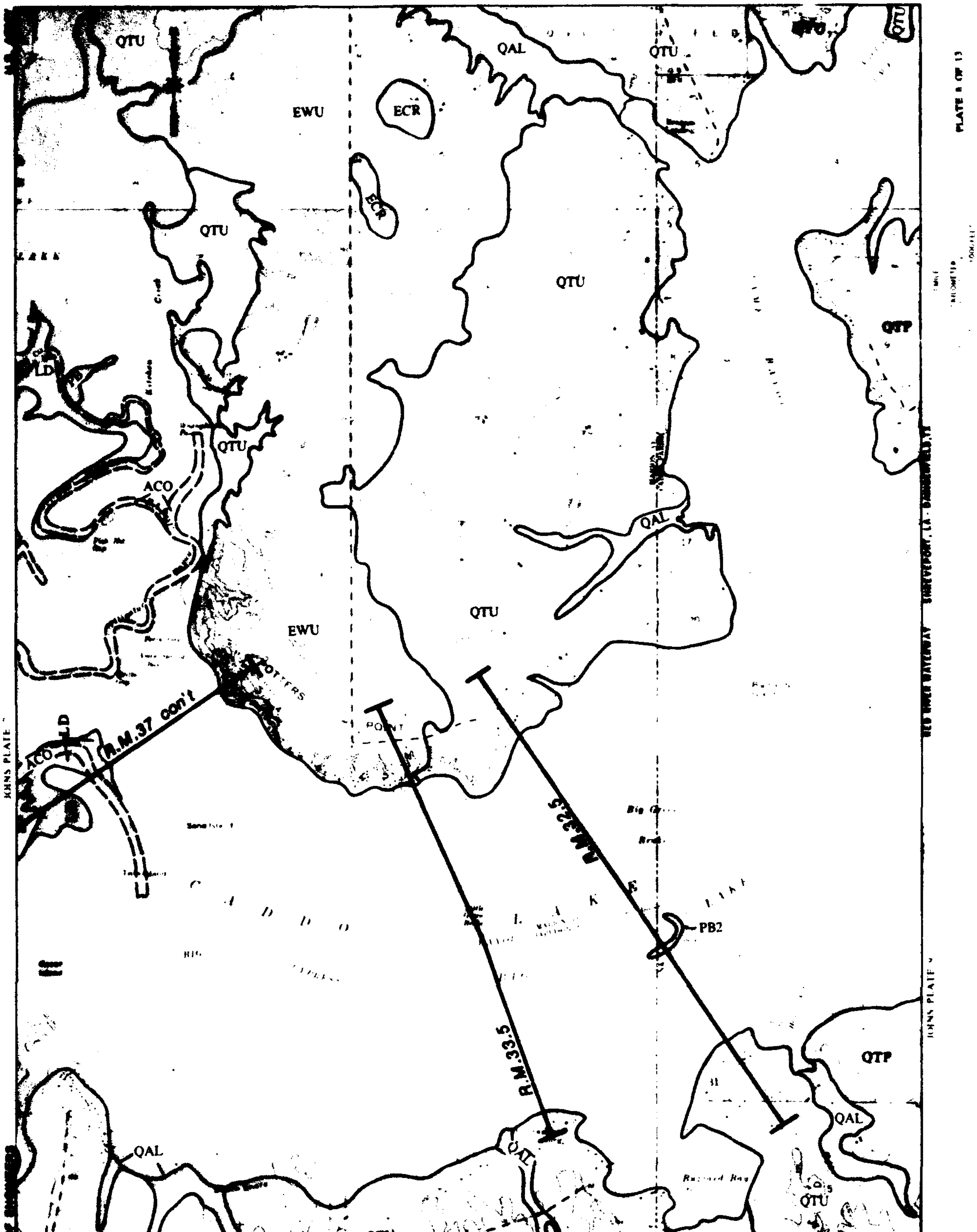
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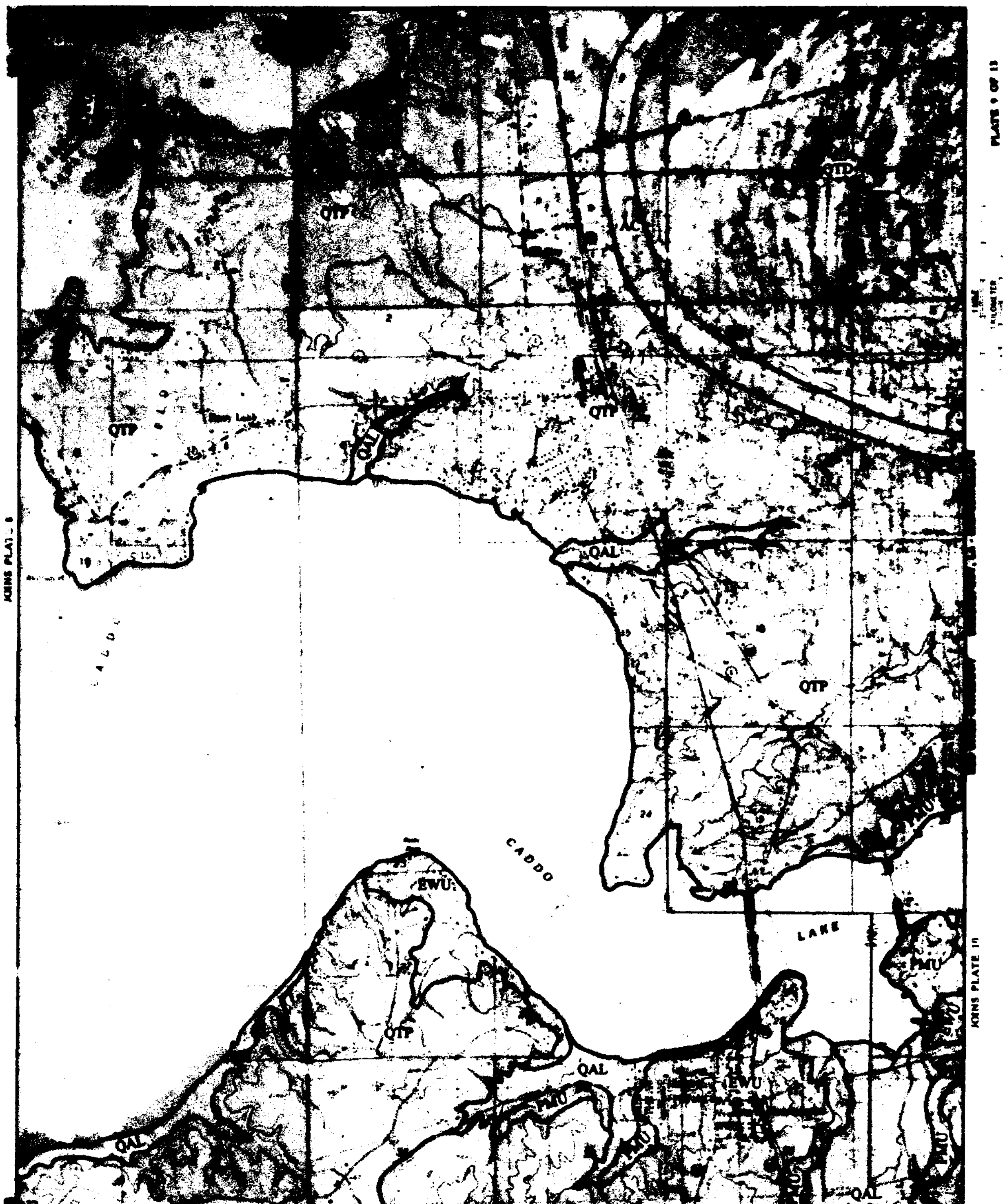
PLATE 8 OF 13

Plate 8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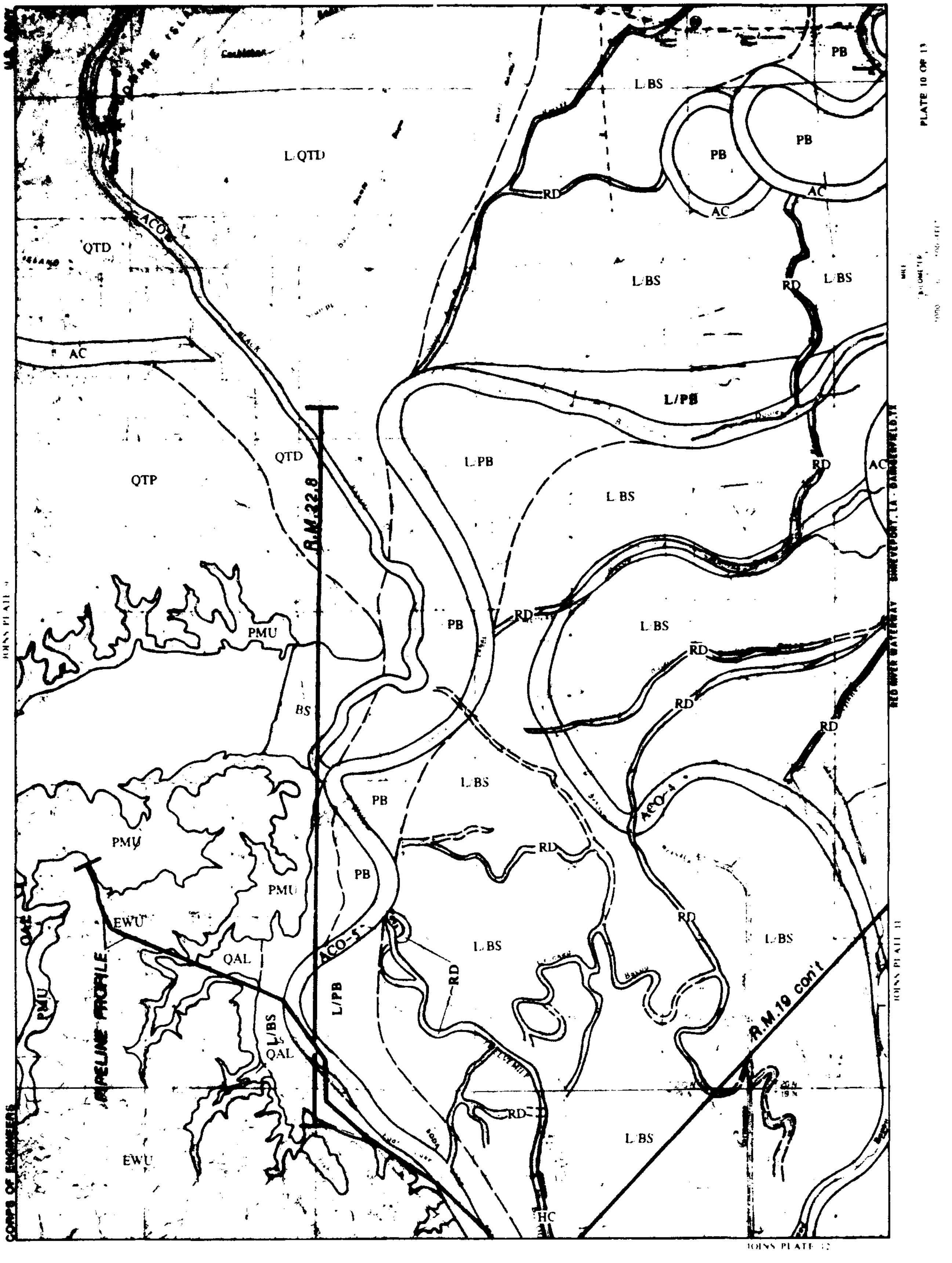
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JOINS PLATE 11
JOINS PLATE 12
PLATE 10 OF 13
RED RIVER WATERWAY SHREVEPORT, LA - DAINGERFIELD, TX

Plate 10


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RED
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RIVER
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PB
AC
Bayou
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PLATE 11 OF 13
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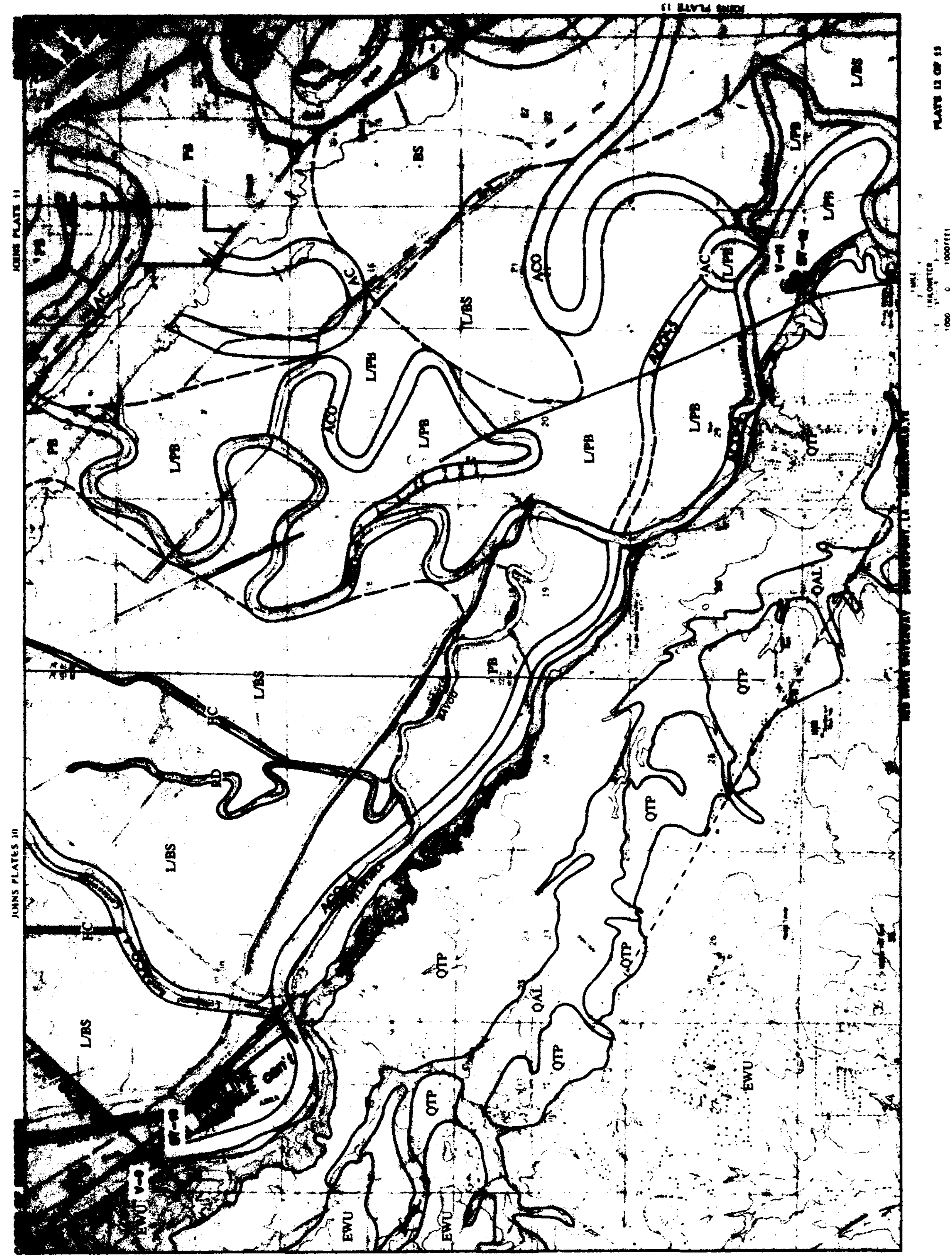
JOINS PLATE 12

Plate 11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JOINS PLATE 13
PLATE 12 OF 13
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QTP
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EWU

Plate 12

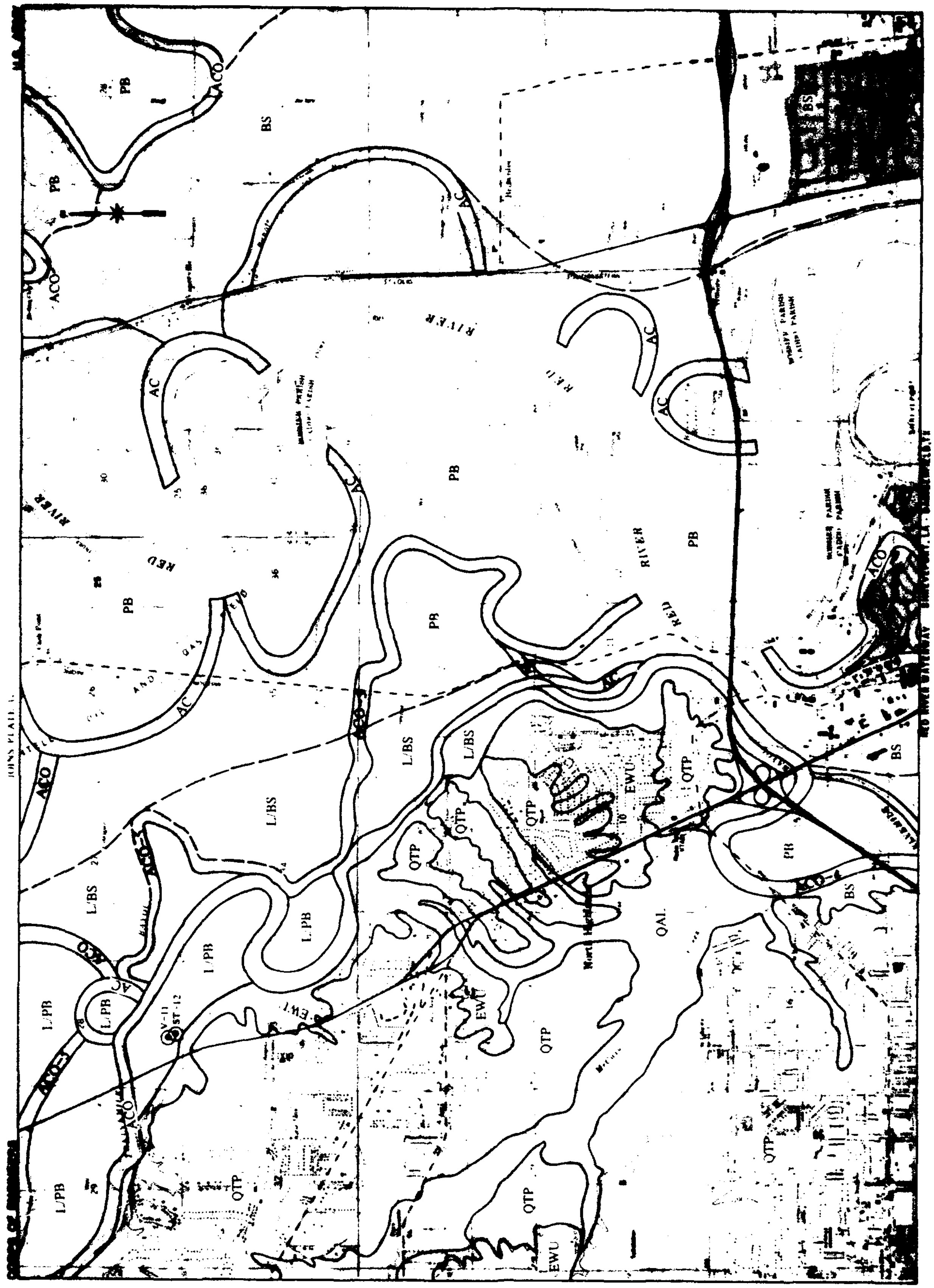
PLATE 13 OF 13
RED RIVER
PB
BS
AC
ACO
ACO-3
ACO-4
ACO-5
ACO-6
L/BS
L/PB
QTP
EWU
QAL
V-11
ST-12
RED RIVER WATERWAY

Plate 13

Appendix A
Soil Boring Logs

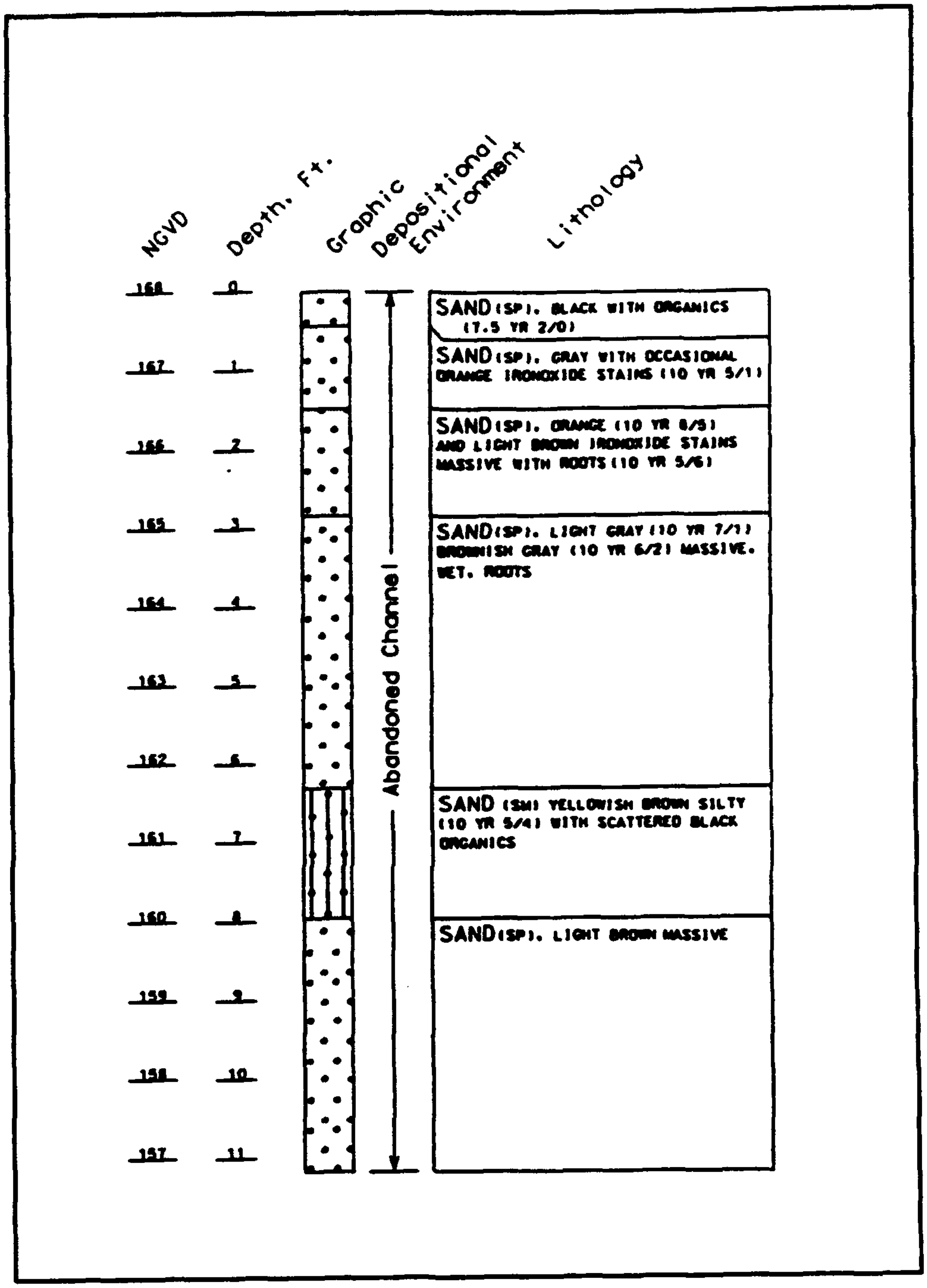

Figure A1. Boring log V-1; for location, see Plate 7

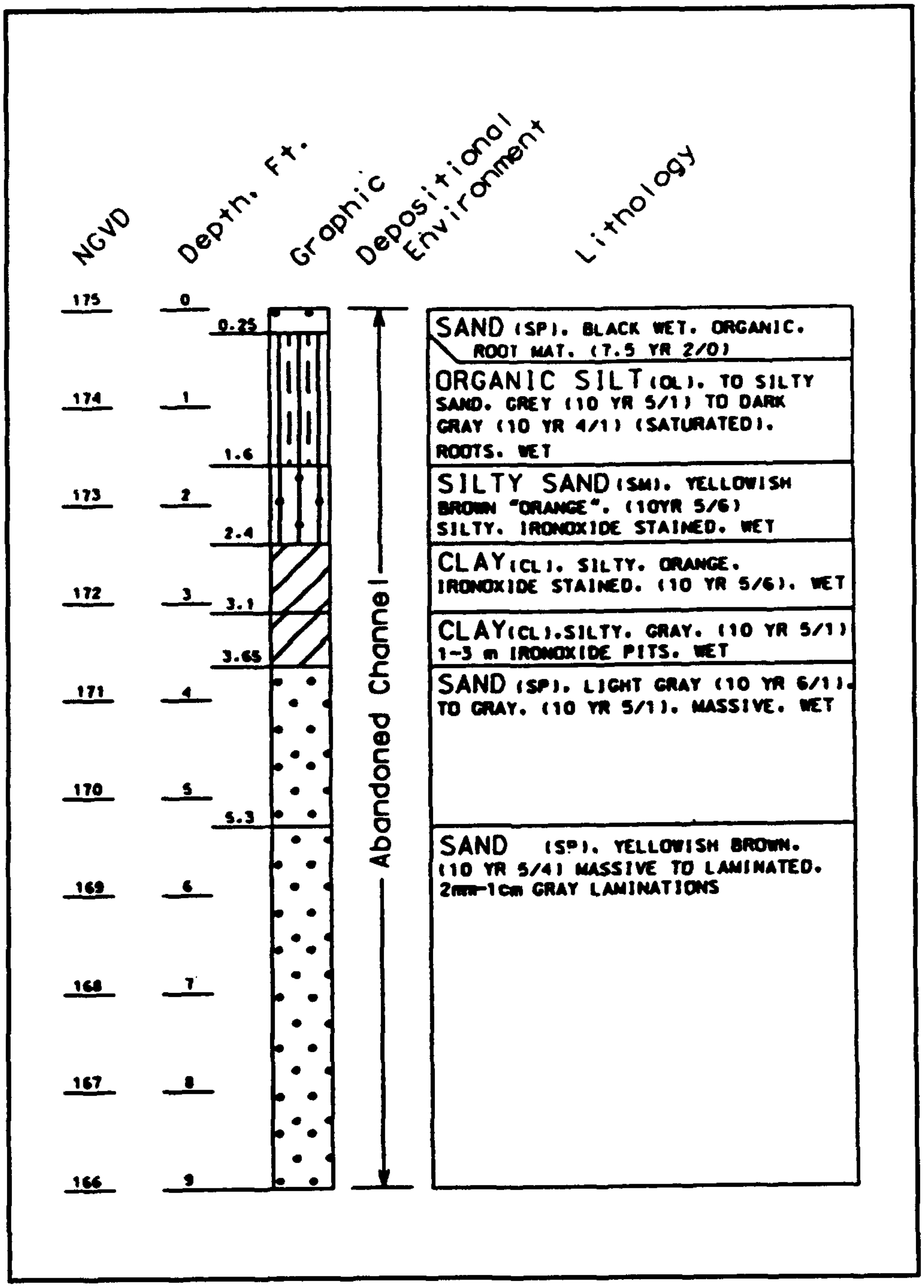

Figure A2. Boring log V-2; for location, see Plate 6

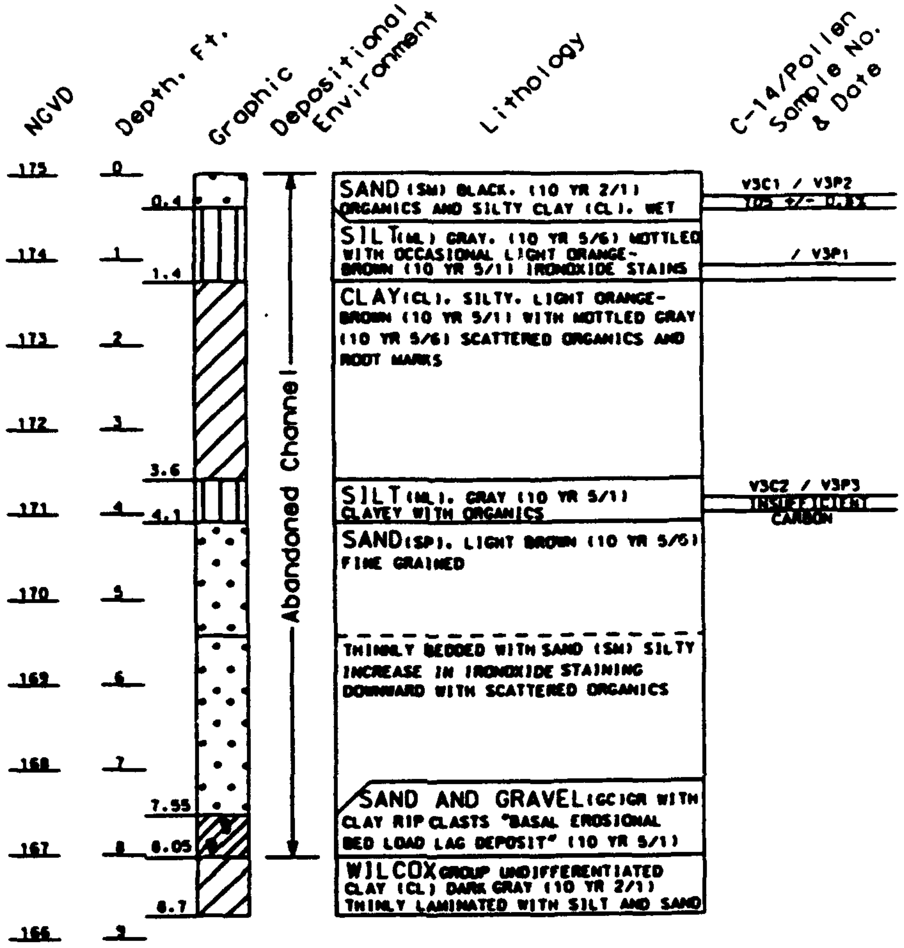

Figure A3. Boring log V-3; for location, see Plate 6

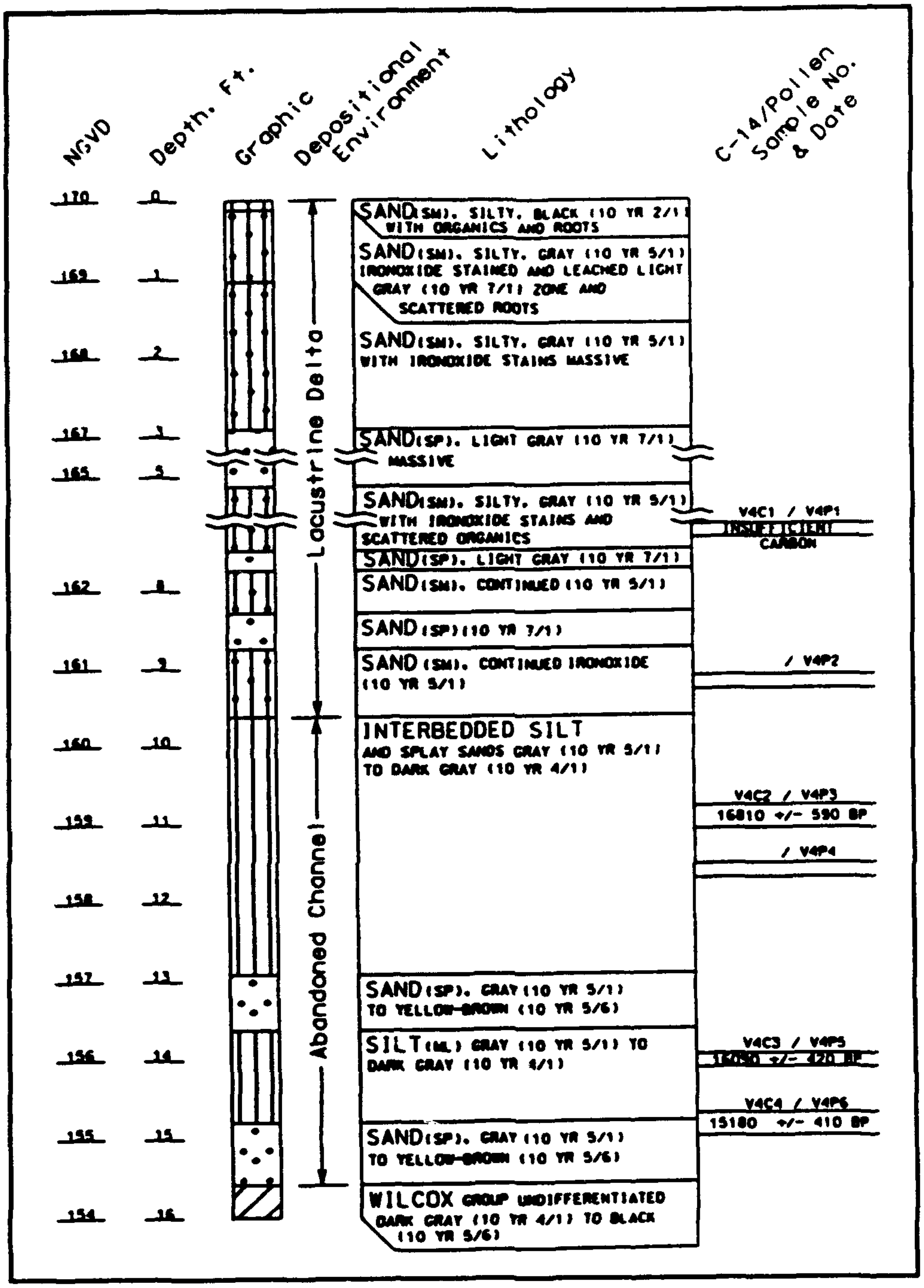

Figure A4. Boring log V-4; for location, see Plate 7

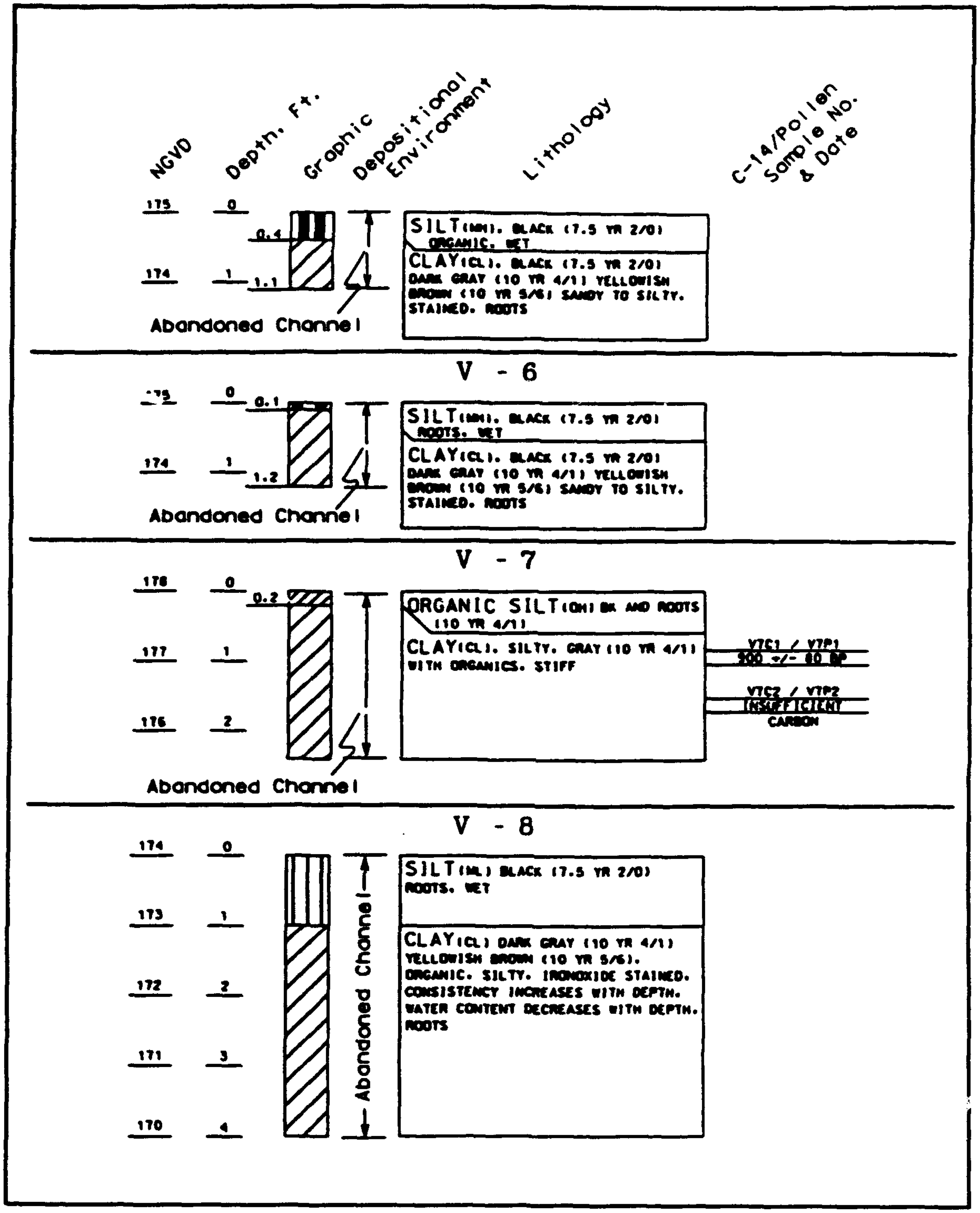

Figure A5. Boring logs V-5, V-6, V-7, and V-8; for location, see Plates 6 and 7

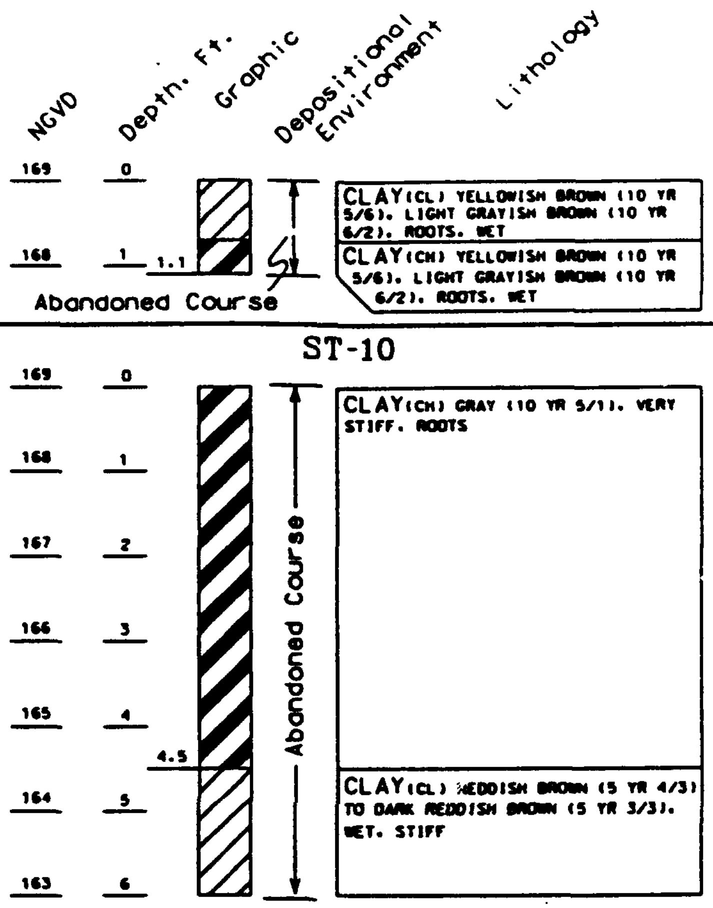

Figure A6. Boring logs V-9 and ST-10; for location, see Plate 12

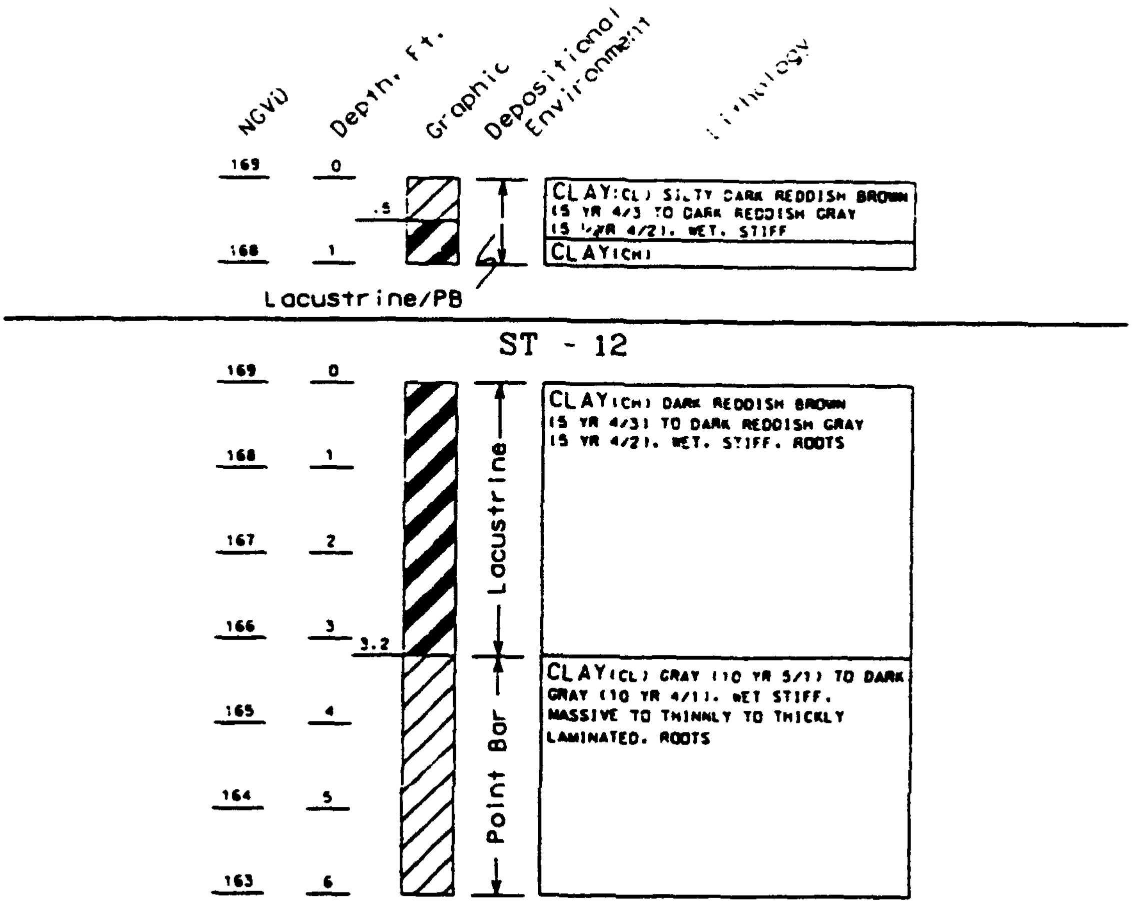

Figure A7. Boring logs V-11 ST-12; for location, see Plates 12 and 13

Appendix B
Radiocarbon Test Results

Table B1
C-14 Test Results

Boring Number	Sample Number	Lab Number	Sample Depth, ft	Material Dated	C14 Date (years BP 1950)
V3	C1	55718	0.3 - 0.5	Sediment	105.1 ± 0.8%
V3	C2	55719	3.8 - 4.0	Sediment	Insuff. Carbon
V4	C1	55720	7.1 - 7.3	Sediment	Insuff. Carbon
V4	C2	55721	10.8 - 11.1	Sediment	16,810 ± 590 BP
V4	C3	55722	13.9 - 14.1	Sediment	16,090 ± 420 BP
V4	C4	55723	14.7 - 15.0	Sediment	15,180 ± 410 BP
V7	C1	55724	0.8 - 1.0	Sediment	900 ± 80 BP
V7	C2	55725	1.5 - 1.7	Sediment	Insuff. Carbon
ST12	14C	55726	5.2 - 5.6	Sediment	2,680 ± 90 BP
ST12	2	55727	3.7 - 4.0	Sediment	510 ± 60 BP

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CORAL GABLES, FLA. 33124

REPORT OF RADIOCARBON DATING ANALYSES

FOR: Paul E. Albertson
US Army Corps of Engineers WES

DATE RECEIVED: September 2, 1992
DATE REPORTED: September 30, 1992
SUBMITTER'S PURCHASE ORDER #

OUR LAB NUMBER	YOUR SAMPLE NUMBER	C-14 AGE YEARS B.P. ± 1σ	C13/C12	C13 adjusted age
Beta-55718	V3-C1 (sediment)	105.1 +/- 0.8 %	-27.2 0/00	105.5 +/- 0.8 %
Beta-55719	V3-C2 (sediment)	Insufficient carbon for analysis		
Beta-55720	V4-C1 (sediment)	Insufficient carbon for analysis		
Beta-55721	V4-C2 (sediment)	16810 +/- 590 BP	-24.9 0/00	16810 +/- 590 BP
Beta-55722	V4-C3 (sediment)	16090 +/- 420 BP	-26.4 0/00	16070 +/- 420 BP
Beta-55723	V4-C4 (sediment)	15180 +/- 410 BP	-26.1 0/00	15160 +/- 410 BP
Beta-55724	V7-C1 (sediment)	900 +/- 80 BP	-29.1 0/00	840 +/- 80 BP
Beta-55725	V7-C2 (sediment)	Insufficient carbon for analysis		
Beta-55726	ST-12 14C 1 (sediment)	2720 +/- 90 BP	-27.2 0/00	2680 +/- 90 BP
Beta-55727	ST-12 2 (sediment)	510 +/- 60 BP	-27.0 0/00	470 +/- 60 BP

These dates are reported as RCYBP (radiocarbon years before 1950 A.D.). By international convention, the half-life of radiocarbon is taken as 5568 years and 95% of the activity of the National Bureau of Standards Oxalic Acid (original batch) used as the modern standard. The quoted errors are from the counting of the modern standard, background, and sample being analyzed. They represent one standard deviation statistics (68% probability), based on the random nature of the radioactive disintegration process. Also by international convention, no corrections are made for DeVries effect, reservoir effect, or isotope fractionation in nature, unless specifically noted above. Stable carbon ratios are measured on request and are calculated relative to the PDB-1 international standard; the adjusted ages are normalized to -25 per mil carbon 13

EXPLANATION OF AGE DETERMINATION TERMS

Conventional radiocarbon date

1. Conventional radiocarbon date is age 8033ln (counts per minute of the oxalic acid - counts per minute of the background times 0.7459 (1-(17.8 + del 13C/1000)/counts per minute of the sample, counts per minute of the background times (1-2~25 + del 1 C/1000). This term also implies:

   a. the use of the 5568 year half-life (mean life 8033).

   b. the assumption of constancy of 14C atmospheric level during the past.

   c. the use of oxalic acid (direct or indirect) as a standard.

   d. isotopic fractionation normalization of all sample activities to the base of del 1 C = -25 per mil (relative to the ^{13}C/^{12}C ratio of the PeeDee Belemnite).

   e. the year 1950 is automatically the base year, with ages given in years BP (i.e., present is 1950 AD).

Counting time

2. All samples are counted for at least 24 hours. Samples that are less than 1 gram, less than 1000 years BP, or greater than 25,000 years BP are counted for at least 48 hours to reduce the error factor on the age.

Error factor

3. Error factor is based on the size of the sample and the number of accumulated counts of the sample, oxalic acid, and background. The statistical uncertainty of the age determination is reported as +/- one standard deviation.

Raw age

4. Raw age does not take into consideration the del ^{13}C value of the sample. The equation is age = 80331n (counts per minute of the oxalic acid, counts per minute of the background/counts per minute of the sample, counts per minute of the background).

Sample size

5. Samples that are less than 1 gram are counted for extended counting times to increase the reliability of the age and reduce the error factor.

Standard pretreatment

6. Once the size fraction to be dated has been isolated, the following steps are followed:

   a. Sample is boiled for 30 min in 500 ml of 0.2N HCl.

   b. Sample is rinsed repeatedly in deionized distilled water till the pH is neutral.

   c. Sample is boiled for 30 min in 500 ml of 0.2N NaOH.

   d. Sample is rinsed repeatedly in deionized distilled water till the water is clear.

   e. Sample is decanted and dried overnight at 75°C.

   f. Sample is crushed with a mortar and pestle, weighed, and stored in an air tight container.

Appendix C
Pollen Analysis of Selected Vibracores

POLLEN ANALYSIS OF CORE SEDIMENTS FROM THE KARNAK QUAD, TEXAS AND OLD SODA LAKE BED, LOUISIANA

by

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and
Vaughn M. Bryant, Jr

Palynology Laboratory
Texas A&M University
College Station, Texas 77843

November, 1992

Introduction

For certain regions of Texas fossil pollen records of vegetational change are available for reconstructing the last 20,000 year period. In general, the fossil pollen records Texas as having cool-loving and mesic vegetational zones during the full glacial period (22,500-14,000 years B.P.) followed by a late glacial period (14,000-10,000 years B.P.) reflecting a climatic transition to vegetation more characteristic of drier and warmer climates (Bryant & Holloway, 1985).

The full glacial to late glacial vegetational transition in west Texas and regions of the Llano Estacado in northwest Texas, changed from low elevation stands of conifers in protected habitats to a loss of most conifers and a gradual replacement by scrub and grasslands (Hafsten, 1961; Oldfield & Schoenwetter, 1975). In Southwest Texas full-glacial pinyon and ponderosa pine stands in canyons and south-facing slope regions were replaced by scrub grasslands and a mosaic of diminishing pinyon-juniper woodlands and parklands (Bryant,1969; Bryant & Holloway, 1985). In central Texas the open deciduous woodlands were gradually replaced by parklands of oaks and finally by grasslands and oak savannas during the mid-to-late Holocene (Bryant, 1977; Larson et al., 1972).

The vegetation and climatic changes during the late glacial period in east Texas (14,000-10,000 years B.P.) is not as well defined as it is for most other regions of the state. This lack of definition, primarily due to soil conditions that do not preserve pollen, has left many questions unanswered. As noted by Bryant and Holloway, over a twenty-year period, sediments recovered from both archaeological and environmental sites have failed to provide sufficient fossil pollen to conduct statistically valid analyses (Bryant & Holloway, 1985).

We believe that the absence of fossil pollen in the majority of east Texas soils results from any of a number of factors. First, the regional soils consist of oxisols and alfisols which are characterized by their high oxidation rates and low percentages of organic matter. Under such circumstances fossil pollen rarely preserve well (Bryant & Holloway, 1983). Second, the high amount of rainfall in most of east Texas contributes to a cyclic wetting and drying phenomenon which is known to be highly destructive to pollen grains. As Holloway (1981) has demonstrated, prolonged, cyclic wetting and drying of pollen grains structurally weakens the outer wall (exine) and contributes to mechanical degradation of the entire grain. Third, the high rates of microbial activity in the leaf litter layer of many temperate deciduous forests, such as those in east Texas and western Louisiana, selectively degrade some pollen taxa and completely destroy others (Goldstein, 1960).

A few samples of late glacial pollen have been recorded from sediments in the Tunica Hills region of western Louisiana. Analyses of those soils show they contain pollen taxa such as *Picea* (spruce), *Pinus* (pine), *Quercus* (oak), and *Larix* (larch); suggesting that western Louisiana, and perhaps neighboring regions of east Texas, was still covered by elements of a mixed conifer-deciduous woodlands during part of the late glacial period (Delcourt & Delcourt, 1977; Kolb & Fredlund, 1981).

Bryant and Holloway (1985) have used pollen evidence from nearby areas to reconstruct the vegetational changes they believe occurred in the deciduous woodlands in east Texas from the middle of the full-glacial through the end of the late-glacial period. First, they see a reduction or disappearance of some cool-loving plants such as *Picea glauca*, *Corylus* (hazelnut), and *Alnus* (alder); and lower proportions of *Acer* (maple), *Betula* (birch), *Fagus* (beech) and *Carpinus* (American hornbeam) in the changing forest of the late glacial period. Coupled with this is a suspected increase in the proportions of *Quercus* (oak), *Liquidambar* (sweet gum), and *Pinus*. However, Bryant and Holloway state that their reconstructions are based on guesses rather than confirmed evidence based on available pollen records from east Texas and western Louisiana sediments.

Materials and Method

As requested, we examined 14 sediment samples from five cores collected from the Karnack Quad in Texas and the Old Soda Lake Bed in Louisiana. The procedure we used to recover fossil pollen from these samples was based on techniques we have found to be successful on Quaternary-age sediments of this type.

All fossil pollen soil samples were processed in the same manner so that their data would be comparable. From each ample we removed 20 ml of soil. To this we added a "spike" of 11,300 ± 400 spores of the cryptogram *Lycopodium* to each sample. These spores are what palynologists refer to as "exotics" and were added to enable us to calculate the pollen concentration values of each fossil sample.

The soil samples were processed for pollen, using several steps. Carbonates were removed, using concentrated hydrochloric acid. Small rocks and coarse-grained silicates were removed by swirling and decanting. This process was repeated several times for each sample before the remaining rocks and large-grained silicates were checked and discarded. Fine-grained silicates, not removed by decanting, were dissolved in a solution of 70% hydrofluoric acid.

After removal of the carbonates and silicates, each sample was sonicated for five minutes in a Delta D-5 sonicator to disaggregate pollen from the remaining matrix. This was followed by a zinc bromide heavy density separation used to isolate the remaining inorganic detritus from the pollen. Finally, a short, weak bleach treatment was used to oxidize the remaining non-pollen organic materials.

All samples were stained with saffranin-0 and mounted in glycerin for examination. Identification and counting were performed using a Nikon binocular microscope. Identifications of pollen and spore types in each sample were checked against modern and fossil reference materials on file in the Texas A&M Palynology Laboratory. These include the Texas A&M Modern Pollen Reference Collection and the Mobil Oil Pollen Reference Collection. The pollen counts from each sample are listed in Tables 1-14.

A statistically-valid quantitative pollen count was attempted for each sample, as recommended by Barkley (1934) and Martin (1963). Their studies showed that the data reliability per sample was over 90% when 200 pollen grains were counted, but that the 90 percentile increased only slightly after counting an additional 1,800 pollen grains. Based on these findings, we attempted to count 200-300 individual pollen grains per sample (excluding fungal spores and exotic Lycopodium spores). As noted in the tables, we were to reach suitable pollen counts in all but three samples (V4 P-1, V4 P-3, ST10 P-2). The three samples contained so few preserved fossil grains that we were unable to make reliable counts even after viewing several slides of each sample.

Each fossil pollen grain was identified to the genus level whenever possible. If the grain could not be differentiated from similar genera based on morphology, it was identified to the family level. For one taxon (Vitis) we listed the pollen type as "cf" meaning that it compares favorably with (but may not necessarily be) the type we have named. For your use, we have also included a sheet of photographs showing some of the representative taxa.

While examining the fossil pollen in these samples, we found a high incidence of Tertiary pollen grains. They were present in many of the samples but exceptionally common in samples from the V3, V4 and ST12 cores. The appearance of these grains in sediments of late Pleistocene and Holocene strata strongly supports our belief that the sediments we examined are mixed with, or contaminated by, Tertiary-aged pollen from nearby sources. Because the region of east Texas and western Louisiana is known to have outcrops of lignites, we presume the pollen grains we found are from weathered lignitic materials of nearby Tertiary outcrops.

Results

The relative pollen counts of each sample is presented in Tables 1-14. As mentioned earlier, also provided are black and white contact sheets of the diagnostic pollen types recovered from these samples. Only 11 of 14 samples contained sufficient fossil pollen to conduct statistically valid counts in excess of 200 grains.

The most common pollen taxa recovered in these samples are: Pinus (pine), Cheno-Am (a combined term used for pollen taxa in the Chenopodiaceae family and the genus Amaranthus), genera of the

Asteraceae (composite) family, Quercus (oak), genera of the Poaceae (grass) family, Carya (pecan and hickory), and Liquidambar (sweet gum). These pollen taxa represent plants common to the indigenous floral communities of east Texas and west Louisiana, and are still common in that region. Many of these pollen taxa are among the types that would be the most likely to remain preserved, due to their chemical and morphological structure, and are among the types of fossil pollen that are likely to be recognizable even after they have undergone severe degradation. Other taxa, such as Betula (birch), Corylus (hazelnut), Myrica (bayberry), and Carpinus (American hornbean) are types that would be less likely to remain preserved, yet are present in small amounts in some samples, especially the sediments of the V4 core.

Other pollen types found in these samples include Juglans (walnut), Nyssa (black gum), Populus (poplar), Fraxinus (ash), Salix (willow), and Myriophyllum (water milfoil). One type, Typha angustifolia (cat-tail) and/or Sparganium (bur-reed) are so similar morphologically that we combine these into a single category.

We were able to identify many of the Tertiary-age pollen grains found in these samples by comparing them with reference material and published photographs of Tertiary pollen from reports conducted on sediments from other locales in the southern United States. Unfortunately, some of the Tertiary pollen is so similar morphologically to taxa of Quaternary-age types that separating the pollen into their respective time periods is nearly impossible. Some of the Tertiary pollen found in these samples were of types that are distinctively different from Quaternary pollen, and these could be determined as being Tertiary-age contaminants. Some of these distinctive Tertiary pollen types include: *Choanopollenites, Momipites, Deltoidospora, Caryapollenites, Polyatriopollenites, Ilexpollenites, Nyssapollenites, Tiliapollenites, Alnus triana, Nudopollis,* and *Symplocus*.

During pollen counts we assign pollen grains that are broken, corroded, or degraded beyond recognition to a category called indeterminates. This means that we believe that even with the best set of comparative pollen types one could find, the accurate identification of these grains would not be possible. As noted in the counts, the percentage frequency of indeterminate pollen ranged from a low of 4.5% to 17.9%. Pollen listed as unknown means that the grain was well preserved, but we lacked sufficient types in our comparative collection to make a positive identification.

The pollen concentration for each sample is a reflection of how much pollen remained preserved in each ml of sediment. Concentration values are useful because they can indicate differences in sedimentation rates, preservation rates, and differences in initial forest pollen dispersion and production rates. The concentration values for these samples ranged from 3,135 to 60,876 grains/ml of sediment.

Discussion

Many factors could have contributed pollen to the original composition of the core samples we examined. These factors include: the type of pollination mechanism used by the plants in the nearby forest, the volume of pollen produced by each of the different plant taxa, differences in the pollen dispersion patterns of nearby plants, and the physical characteristics (i.e., the size, weight, and aerodynamics of the pollen) of the various pollen types that were produced and dispersed.

Once deposited, some or all of the fresh pollen could have been lost due to degradation either before or after it became fossilized. Studies have shown that each pollen type reacts differently to various agents of degradation. How rapid or slow the degradation process will be for each pollen type will depend on factors such as: pollen recycling, the chemical composition of pollen wall, surface ornamentation and morphology patterns, and the pollen grain's susceptibility to degradation by mechanical, chemical, or biological agents (Bryant 1978, 1988; Bryant and Holloway 1983; Holloway 1989; O'Rourke 1990).

Pollen concentration values are used during pollen analyses to determine the density of fossil grains in a sample. This aspect is generally defined as the number of pollen grains recovered per unit volume, or weight, of sediment. The reason that fossil pollen concentration values are reconstructed for sediments is indicated by the types of data this technique can provide. For example, pollen concentration values are useful indications of sedimentation rate and can reveal the degree to which a depositional environment may have been disturbed and/or mixed. Concentration values can also suggest the quality of pollen grain preservation and can indicate when the fossil pollen in a deposit may not be an accurate representation of the original environmental conditions.

Hall (1981) was one of the first to suggest that sediment samples yielding fewer than 1000 fossil pollen grains per gram of soil were probably indicative of highly degraded conditions and that the remaining pollen was usually so modified that it was no longer useful for interpretive purposes. An example of this is seen in the three samples we examined which did not contain a minimum of 1000+ pollen grains per gram of sediment.

Pollen concentration values commonly found in the soils of deciduous forests, like those of east Texas and western Louisiana, can be as low as 20,000 or reach levels of nearly one million pollen grains per gram of deposit. Thus, many of the samples from your cores were within the expected pollen concentration values for the area where they were collected. Almost half (6) of the samples had pollen concentration values between 0-10,000 grains/ml, which is considered low for deciduous forests. However, the low recovery rate could reflect significant destruction of the pollen after it was deposited. The remainder of the samples (8) had concentration values that ranged between 20,900-60,876 grains/ml, amounts more commonly found in the soils of deciduous forests. Although only one sample fell below the 1000 grain limit mentioned by Hall (1981), the pollen concentration values of another five samples were not significantly high enough to consider as valid indicators of the actual pollen record for the region. In the context of this study, it appears that the samples with the lowest concentration values are indicative of both a modified depositional environment and the presence of pollen in an active state of decay. This assessment is supported by the high levels of indeterminate pollen grains caused by severe degradation.

One type of pollen, Corylus (hazelnut), occurred in a number of the sediment samples, yet it comes from a plant that no longer grows in east Texas or western Louisiana. Available climatic and pollen data from other regions suggest this plant became extant in these regions by the end of the Pleistocene. Thus, the few grains of hazelnut we found in a number of the samples most probably came from grains that were recycled from earlier-aged Pleistocene sediments or from hazelnut pollen that may have been present in some of the nearby recycled Tertiary sediments.

Based on our pollen analysis of these samples, we do not believe that any type of reliable fossil pollen assemblage can be reconstructed and used for paleoenvironmental interpretation. When we compare the radiocarbon dates with the results of our pollen counts for various samples we note a number of inconsistencies. For example, what data we might expect to find in valid fossil pollen records from these various time periods does not compare with what we actually recovered. For example, samples that are dated as being Holocene, or even late glacial, in age contain pollen types that should not be present. In addition, these same deposits also contain pollen grains known to be Tertiary in age. Therefore, even in the 11 samples which yielded statistically valid fossil pollen counts, the information recovered is of minimal value. Second, as stated earlier, many of the Tertiary-age and Quaternary-age fossil pollen types (i.e. pine, oak, composite, chestnut, hazelnut, American hornbean, etc.) look nearly identical because these plants, and their ancestors, produced nearly identical pollen types.

Unfortunately, there is no currently known method to split the similar-looking fossil pollen types of Tertiary and Quaternary-age plants into separate categories with any degree of reliability. Third, although we cannot be certain, we suspect that most, if not all, of the Quaternary-aged pollen in some of these samples may have been destroyed and was replaced by already-fossilized fossil pollen that were recycled from Tertiary sources. We also suspect that the absence, or near total absence, of any fossil pollen in some of the samples may reflect severe weathering that destroyed not only the Quaternary-aged pollen, but also affected any recycled Tertiary pollen that may have been present.

The results of this pollen analysis are consistent with the results exhibited by samples we have examined in the past from other east Texas alluvial soils. Although we were unable to reconstruct the late Quaternary paleoenvironment, based on the pollen record, we believe that this analysis was useful. The study showed that the sediments in the area are characterized by a mixture of Tertiary and Quaternary materials. Consequently, unless future cores are recovered outside this mixed sediment zone, we suspect future pollen studies will be similar to those of the present study.

For your information, we have listed general information about some of the pollen types found in the samples:

1. Alnus (alder) Pinus (pine), Quercus (oak), Betula (birch) pollen are from plants that produce great quantities of pollen that are normally considered less likely to be decay-resistant. In addition, these taxa produce prolific amounts of pollen that are widely dispersed by atmospheric winds. As a result, pollen from these taxa are often over-represented in the fossil pollen record and traces can often appear in small percentages even hundreds of miles from their point of dispersal.
2. The prevalence of Pinus, Quercus, Carya (pecan or hickory), and Betula, accompanied by Juglans (walnut), Castanea (chestnut), and Fraxinus (ash), would normally be considered types commonly found in the soils of a mixed hardwood deciduous forest. As such, they are considered key indicators of this type of past vegetation.
3. The presence of Carpinus (American hornbean), Myrica (bayberry), Alnus, Acer (maple), Nyssa (black gum), Salix (willow), Liquidambar (sweet gum), Typha angustifolia (cat-tail), Sparganium (bur-reed), and Myriophyllum (water milfoil), are pollen types generally associated with wet to swampy-type environments.
4. POACEAE (grass) pollen is a windborne type that is often found in many different types of environments. Grasses do not produce as much pollen as some airborne pollinators, but they do produce large quantities. Unfortunately, the only grass pollen grain that we can identify with certainty is maize (*Zea*). We suspect that many of the grass grains found in these samples could have come from swamp-type grasses that may have been part of the local vegetation cover at the site.
5. The ASTERACEAE (composites) family is composed of many genera with similar morphological features. This makes it difficult to differentiate between individual taxa under the light microscope. Consequently, the pollen taxa in this family are often divided into three major groups based on three major morphological types. These include: the Ambrosia group, the Helianthus group, and the Chicorium group. In general, many genera in the Ambrosia group are types found in drier environments, while the taxa in the Helianthus group are more commonly found in more mesic environments. The Chichorium group is also most commonly found in mesic environments. The presence of small pollen percentages of these groups in these samples reflects the probable presence of these plant types in local vegetation.
6. Several types of dinoflaggelates were identified in the V4 core samples. This suggests the deposits were either formed

while the area was a swamp or it may mean that the dinoflaggelates could have been recycled into these deposits from nearby Tertiary deposits

7. The INDETERMINATE category is composed of pollen grains that are so badly degraded that we could not identify them on the basis of morphological characteristics. These grains are included in counts as a general guide to the quality of pollen preservation in a sample.
8. The UNKNOWN category consists of those few pollen grains that are well to fairly well preserved, but represent types we were not able to identify. We suspect that most of these may represent recycled Tertiary types we were not able to identify from our collections or from the published sources we used.

Summary

If further research is planned for this study area, we recommend that the core sampling sites should be located as far away as possible from known Tertiary outcrops. Care should also be taken to determine if the soils of the region contain mixing from Tertiary deposits.

The reconstruction of the paleoenvironmental conditions that existed in Texas during the late Quaternary is an important goal that should not be abandoned. The region has a key geographic location in North America because it is the crossroad between the mixed deciduous and conifer forests of the southeastern United States and the arid and semi-arid flora of the American Southwest. In addition, the region could have been influenced by elements moving up from the semi-tropical and tropical flora from Mexico and could also record any late Quaternary vegetational movement from the south central portion of North America into the deciduous woodlands.

To date, very few regions of western Louisiana and no areas of east Texas have provided well preserved pollen records dating from the late Quaternary period. We encourage your efforts to find suitable cores of sediments that might provide reliable data for this area. Hopefully, someday soon we will find suitable sediments that will answer many of our questions about late Quaternary vegetational changes in the region of east Texas and western Louisiana.

Table 1-14

Quantitative pollen counts of samples from the Karnak Quad., Texas and the Old Soda Lake Bed, Louisiana.

Table 1

QUANTITATIVE POLLEN COUNT

Sample: V3 P-1 **Date:**

Pollen Analyst: Eri Weinstein and Vaughn M. Bryant, Jr.

Date: October 13, 1992

Total Pollen Counted: 222

Fossil Pollen Concentration per gram of sediment: 7,909

Pollen Type	Percentage
ASTERACEAE	
Ambrosia group	4.9
Helianthus group	1.2
Chichorium group	.0
Carya	0.8
Cornus	0.4
Corylus	0.4
CYPERACEAE	1.2
Juglans	0.8
Liquidambar	11.0
Myrica	0.4
Nyssa	3.3
Pinus	29.6
POACEAE (excl. Zea)	4.1
Polygonum	0.8
Populus	3.7
Quercus	32.5
Ulmus	0.4
INDETERMINATE	4.5
UNKNOWN	.0
Total	100.0%

Table 2

QUANTITATIVE POLLEN COUNT

Sample: V7 P-2 **Date:**

Pollen Analyst: Eri Weinstein and Vaughn M. Bryant, Jr.

Date: October 13, 1992

Total Pollen Counted: 222

Fossil Pollen Concentration per gram of sediment: 70,110

Pollen Type	Percentage
Artemisia	0.5
ASTERACEAE	
Ambrosia group	15.3
Helianthus group	0.9
Chichorium group	.0
Carya	1.4
Corylus	0.9
Fraxinus	0.5
Juglans	0.5
Liquidambar	0.9
Pinus	23.9
POACEAE (excl. Zea)	7.2
Quercus	27.0
Ulmus	0.5
INDETERMINATE	19.6
UNKNOWN	0.9
Total	100.0%

Table 3

QUANTITATIVE POLLEN COUNT

Sample: V3 P-2 **Date:** 105 BP

Pollen Analyst: Eri Weinstein and Vaughn M. Bryant, Jr.

Date: October 13, 1992

Total Pollen Counted: 228

Fossil Pollen Concentration per gram of sediment: 51,984

Pollen Type	Percentage
ASTERACEAE	
Ambrosia group	3.1
Helianthus group	2.6
Chichorium group	7.0
Carya	0.9
Corylus	0.9
Fraxinus	0.9
Juglans	0.4
Myrica	0.4
Nyssa	1.8
Pinus	40.2
POACEAE (excl. Zea)	1.3
Polygonum	1.8
Populus	2.2
Quercus	30.0
INDETERMINATE	6.1
UNKNOWN	0.4
Total	100.0%

Table 4

QUANTITATIVE POLLEN COUNT

Sample: V7 P-1 **Date:** 840 BP

Pollen Analyst: Eri Weinstein and Vaughn M. Bryant, Jr.

Date: October 13, 1992

Total Pollen Counted: 217

Fossil Pollen Concentration per gram of sediment: 41,230

Pollen Type	Percentage
Acer	0.5
Alnus	1.4
ASTERACEAE	
Ambrosia group	1.4
Helianthus group	0.5
Chichorium group	.0
Carya	1.8
Fraxinus	1.8
Liquidambar	1.8
Nyssa	0.5
Pinus	37.8
POACEAE (excl. Zea)	3.2
Quercus	22.1
Ulmus	0.9
INDETERMINATE	25.8
UNKNOWN	0.5
Total	100.0%

Table 11

QUANTITATIVE POLLEN COUNT

Sample: V4 P-3 **Date:**

Pollen Analyst: Eri Weinstein and Vaughn M. Bryant, Jr.

Date: October 14, 1992

Total Pollen Counted: 64

Fossil Pollen Concentration per gram of sediment: 24,320

Pollen Type	Number of Grains
ANACARDIACEAE	2
APIACEAE	8
ASTERACEAE	
Ambrosia group	1
Helianthus group	2
Chichorium group	0
Berchemia	1
Carpinus	6
Castanea	4
CYPERACEAE	1
Fagus	1
Myriophyllum	1
Nyssa	1
Pinus	2
POACEAE (excl. Zea)	6
Quercus	8
Rumex	1
Tillia	1
INDETERMINATE	16
UNKNOWN	17
Total	

Table 12

QUANTITATIVE POLLEN COUNT

Sample: V4 P-1 **Date:**

Pollen Analyst: Eri Weinstein and Vaughn M. Bryant, Jr.

Date: October 14, 1992

Total Pollen Counted:

Fossil Pollen Concentration per gram of sediment: 3,135

Pollen Type	Number of pollen grains
ASTERACEAE	
Ambrosia group	1
Helianthus group	0
Chichorium group	0
CHENOPODIACEAE + *Amaranthus*	2
Liquidambar	1
POACEAE (excl. Zea)	1
Typha/Sparganium	2
INDETERMINATE	1
UNKNOWN	2
Total	

Table 13

QUANTITATIVE POLLEN COUNT

Sample: V4 P6 **Date:**

Pollen Analyst: Eri Weinstein and Vaughn M. Bryant, Jr.

Date: October 14, 1992

Total Pollen Counted: 220

Fossil Pollen Concentration per gram of sediment: 20,900

Pollen Type	Percentage
Alnus	1.8
ANACARDIACEAE	0.5
APIACEAE	0.5
ASTERACEAE	
Ambrosia group	0.9
Helianthus group	2.7
Chichorium group	.0
Betula	3.6
BRASSICACEAE	0.9
Carpinus	3.6
Carya	6.8
Castanea	19.0
CHENOPODIACEAE + *Amaranthus*	0.5
Corylus	1.8
CYPERACEAE	1.4
ERICACEAE	0.5
Fraxinus	1.4
LAMIACEAE	0.5
Myrica	1.4
Myriophyllum	0.5
Picea	0.5
Pinus	3.6
POACEAE (excl. Zea)	8.1
Quercus	19.0
Rhus	1.8
Rumex	0.9
Salix	3.6
Typha/Sparganium	0.5
INDETERMINATE	11.4
UNKNOWN	2.3
Total	100.0%

Table 14

QUANTITATIVE POLLEN COUNT

Sample: ST12 P2 **Date:**

Pollen Analyst: Eri Weinstein and Vaughn M. Bryant, Jr.

Date: October 14, 1992

Total Pollen Counted: 228

Fossil Pollen Concentration per gram of sediment: 30,490

Pollen Type	Percentage
Acer	0.4
ASTERACEAE	
Ambrosia group	3.1
Helianthus group	1.8
Chichorium group	.0
Carpinus	0.9
Carya	4.4
Castanea	0.4
Juglans	0.4
Liquidambar	3.5
Myriophyllum	0.4
Nyssa	3.5
Pinus	18.5
POACEAE (excl. *Zea*)	17.1
Populus	3.5
Quercus	22.4
Salix	2.6
Typha/Sparganium	5.7
Ulmus	0.9
INDETERMINATE	8.3
UNKNOWN	2.2
Total	100.0%

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Appendix D
Topographic Profiles

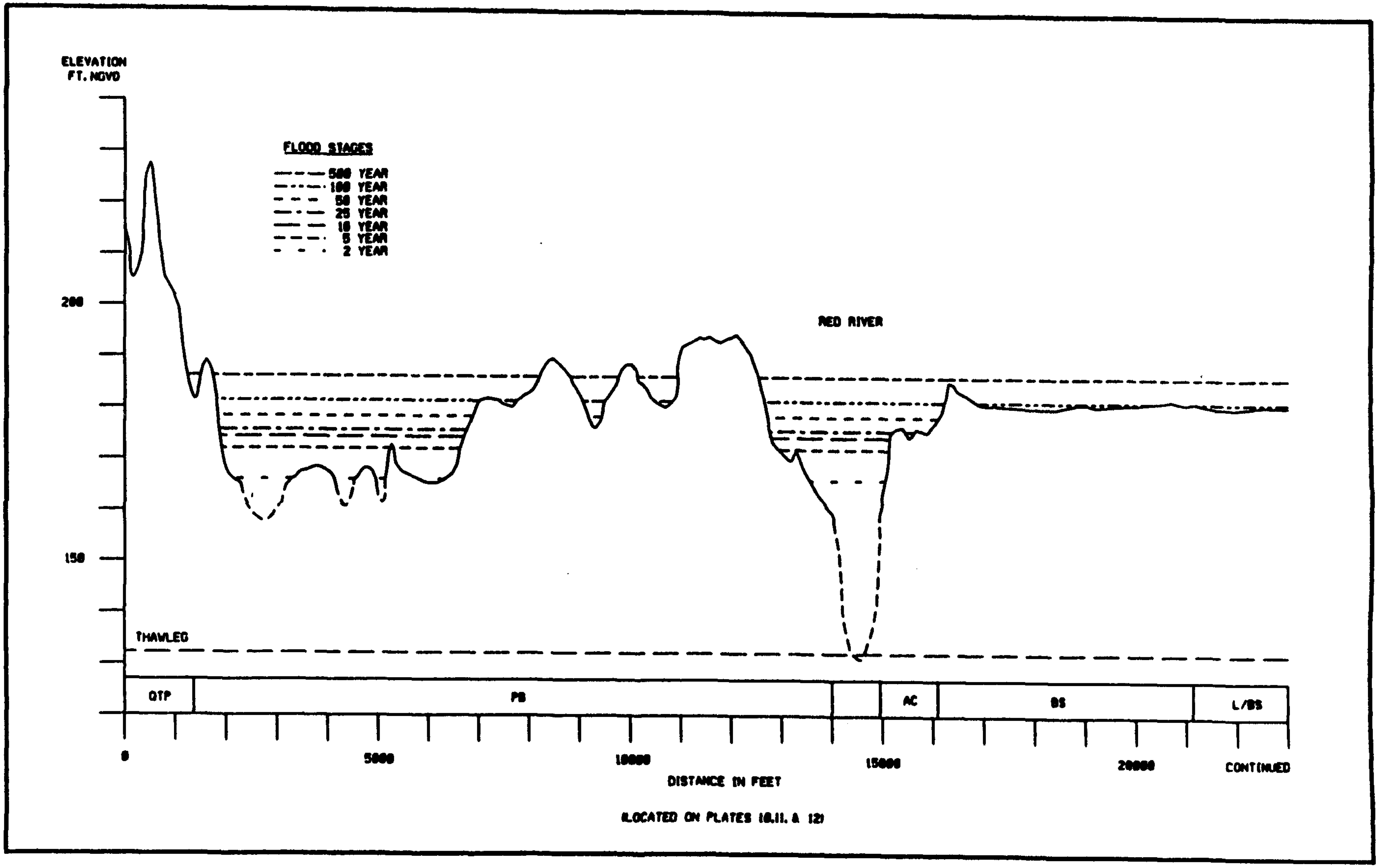

Figure D1. River mile 19a

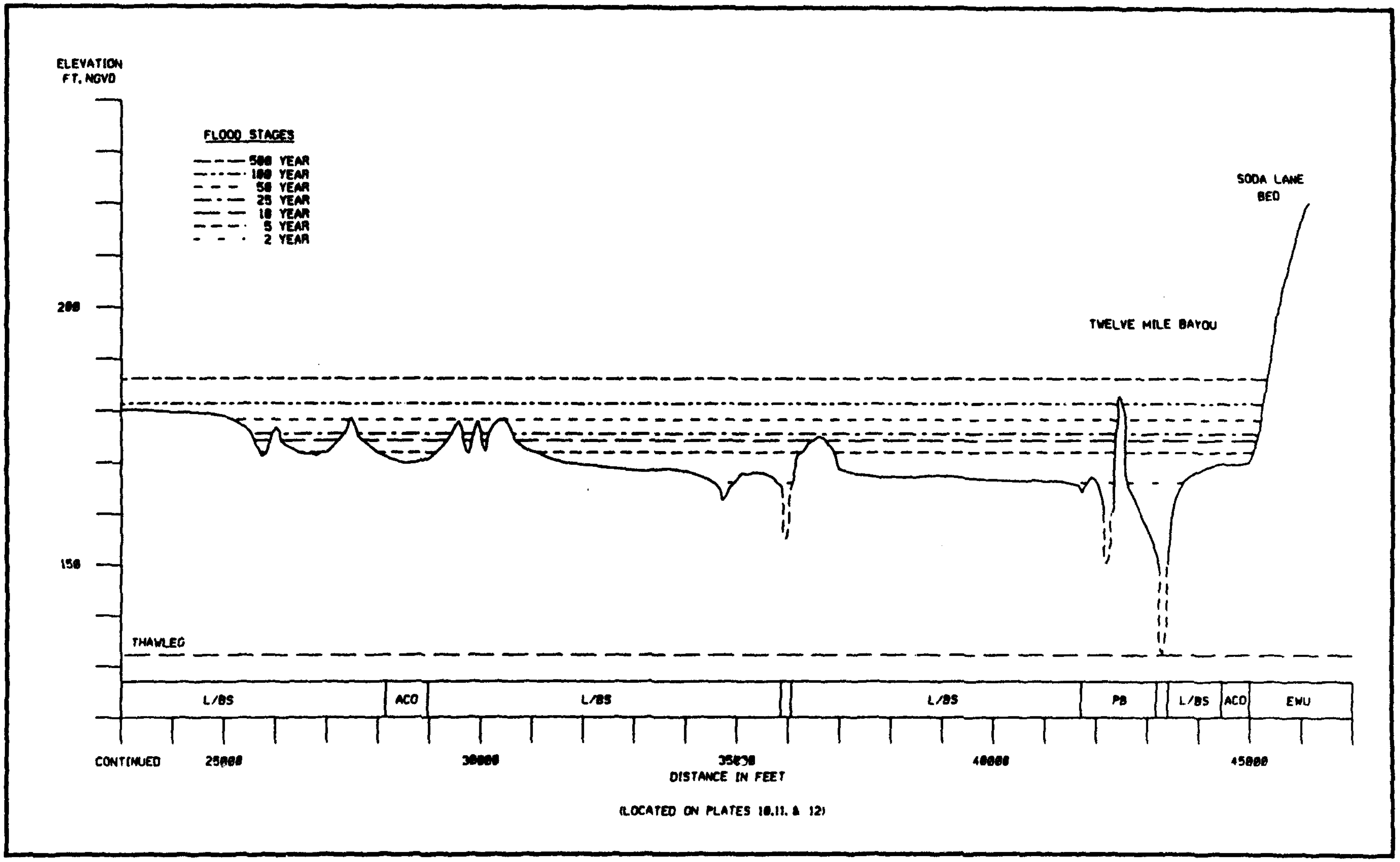

Figure D2. River mile 19b

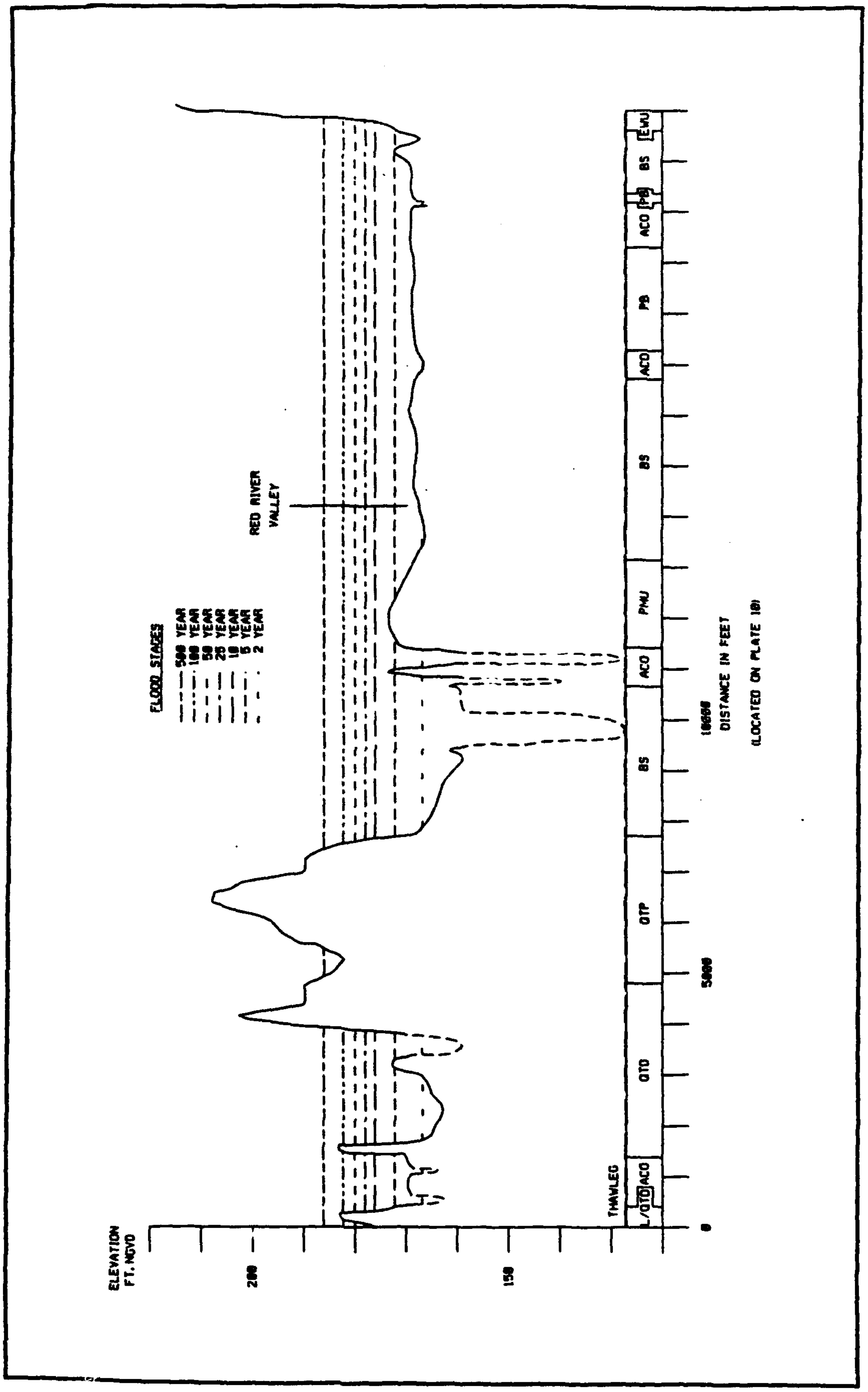

Figure D3. River mile 22.8

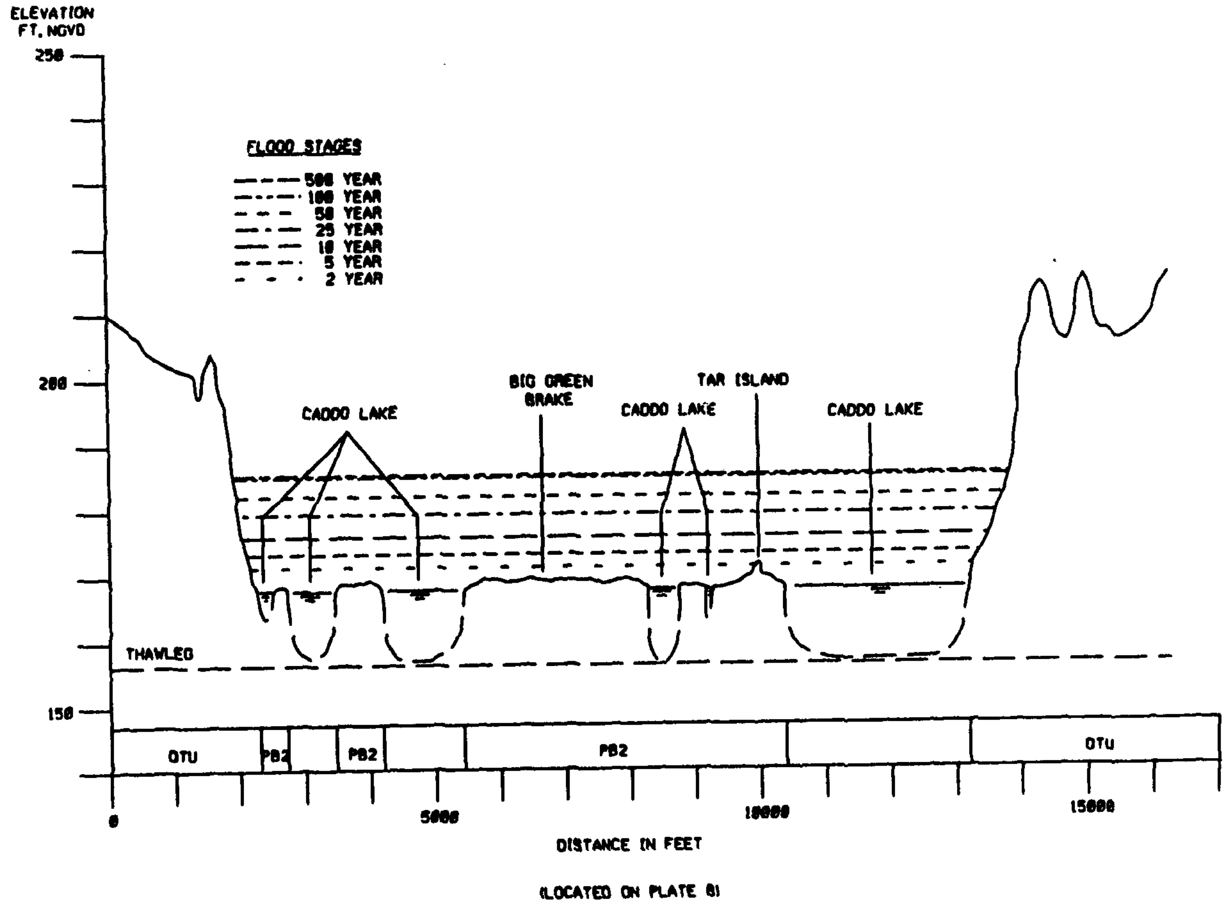

Figure D4. River mile 32.5

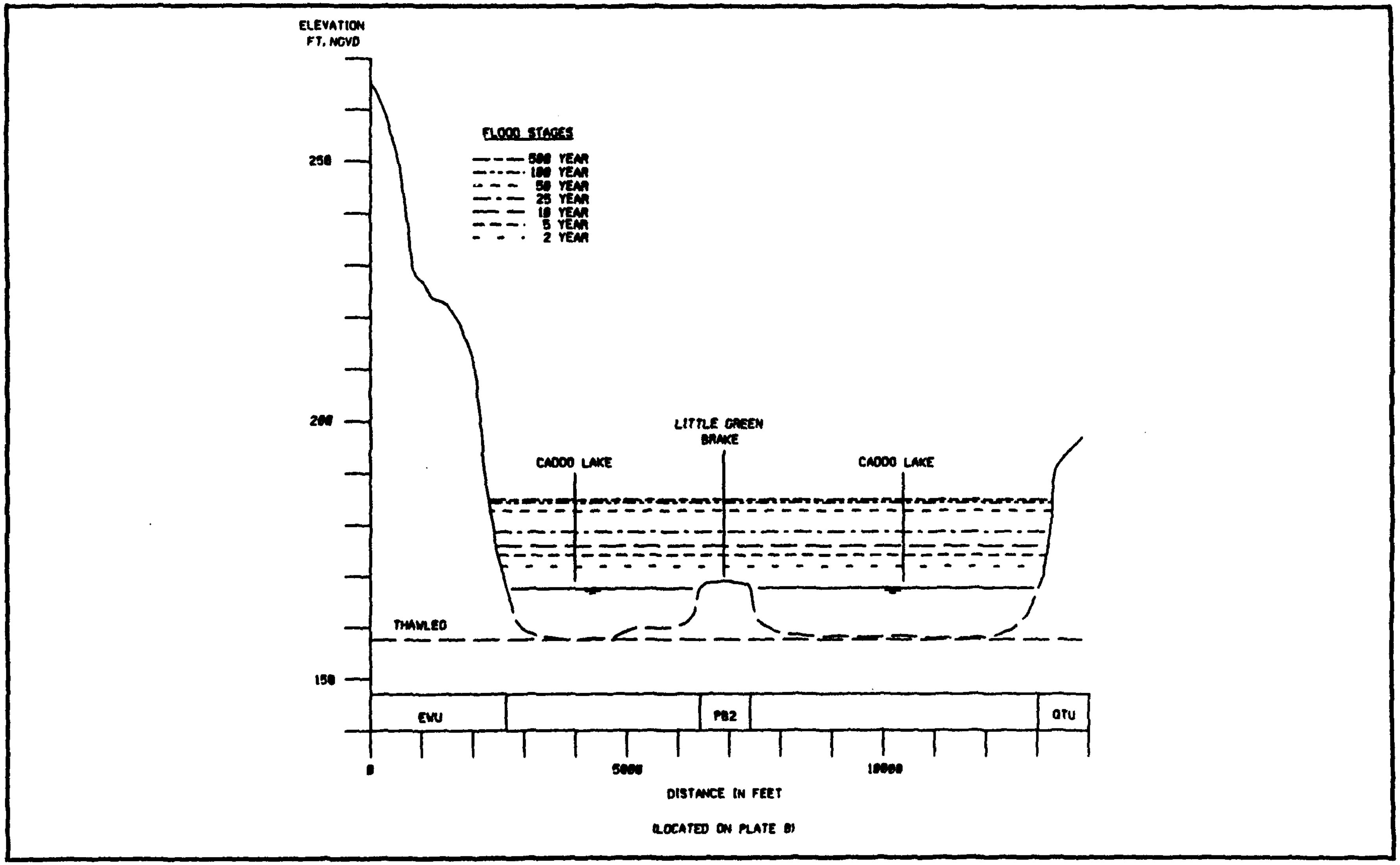

Figure D5. River mile 33.5

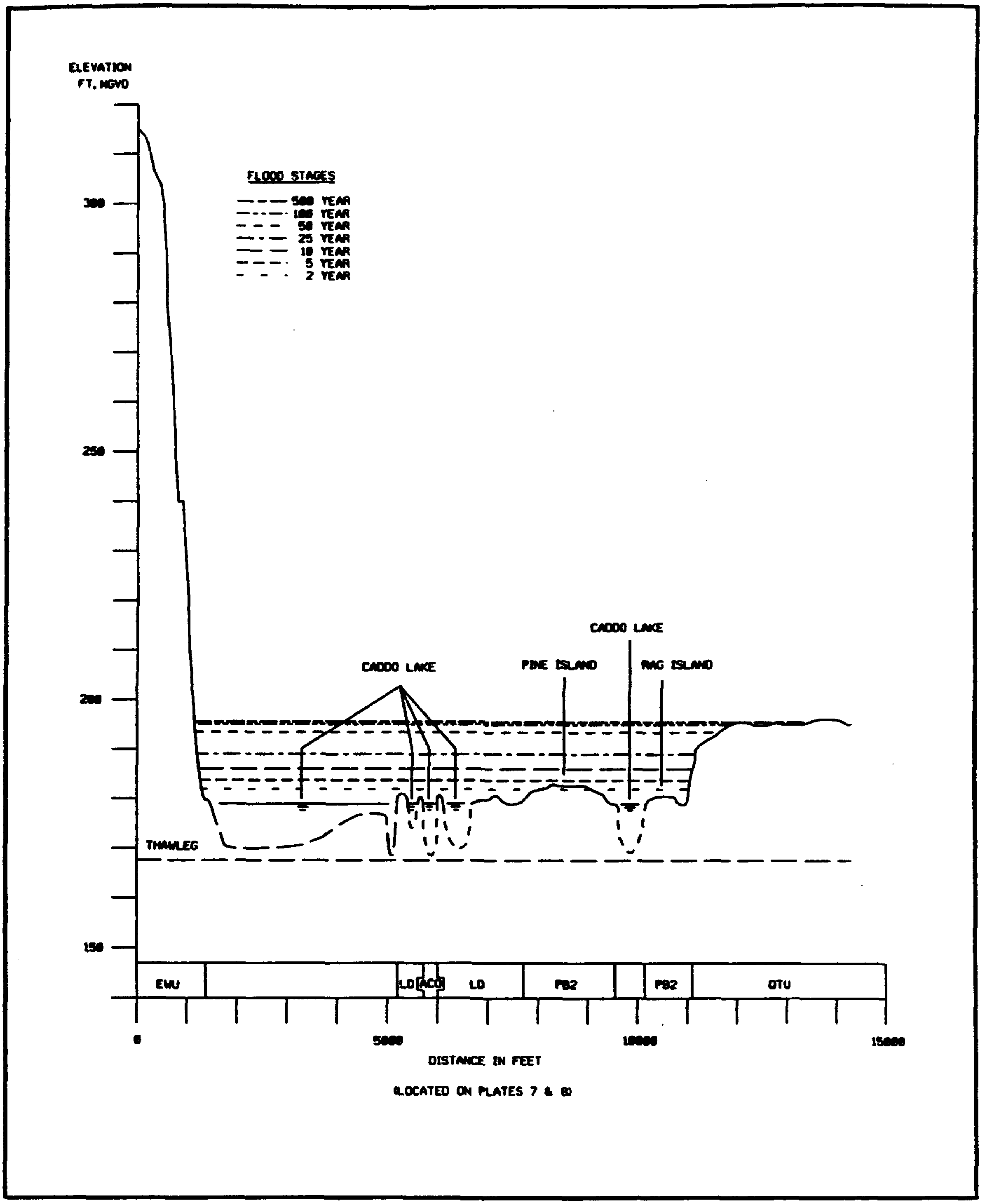

Figure D6. River mile 37.0

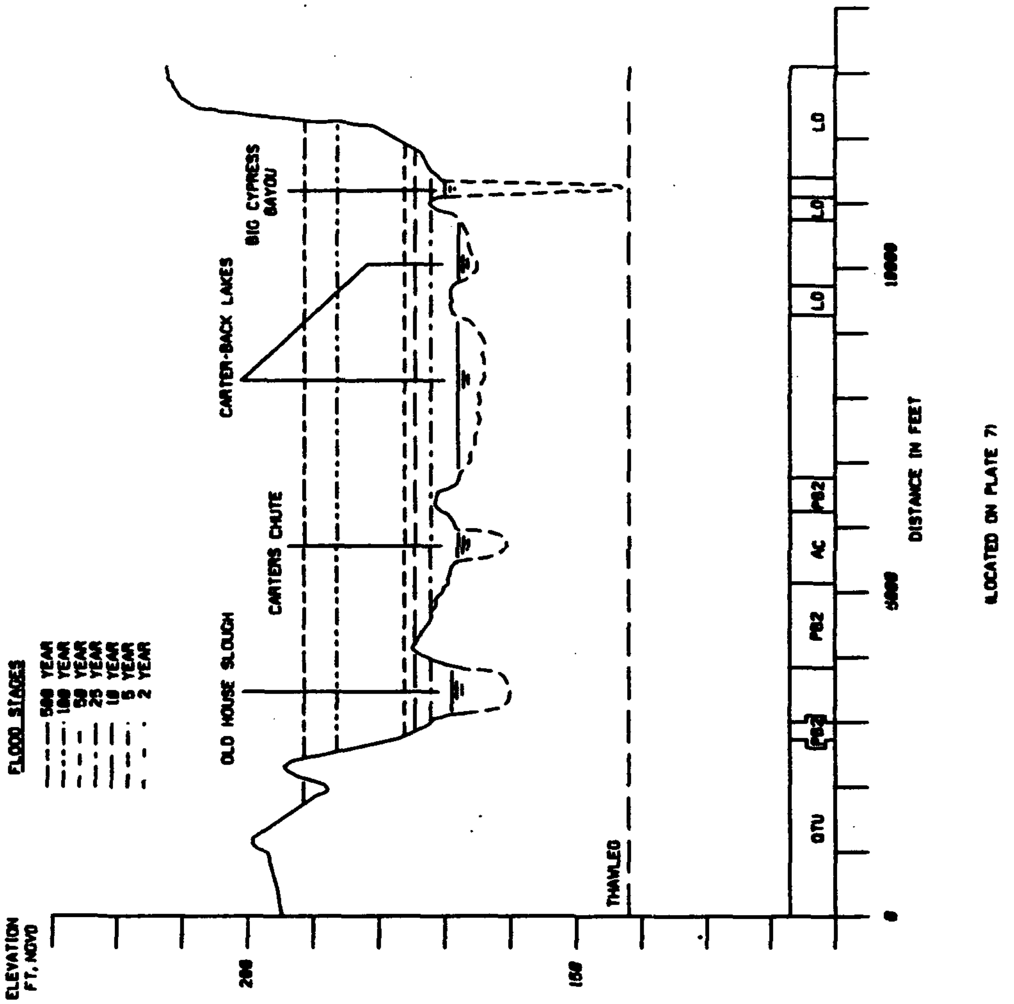

Figure D7. River mile 46.8

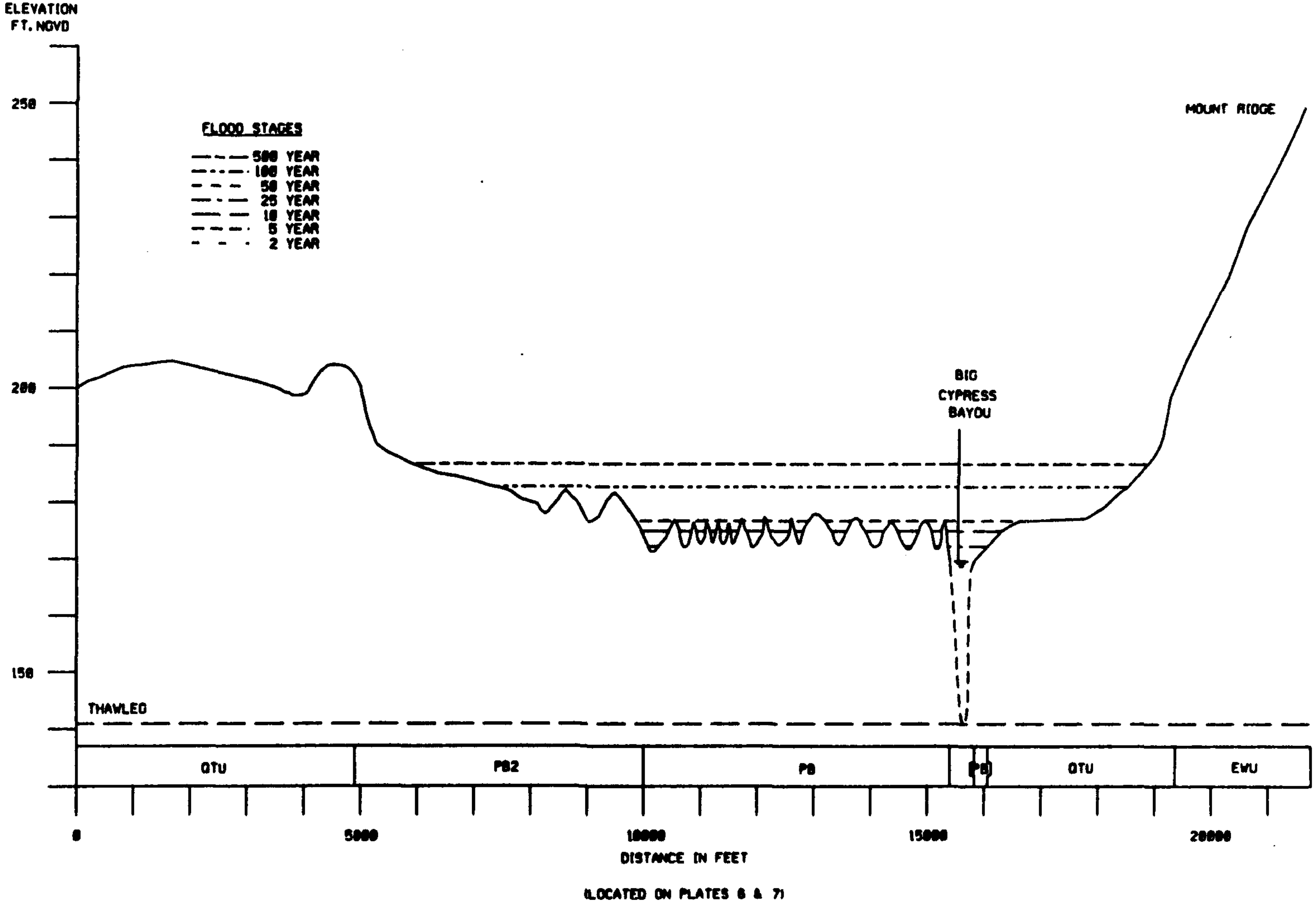

Figure D8. River mile 51.9

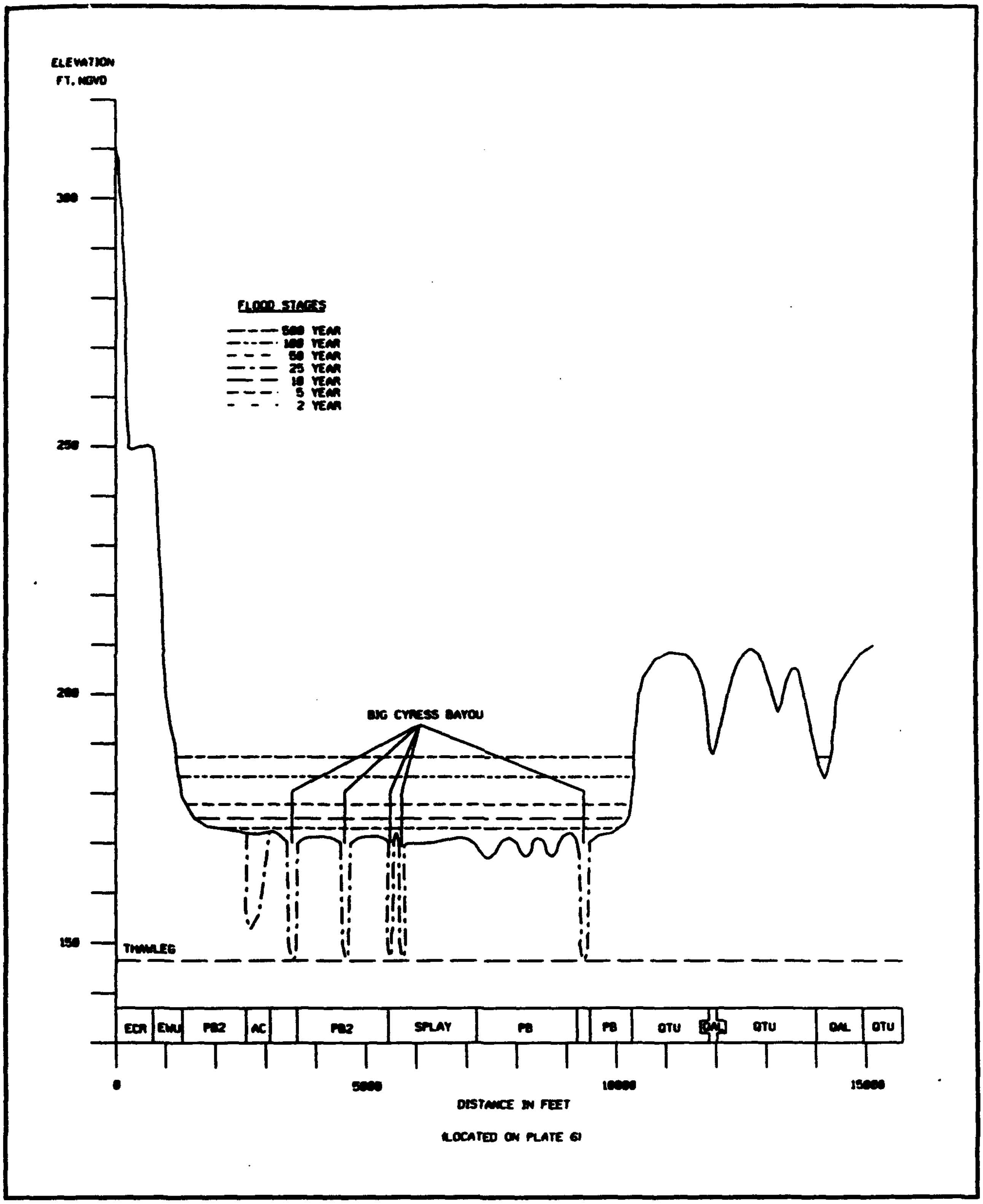

Figure D9. River mile 55.0

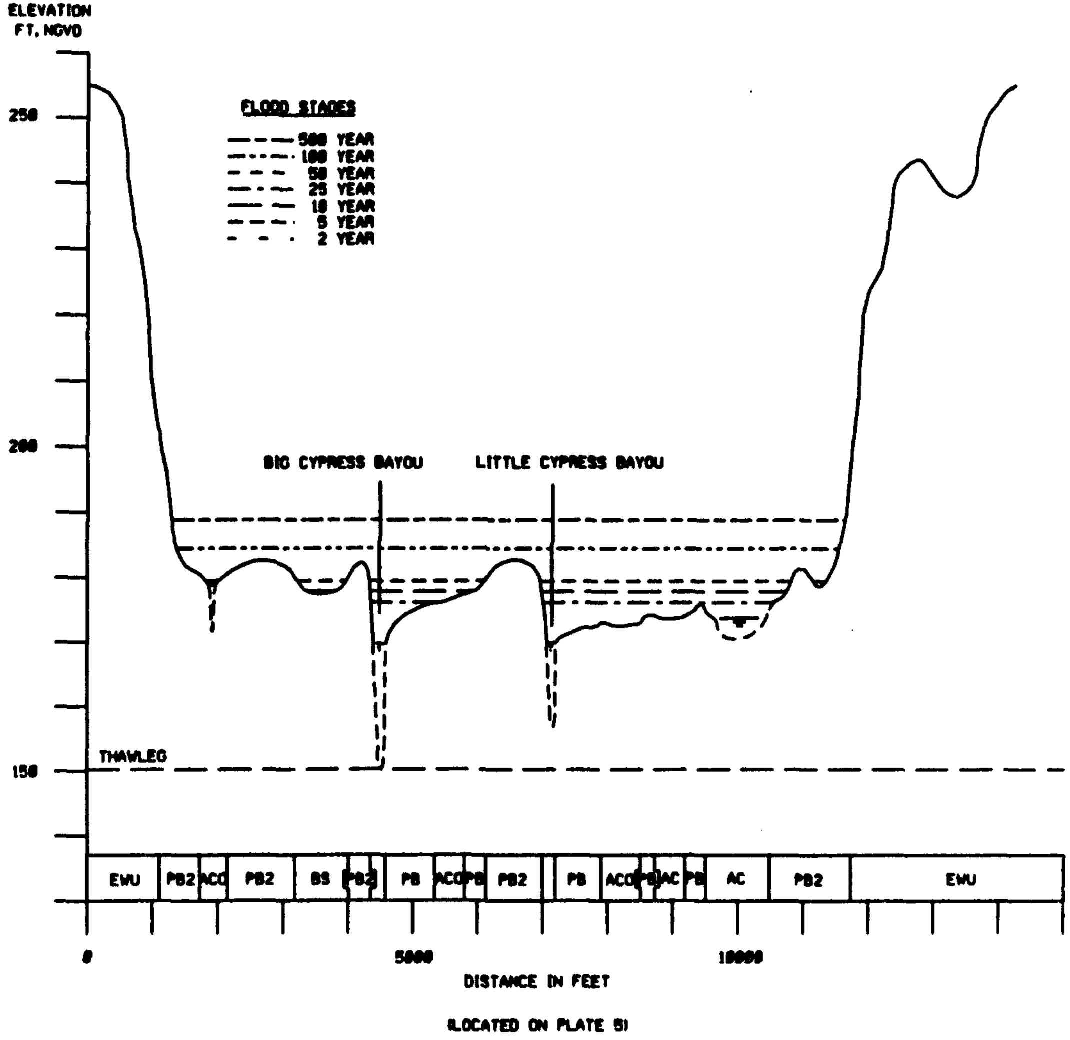

Figure D10. River mile 62.0

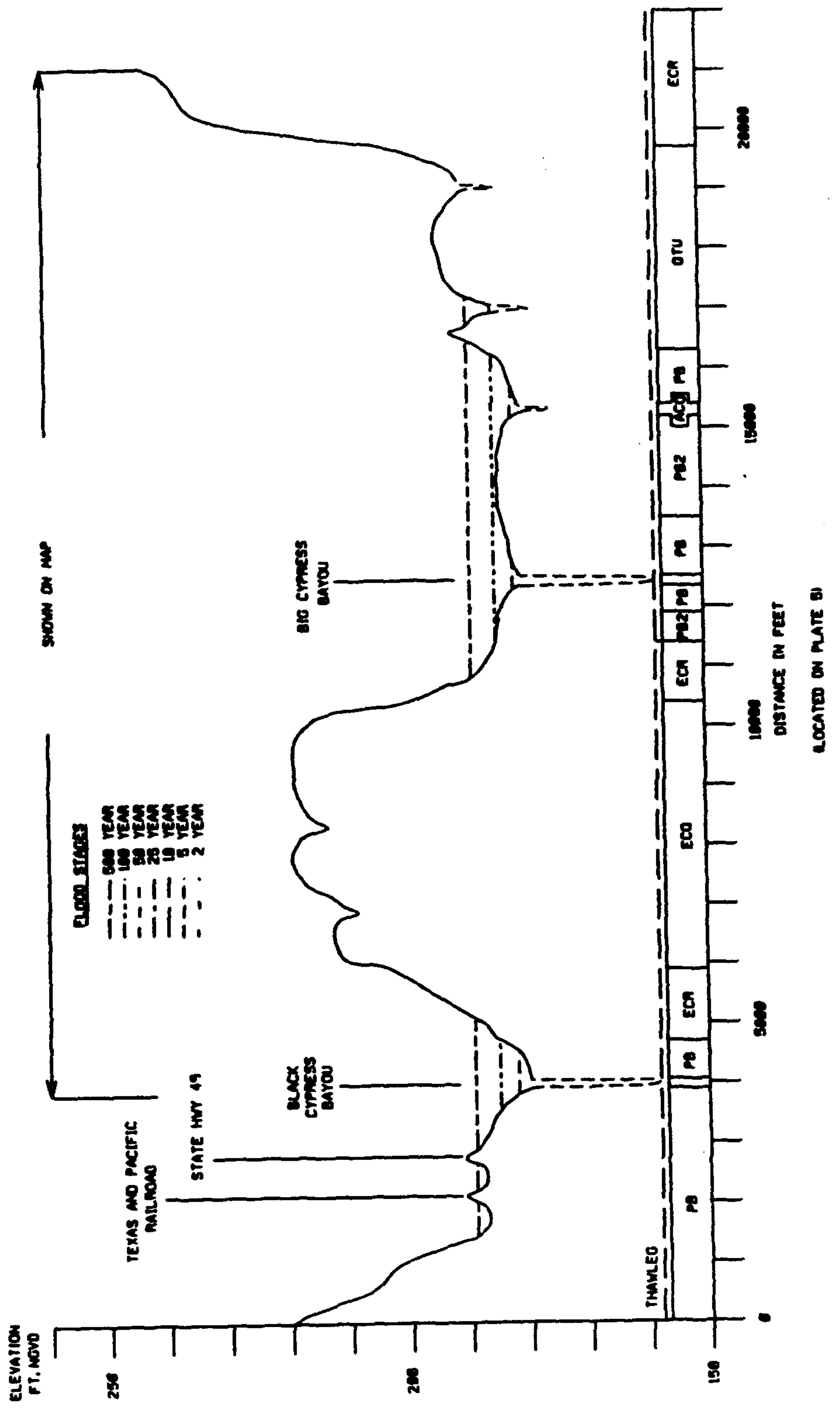

Figure D11. River mile 66.0

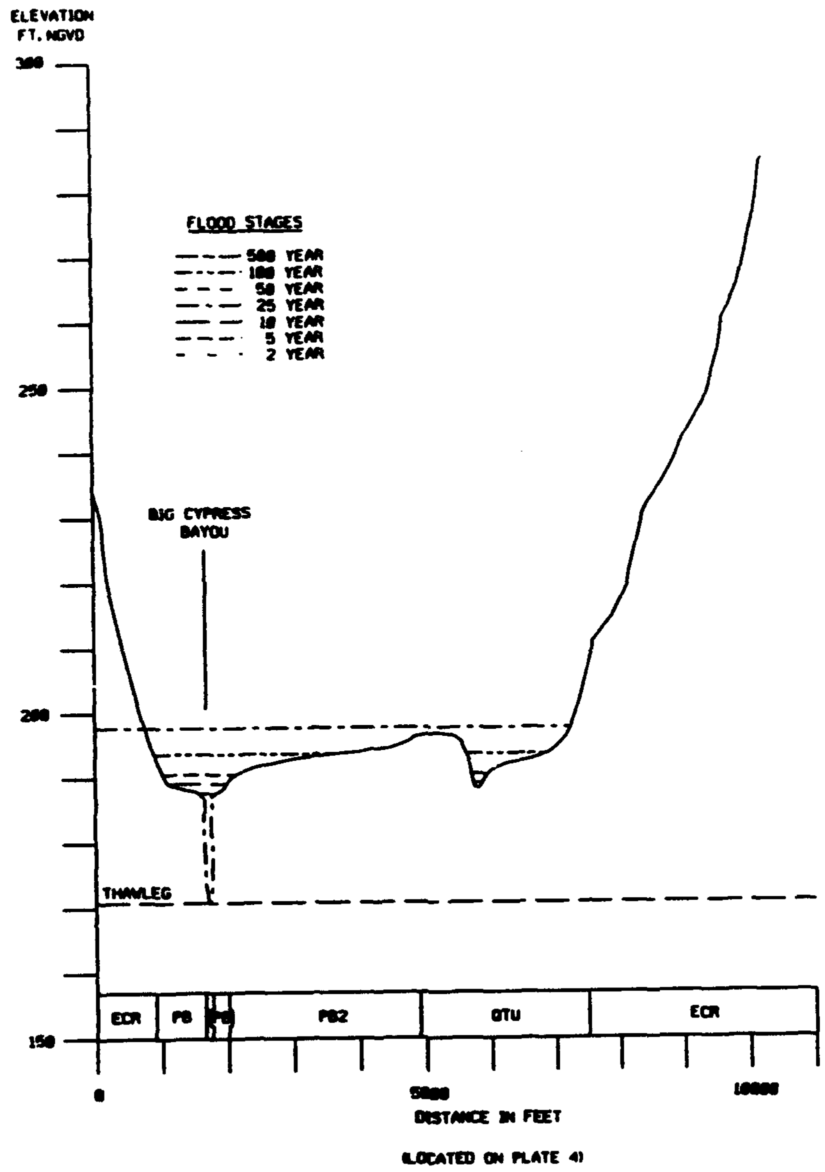

Figure D12. River mile 76.0

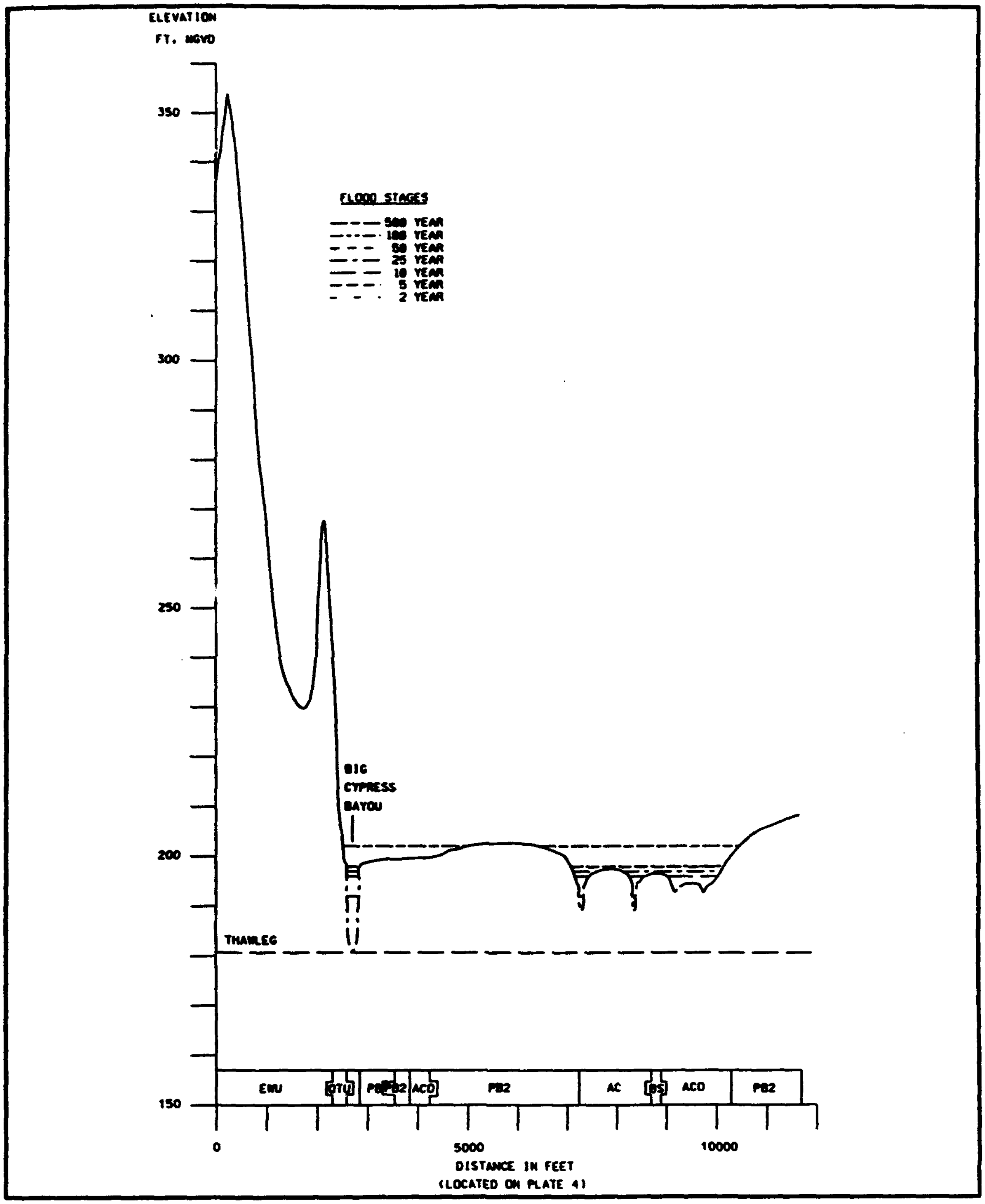

Figure D13. River mile 83.0

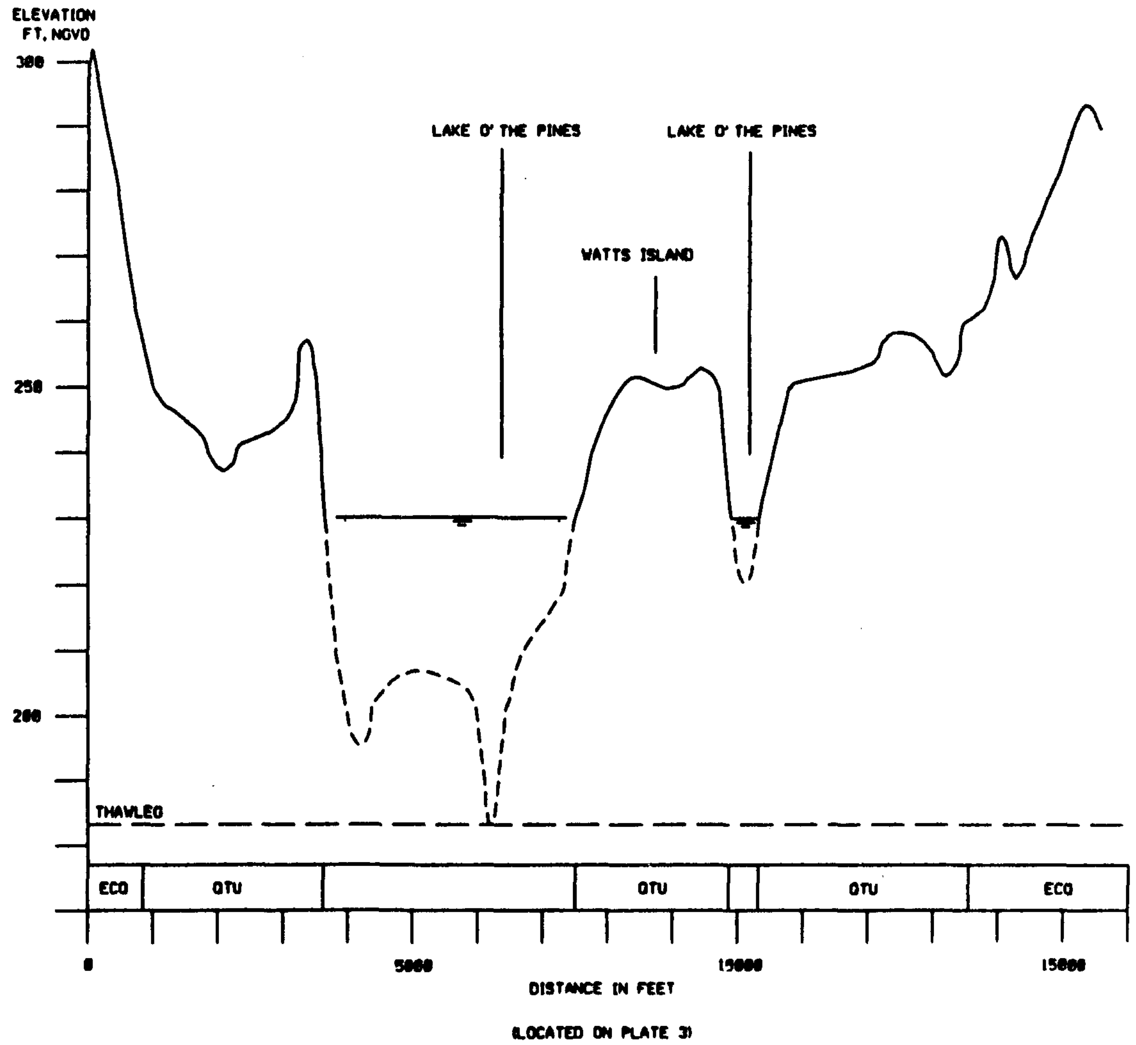

Figure D14. River mile 89.3

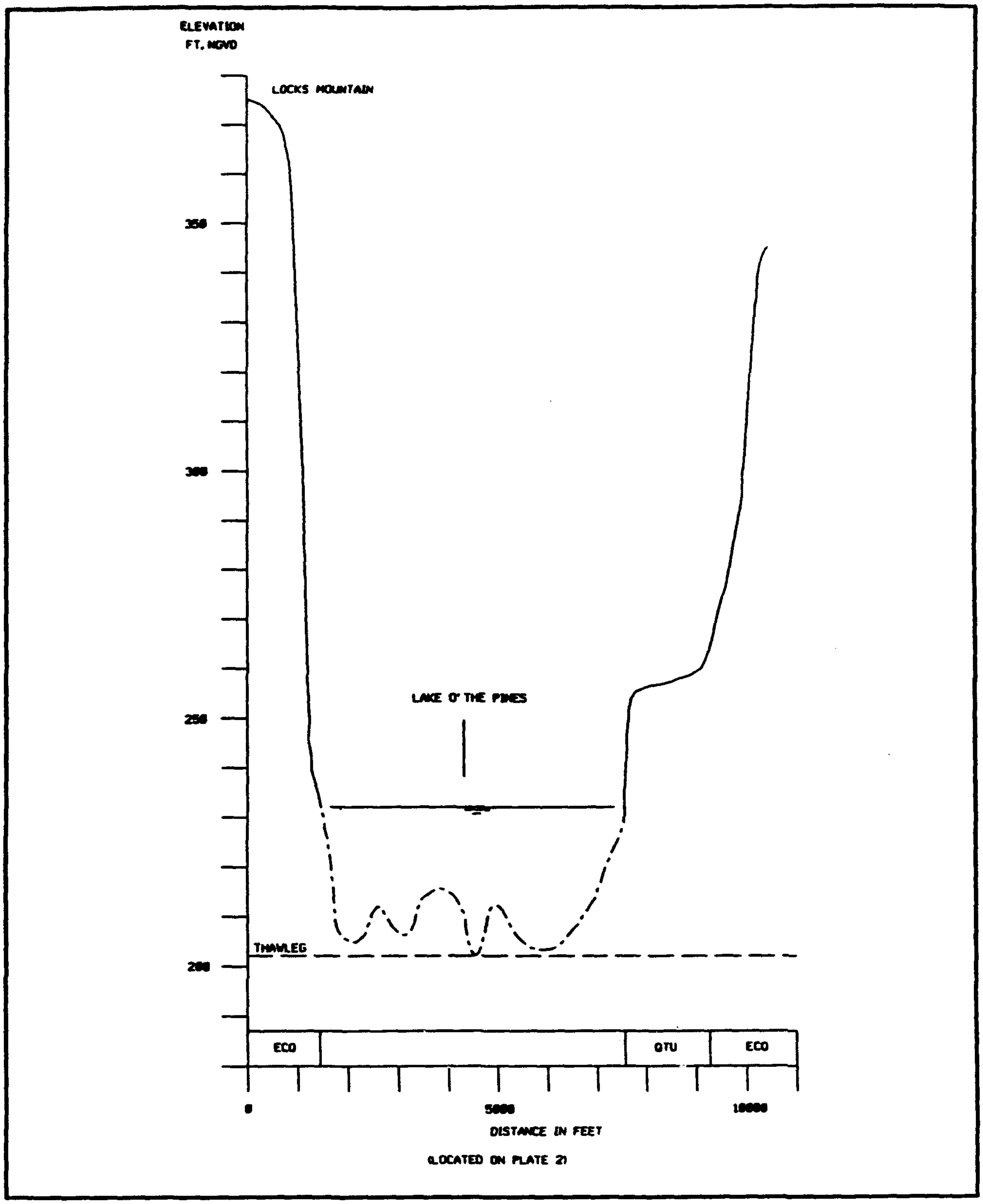

Figure D15. River mile 96.0

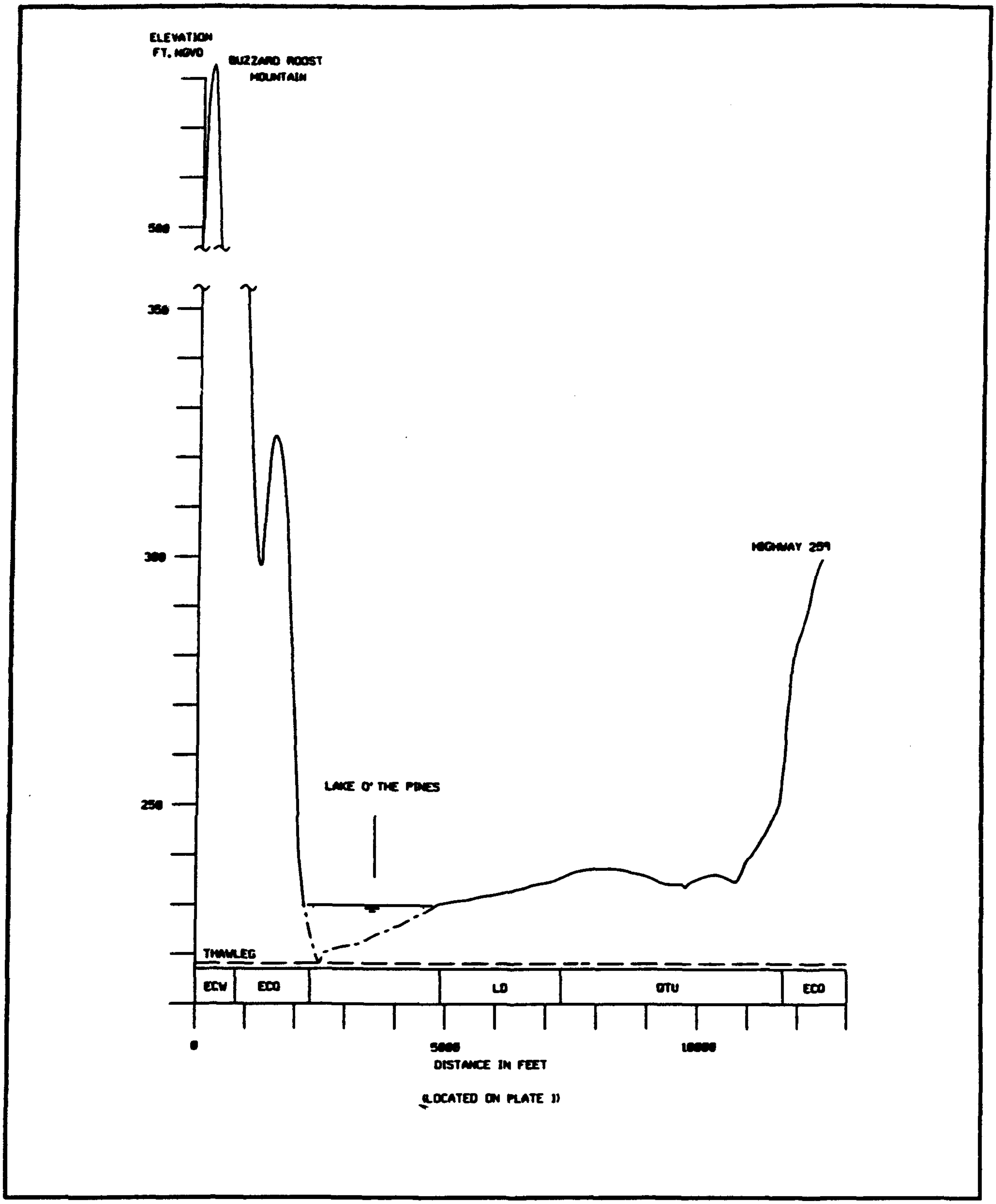

Figure D16. River mile 110.0

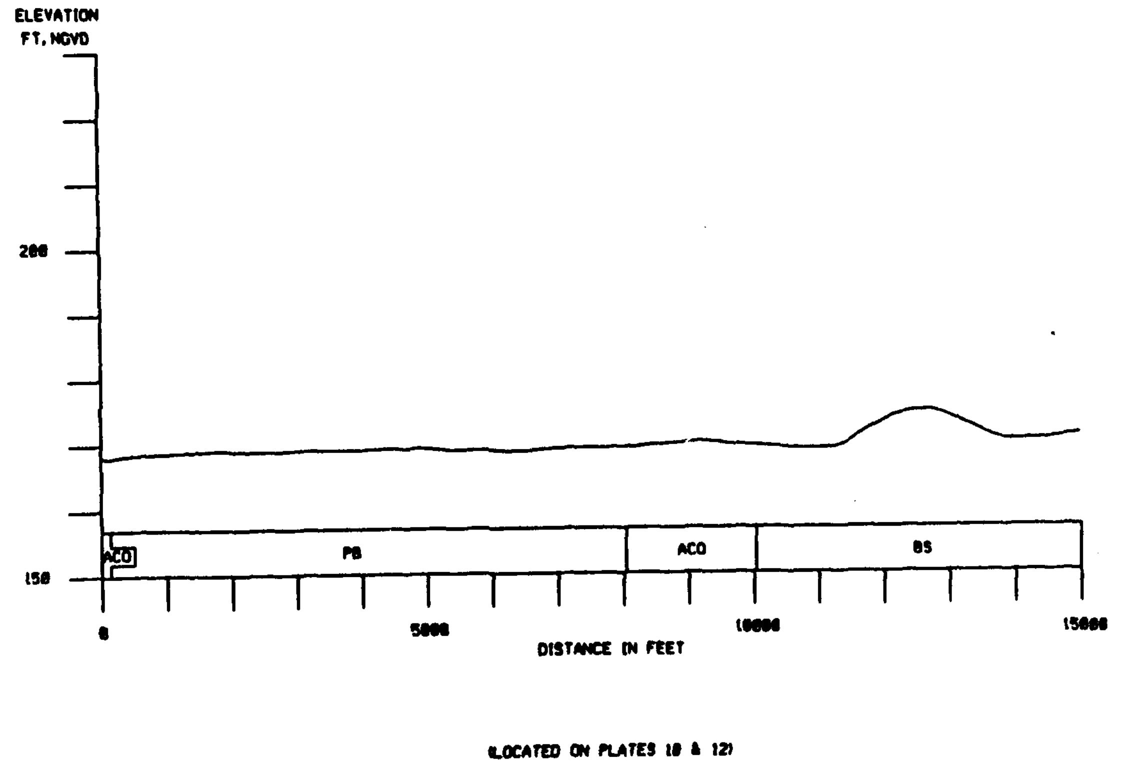

Figure D17. Profile A

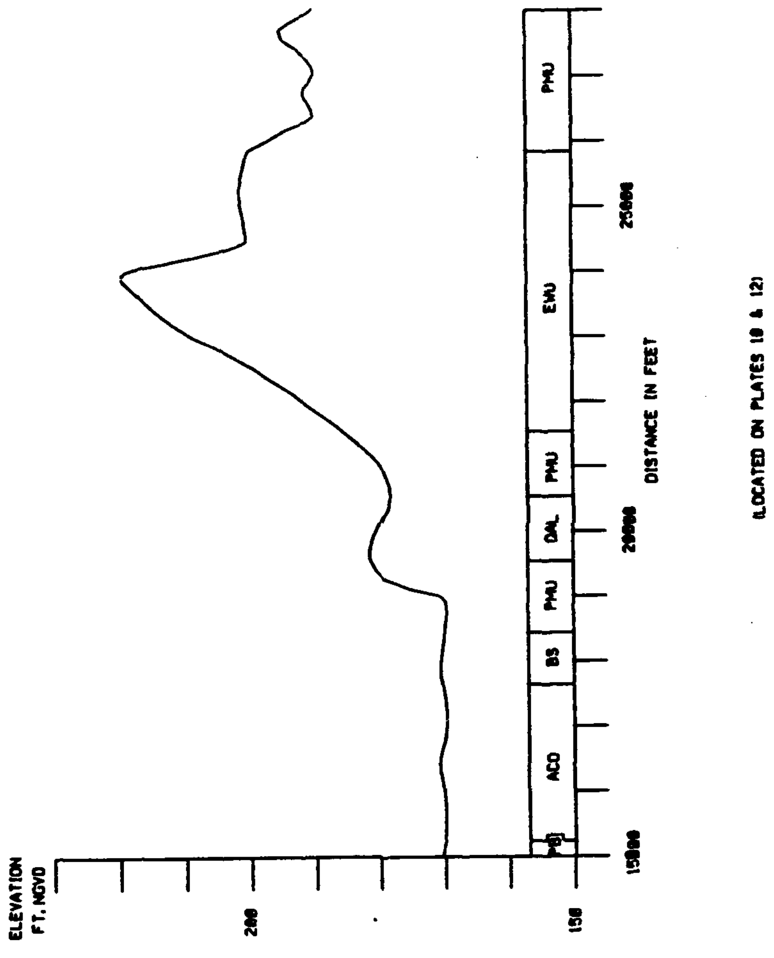

Figure D18. Profile B

Appendix E
SCS Soil Types and Landform Associations

TABLE E1
CORRELATION OF GEOMORPHIC UNITS TO SOIL SERIES

GEOMORPHIC UNIT	SOIL # & SERIES	SOIL CLASS
AC	2 ARMISTEAD CLAY	AQUIC ARGIUDOLLS
	14 GALION SILT LOAM	TYPIC HAPLUDALFS
	15 GALION SILTY CLAY LOAM	" "
	23 MORELAND SILTY CLAY LOAM	VERTIC HAPLUDOLLS
	24 MORELAND CLAY	" "
	25 FORBING SILT LOAM	VERTIC PALEUALFS
	27 NORWOOD SILT LOAM	TYPIC UDIFLUVEVTS
	29 NORWOOD SILTY CLAY LOAM	" "
	33 SEVERN V. FINE SANDY LOAM	TYPIC UDIFLUVENTS
	34 SEVERN GENTLY UNDULATING	" "
	75 EVADALE CART COMLEX	FRAGLOSSUDALFS
	192 SOCAGEE SILTY CLAY LOAM	TYPIC UDIFLUVENTS
ACO	1 BUXIN CLAY	VERTIC HAPLUDOLLS
	2 ARMISTEAD CLAY	AQUIC ARGIUDOLLS
	14 GALION SILT LOAM	TYPIC HAPLUDALFS
	15 GALION SILTY CLAY LOAM	" "
	20 MORELAND CLAY	VERTIC HAPLUDOLLS
	22 MORELAND SILT LOAM	" "
	27 NORWOOD SILT LOAM	TYPIC UDIFLUVEVTS
	29 NORWOOD SILTY CLAY LOAM	" "
	35 SEVERN OCC. FLOODED	TYPIC UDIFLUVENTS
	192 SOCAGEE SILTY CLAY LOAM	" "
	207 MOOREVILLE-MANTACHIE	AERIC FLUVAQUENTS
BS	2 ARMISTEAD CLAY	AQUIC ARGIUDOLLS
	20 MORELAND CLAY	VERTIC HAPLUDOLLS
	22 MORELAND SILT LOAM	" "
	27 NORWOOD SILT LOAM	TYPIC UDIFLUVEVTS
	29 NORWOOD SILTY CLAY LOAM	" "
HC	0 WATER	
LD	17 CYPRESS CLAY LOAM	AQUIC FLUVAQUENTS
	107 SARDIS-MATHISTON	DYSTROCHREPTS
	165 ESTES CLAY	AERIC HAPAQUEPTS
	207 MOOREVILLE-MANTACHIE	AERIC FLUVAQUENTS
L/BS	1 BUXIN CLAY	VERTIC HAPLUDOLLS
	2 ARMISTEAD CLAY	AQUIC ARGIUDOLLS
	12 CASPIANA SILT LOAM	TYPIC ARGIUDOLLS
	20 MORELAND CLAY	VERTIC HAPLUDOLLS
	23 MORELAND SILTY CLAY LOAM	" "
	24 MORELAND CLAY	" "
	27 NORWOOD SILT LOAM	TYPIC UDIFLUVEVTS
	29 NORWOOD SILTY CLAY LOAM	" "
	34 SEVERN V.FINE SANDY LOAM	" "

L/PB	1 BUXIN CLAY	VERTIC HAPLUDOLLS
	2 ARMISTEAD CLAY	AQUIC ARGIUDOLLS
	20 MORELAND CLAY	VERTIC HAPLUDOLLS
	24 MORELAND CLAY	" "
	27 NORWOOD SILT LOAM	TYPIC UDIFLUVEVTS
PB	1 BUXIN CLAY	VERTIC HAPLUDOLLS
	2 ARMISTEAD CLAY	AQUIC ARGIUDOLLS
	3 BEAUREGARD	PALEUDULTS
	11 CASPIANA SILTY CLAY LOAM	TYPIC ARGIUDOLLS
	12 CASPIANA SILT LOAM	" "
	15 GALLION SILTY CLAY LOAM	TYPIC HAPLUDALFS
	16 GORE SILT LOAM	GLOSSAQUALFS
	17 CYPRESS CLAY LOAM	?
	20 MORELAND CLAY	VERTIC HAPLUDALFS
	23 MORELAND SILTY CLAY LOAM	" "
	24 MORELAND CLAY	" "
	26 DARDEN LOAMY FINE SAND	QUARTZIPSAMMENTS
	27 NORWOOD SILT LOAM	TYPIC UDIFLUVENTS
	29 NORWOOD SILTY CLAY LOAM	" "
	33 SEVERN V. FINE SANDY LOAM	TYPIC UDIFLUVENTS
	34 SEVERN GENTLY UNDULATING	" "
	35 SEVERN OCC. FLOODED	" "
	36 SEVERN FREQ FLOODED	" "
	75 EVADALE CART COMLEX	PALEUDALFS
	111 LATCH-MOLLVILLE	PALEUDALFS
	115 GUYTON-CART	PALEUALFS
	165 ESTES CLAY	GLOSSAQUALFS
	183 BIENVILLE	PALEUDALFS
	207 MOOREVILLE-MANTACHIE	PALEUDALFS
PB2	111 LATCH-MOLLVILLE	PALEUALFS
	115 GUYTON-CART	GLOSSAQUALFS
	120 IUKA	AQUIC UDIFLUVENTS
	150 BERNALDO	PALEUDALFS
	183 BIENVILLE	PALEUDALFS
	203 METCALF-CART	GLOSSAQUALFS
QAL	1 BUXIN CLAY	VERTIC HAPLUDOLLS
	3 BEAUREGARD SILT LOAM	PALEUDULTS
	4 BERNALDO	PALEUDALFS
	16 GORE SILT LOAM	PALEUDALFS
	18 GUYTON FREQ FLOODED	GLOSSAQUALFS
	25 FORBING SILTY LOAM	PALEUDALFS
	39 WRIGHTSVILLE-MESSR	GLOSSAQUALFS
	107 SARDIS-MATHISTON	DYSTROCHREPTS
	115 GUYTON-CART	PALEUDALFS
	120 IUKA FINE SANDY LOAM	AQUIC UDIFLUVENTS
	150 BERNALDO FINE SANDY LOAM	PALEUDALFS
	192 SOCAGEE SILTY CLAY LOAM	TYPIC UDIFLUVIENT

QTD	1 BUXIN CLAY	VERTIC HAPLUDOLLS
	9 BETIS LOAMY FINE SAND	PALEUDULTS
	17 CYPRESS CLAY LOAM	?
	19 BRILEY LOAMY FINE SAND	PALEUDULTS
	21 FORBING SILT LOAM	PALEUDALFS
QTP	3 BEAUREGARD SILT LOAM	PALEUDULTS
	6 WOODTELL FINE SANDY LOAM	VERTIC HAPUDALFS
	7 WOODTELL 3-8% SLOPES	" "
	13 KEITVILLE FINE SANDY LOAM	PALEUDALFS
	21 FORBING SILT LOAM	" "
	24 MORELAND CLAY	VERTIC HAPUDOLLS
	25 FORBING SILT LOAM	PALEUDALFS
	32 SMITHDALE FINE SANDY LOAM	PALEUDULTS
	37 METCALF-MESSER	GLOSSUDALFS
	38 GUYTON-MESSER	GLOSSUDALFS
	39 WRIGHTSVILLE-MESSR	GLOSSUDALFS
	40 BOWIE FINE SANDY LOAM	PALEUDULTS
QTU	75 EVADALE CART COMLEX	FRAGLOSSUDALFS
	107 SARDIS-MATHISTON	DYSTROCEPTS
	109 THAGE-CART	PALEUDALFS
	111 LATCH-MOLLVILLE	PALEUDALFS
	113 BONN-CART	PALEUDALFS
	150 BERNALDO FINE SANDY LOAM	PALEUDALFS
	194 METH FINE SANDY LOAM	ULTIC HAPLUDALFS
	195 EASTWOOD V.FINE SANDY LOAM	VERTIC HAPLUDALFS
	196 LATEX FINE SANDY LOAM	PALEUDALFS
	198 SCOTSVILLE	PALEUDALFS
	203 METCALF-CART	GLOSSAQUALFS
ECS	NO DATA	
ECW	224 ELROSE FINE SANDY LOAM	TYPIC PALEUDALFS
ECQ	40 BOWIE	PALEUDULTS
	146 KIRVIN	TYPIC HAPLUDALTS
ECR	118 PICKTON LOAMY FINE SAND	PALEUDALFS
	130 WOLFPEN LOAMY FINE SAND	ARENIC PALEUALFS
	146 KIRVIN 2-8 SLOPES	TYPIC HAPLUDULTS
	172 WOLFPEN 8-15 SLOPES	ARENIC PALEUDALFS
	194 METH FINE SANDY LOAM	ULTIC HAPLUALFS

EWU	4 BERNALDO	PALEUDALFS
	6 WOODTELL FINE SANDY LOAM	VERTIC HAPLUDALFS
	7 WOODTELL 3-8 % SLOPE	" "
	8 WOODTELL 8-20 % SLOPE	" "
	9 BETIS LOAMY FINE SAND	PALEUDULTS
	10 BETIS 5-12 % SLOPES	" "
	13 KEITHVILLE	PALEUDALFS
	19 BRILEY LOAMY FINE SAND	PALEUDULTS
	40 BOWIE FINE SANDY LOAM	PALEUDULTS
	42 METH FINE SANDY LOAM	ULTIC HAPLUDALFS
	130 WOLFPEN LOAMY FINE SAND	ARENIC PALEUDALFS
	150 BERNALDO FINE SANDY LOAM	GLOSSIC PALUDALFS
	172 WOLFPEN 8-15 SLOPE	ARENIC PALEUDALFS
	194 METH FINE SANDY LOAM	ULTIC HAPLUDALFS
	195 EASTWOOD V.FINE SANDY LOAM	VERTIC HAPLUDALFS
	196 LATEX FINE SANDY LOAM	?
	198 SCOTSVILLEFINE SANDY LOAM	PALEUDALFS
	201 ERNO-CART	GLOSSAQUALFS
	203 METCALF-CART	GLOSSAQUALFS
PMU	6 WOODTELL FINE SANDY LOAM	VERTIC HAPLUALFS
	7 WOODTELL 3-8 % SLOPE	" "
	8 WOODTELL 8-20 % SLOPE	" "
	13 KEITVILLE	PALEUDALFS
	37 METCALF-MESSER	ULTIC HAPLUALFS

TABLE E2
CORRELATION OF SOIL SERIES TO GEOMORPHIC UNITS

SOIL SERIES		GEOMORPHIC UNIT	
ARMISTEAD CLAY		AC, BS, L/BS, PB	
BEAUREGARD SILT LOAM		PB, QAL, QTP	
BERNALDO FINE SANDY LOAM		QAL, QTU, EWU	
BETIS LOAMY FINE SAND		QTD, QAL, EWU	
BIENVILLE LOAMY FINE SAND		PB, QAL	
BONN-CART		QTU	
BOWIE FINE SANDY LOAM		QTU, EWU	
BRILEY LOAMY FINE SAND		EWU	
BUXIN CLAY		ACO, L/BS, L/PB, PB, QAL	
CASPIANA SILTY CLAY LOAM		L/BS, PB	
CYPRESS CLAY LOAM		LD, PB,	
DARDEN LOAMY FINE SAND		PB	
EASTWOOD V.FINE SANDY LOAM		QTU, EWU	
ELROSE FINE SANDY LOAM		ECW	
ERNO-CART		EWU	
ESTES CLAY		PB, LD	
EVADALE CART COMPLEX		PB, QTU	
FORBING SILT LOAM		AC, QAL, QTD, QTP	
GALION SILT LOAM		AC, ACO, PB	
GORE SILT LOAM		PB, QAL	
GUYTON		QAL	
GUYTON-CART		PB2	
GUYTON-MESSER		QTP	
IUKA FINE SANDY LOAM		PB2, QAL	
KEITVILLE		QTP, EWU	
KIRVIN		ECQ	
LATCH-MOLLVILLE		PB, PB2, QTU	
METCALF-CART		PB2, QTU, EWU	
METCALF-MESSER		PMU, QTP	

METH FINE SANY LOAM		QTU, ECR, EWU	
MOOREVILLE-MANTACHIE		ACO, LD, PB	
MORELAND CLAY		AC, ACO, BS, L/BS, PB	
NORWOOD SILT LOAM		AC, ACO, BS, L/BS, PB	
PICKTON LOAMY FINE SAND		ECR	
SARDIS-MATHISTON		LD, QAL, QTU	
SCOTSVILLE		QTU, EWU	
SEVERN FINE SANDY LOAM		AC, ACO, L/BS, PB	
SOCAGEE SILTY CLAY LOAM		ACO, QAL	
THAGE-CART		QTU	
WOLFPEN LOAMY FINE SAND		ECR, EWU	
WOODTELL FINE SANDY LOAM		QTP, EWU, PMU	
WRIGHTSVILLE-MESSR		QAL, QTP	

Appendix F
Catalogue of Known Archaeological Sites

LEGEND

LANDFORM

ACO	ABANDONED COURSE
BS	BACKSWAMP
L/BS	LACUSTRINE OVERLYING BACKSWAMP
L/PB	LACUSTRINE OVERLYING POINT BAR
L/PB2	LACUSTRINE OVERLYING OLDER POINT BAR
LS	LAKE SHORE
PB	RECENT POINT BAR
PB2	OLDER POINT BAR
QAL	QUATERNARY ALLUVIUM UNDIFFERENTIATED
QTP	QUATERNARY TERRACE PRAIRIE
QTU	QUATERNARY TERRACE UNDIFFERENTIATED
SUM	SUMMIT
VS	VALLEY SLOPE

CULTURAL ASSOCIATIONS

ARC	ARCHAIC INDIAN (Before 200 BC)
CAD	CADDO INDIAN (200 BC to 1650 AD)
HIS	HISTORIC (1700's to present)

LOUISIANA

SITE NUMBER	SHEET NUMBER	LANDFORM	CULTURAL ASSOCIATION	REMARKS
16CD02	12	QTP-LS	CAD	CAMP; HAMLET
16CD03	12	QTP-LS	ARC-CAD	CAMP; HAMLET
16CD04	12	PB-LS	CAD-HIS	PREH HAMLET; HIS (UNKNOWN)
16CD07	10	VS	ARC-CAD	VILLAGE
16CD08	8	QTU-LS	ARC-CAD	VILLAGE
16CD09	12	VS	ARC	VILLAGE
16CD11	13	BS	ARC-CAD	VILLAGE
16CD12	11	PB-LS	CAD	HAMLET; CEREMONIAL; BURIALS
16CD13	11	PB-LS	CAD	HAMLET
16CD16	9	QAL	CAD	HAMLET
16CD17	9-10	QAL	ARC	PREHISTORIC (UNKNOWN)
16CD19	10	SUM	ARC	HAMLET; VILLAGE
16CD23	12	QTP	ARC-CAD	CAMPSITE; HAMLET
16CD24	9	VS-LS	CAD	PREHISTORIC (UNKNOWN)
16CD29	9	QTP-LS	ARC-CAD-HIS	HIS (UNKNOWN); PREH HAMLET
16CD31	10	L/BS	ARC-CAD	CEREMONIAL CENTER; HAMLET
16CD36	11	ACO-LS	CAD	HAMLET
16CD48	13	L/BS-LS	ARC-CAD	CAMP; HAMLET
16CD57	8-9	QTP-LS	ARC	CAMPSITE
16CD100	12-13	ACO	HIS	HISTORIC (UNKNOWN)
16CD101	12	PB	HIS	HISTORIC (UNKNOWN)
16CD102	12-13	PB-LS	CAD	HAMLET
16CD103	11	PB-LS	CAD	HIS (UNKNOWN) PREH HAMLET
16CD104	11	PB	HIS	HISTORIC (UNKNOWN)
16CD105	11	PB-LS	CAD-HIS	HISTORIC (UNKNOWN)
16CD107	8	QTU-LS	HIS	PREH (UNKNOWN); HIS CEMENTARY
16CD108	8	QTU	ARC-CAD	CAMPSITE; HAMLET
16CD109	9	QAL-LS	CAD	CAMPSITE; HIS (UNKNOWN)
16CD110	8	QTU	ARC	CAMPSITE
16CD111	12-13	QTP-LS	ARC	CHIPPING STATION
16CD114	9	QTP-LS	CAD-HIS	PREH; HIS (UNKNOWN)
16CD115	10	VS-LS	CAD-HIS	HAMLET
16CD131	9	QTP-LS	HIS	CEMENTARY
16CD132	8	QTU-LS	ARC-CAD	HAMLET; VILLAGE
16CD138	12-13	QTP-LS	ARC	CAMPSITE
16CD139	12-13	QTP-LS	ARC	CAMPSITE
16CD169	11	PB	CAD	WATER TRANSPORT
16CD172	9	QTP-LS	CAD	PREH HAMLET; VILLAGE
16CD189	11	PB-LS	CAD	LIVING SITE
16CD190	11	PB-LS	CAD	LIVING SITE
16CD191	11	PB-LS	CAD	LIVING SITE
16CD192	11	PB-LS	CAD	LIVING SITE
16CD193	11	PB-LS	CAD	LIVING SITE
16CD194	11	PB-LS	CAD	LIVING SITE
16CD195	11	PB-LS	CAD	LIVING SITE
16CD196	11	PB-LS	CAD	LIVING SITE
16CD197	11	PB-LS	CAD	LIVING SITE
16CD204	8	PB2-LS	CAD	CAMPSITE
16CD209	9	QTP-LS	ARC-CAD-HIS	LIVING AREA

TEXAS

SITE NUMBER	SHEET NUMBER	LANDFORM	CULTURAL ASSOCIATION	REMARKS
41HS12	7	PB2	CAD	UNKNOWN
41HS19	6	VS	ARC	LIMITED USE AREA
41HS25	8	QTU	ARC	LIMITED USE AREA
41HS26	6	QTU	ARC	LIMITED USE AREA
41HS27	6	PB2	CAD	SMALL SETTLMENT
41HS28	6	QTU-LS	ARC	LIMITED USE AREA
41HS30	8	QTU	HIS	DOMICILE
41HS239	7	QTU	ARC	LIMITED USE AREA
41HS385	7	PB2-LS	ARC	UNKNOWN
No. 36	7	QTU-LS	CAD	UNKNOWN
41MR1	2-3	VS	ARC-CAD	LIMITED USE AREA; SMALL SETTLMENT
41MR2	3	LAKE	ARC-CAD-HIS	LIMITED USE AREA; SETTLMENT
41MR3	1	QTU	CAD	SMALL SETTLMENT
41MR4	1-2	LAKE	ARC-CAD	LIMITED USE AREAS
41MR6	2	QAL	CAD	LARGE SETTLMENT
41MR8	3	VS	CAD	LARGE SETTLEMENT
41MR10	2	VS	CAD-HIS	SETTLEMENT; DOMICILE
41MR12	2	QTU	ARC-CAD	LIMITED USE AREA; SMALL SETTLMENT
41MR13	2	LAKE	ARC-CAD	LIMITED USE AREA; SMALL SETTLMENT
41MR16	3	VS	ARC	LIMITED USE AREA
41MR18	3	VS	CAD	LIMITED USE AREA
41MR27	3	QTU	CAD	SMALL SETTLEMENT
41MR29	3	QTU	ARC-CAD	LIMITED USE AREA
41MR30	3	QTU-LS	CAD	LIMITED USE AREA
41MR32	3	VS	CAD	LIMITED USE AREA
41MR33	2-3	VS	CAD	SMALL SETTLMENT
41MR34	3	VS	ARC-CAD-HIS	LIMITED USE AREA
41MR39	5	QTU	HIS	IRON FOUNDRY
41MR40	5	PB2	HIS	IRON FOUNDRY
41MR41	2	QTU	ARC	LIMITED USE AREA
41MR44	5	QTU	HIS	DOMICILE
41MR46	5	PB2	HIS	TOWNSITE
41MR49	5	VS	ARC-HIS	LIMITED USE AREA; DOMICILE (?)
41MR50	2	VS	CAD	LIMITED USE AREA
41MR51	8	VS-LS	ARC-CAD	LIMITED USE AREAS
41UR9	1	QAL	ARC-CAD	LIMITED USE AREAS
41UR11	1	QTU	ARC-CAD	LIMITED USE AREA; SMALL MOUND CENTER
41UR12	1	QTU	ARC-CAD	HEAVY USE AREA; LIMITED USE AREA
41UR13	1	QTU	ARC-CAD	LIMITED USE AREA; SMALL SETTLMENT
41UR14	1	QTU	ARC-CAD	LIMITED USE AREA; SMALL SETTLMENT
41UR15	1	QTU	CAD	SETTLEMENT
41UR16	1	QTU	ARC-CAD	LIMITED USE AREAS
41UR18	1	QTU	ARC-CAD	LIMITED USE AREA; MOUND & CEM

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13. ABSTRACT *(Maximum 200 words)*

The investigation presented in this report provides a geomorphic framework for cultural resources evaluation along the Shreveport, LA, to Daingerfield, TX, reach of the Red River Waterway. The main focus of the study examined the Big Cypress Bayou portion of the proposed navigational project. The Red River segment was evaluated in general geomorphic terms and how its processes affect Caddo Lake and the Big Cypress Bayou reach. The study consisted of two phases. Phase I was a preliminary investigation involving field reconnaissance and geomorphic mapping. The mapping identified three major landforms surfaces, i.e. valley slopes, terraces, and the floodplain. Phase II expanded the study to test site specific stratigraphic and chronological characteristics of different depositional environments. Radiometric dates provide a partial chronology for the geomorphic development of the study area. The archaeological significance of the geomorphic features and history is provided to predict site potential. Correlation of existing archaeological data indicates a landscape affinity by cultural component. Archaic sites are concentrated on the valley slopes and terraces. Caddo sites correlate to historic shorelines and with point bar and natural levee deposits on the floodplain.

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Caddo	Red River

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