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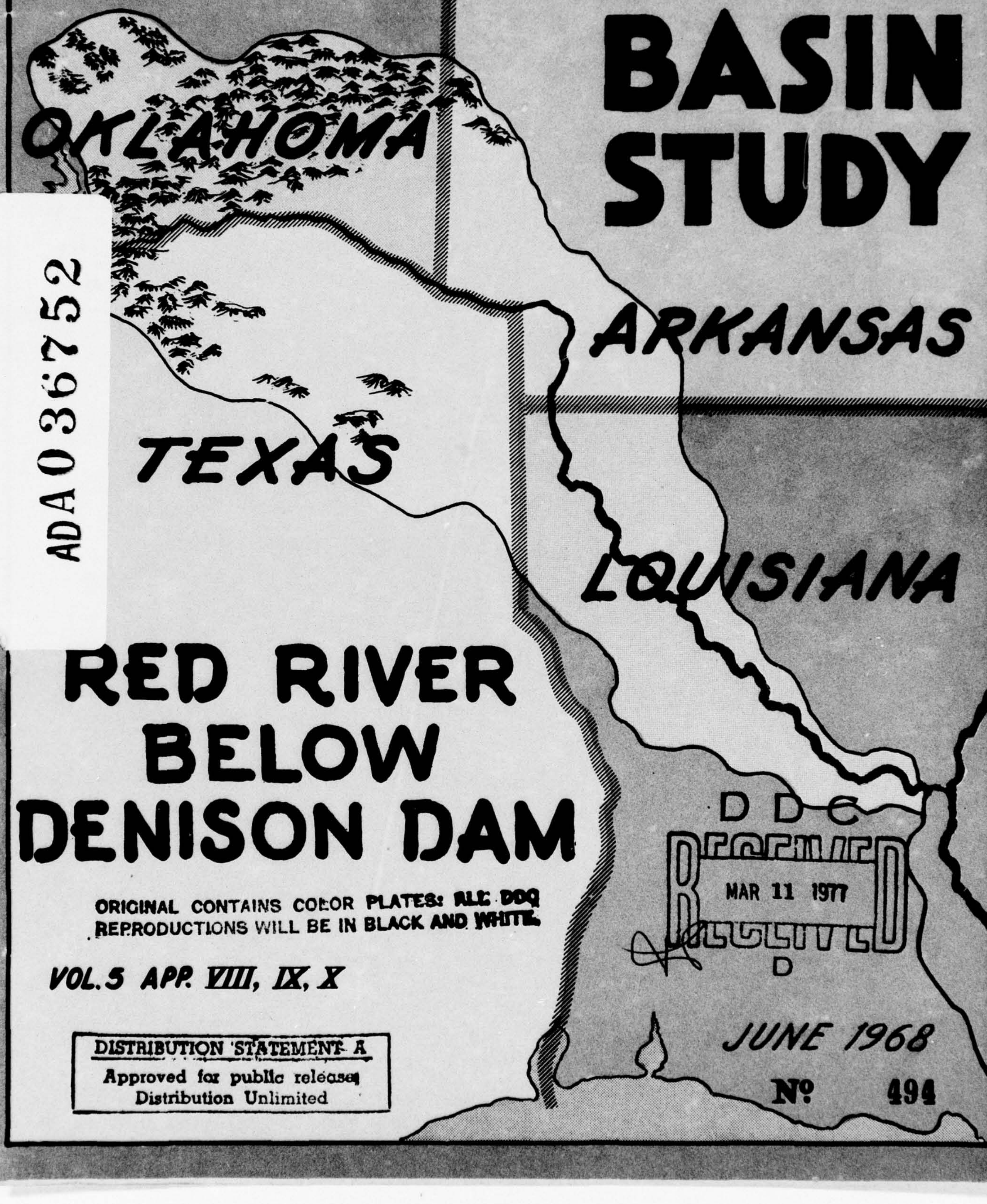

RED RIVER BELOW DENISON DAM

ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE.

VOL. 5 APP. VIII, IX, X

JUNE 1968

Nº 494

RED RIVER BELOW DENISON DAM
ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS
COMPREHENSIVE BASIN STUDY

VOLUME INDEX

Comprehensive Basin Study.

RED RIVER BELOW DENISON DAM
ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS
~~COMPREHENSIVE BASIN STUDY~~

Volume 5.
Appendices VIII, IX and X.

11 Jun 68

12 219p.

APPENDIX VIII

MINERAL RESOURCES AND MINERAL INDUSTRY

ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE.

Prepared by
U. S. Department of the Interior
Bureau of Mines

June 1968

APPENDIX VIII

MINERAL RESOURCES AND MINERAL INDUSTRY

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CHAPTER I - INTRODUCTION

1. AUTHORITY AND PURPOSE

A comprehensive study for development of water and land resources within the Red River Basin below Denison Dam in Oklahoma, Texas, Arkansas, and Louisiana was made in keeping with the basin-planning concept of Senate Document No. 97. The Chief of Engineers was directed to expand the scope of the study of Red River below Denison Dam authorized by resolutions of the Committees on Public Works of the Senate and House of Representatives, adopted September 12, 1959 and February 24, 1960, respectively.

A Coordinating Committee, with the New Orleans District of the Corps of Engineers as the chairman agency, was supported by representatives of Departments of the Interior; Agriculture; Commerce; and Health, Education, and Welfare; the Federal Power Commission; and by representatives of the States of Oklahoma, Texas, Arkansas, and Louisiana.

Appendix VIII, Mineral Resources and Mineral Industry, was prepared by the Bartlesville Office of Mineral Resources in partial fulfillment of an assignment by the Coordinating Committee. Objectives of the appendix are to report on the nature and extent of mineral occurrences and of the mineral industry in the basin, and to determine the manner and scope of involvement of mineral resources and the minerals industry in basin development plans.

2. SCOPE

Appendix VIII presents current and past mineral production data and industry activities for the years 1958 through 1966. The potential of the mineral resources, future technological developments, and resource depletion are considered.

CHAPTER II - PHYSICAL ASPECTS OF THE RED RIVER BASIN

3. GEOGRAPHY AND GEOLOGY

The Red River Basin below Denison Dam (lower Red River basin) covers about 29,500 square miles. All or parts of 56 counties in southeastern Oklahoma, northeastern Texas, southwestern Arkansas, and northwestern Louisiana comprise the area included in this study.

The lower Red River basin includes sections of three physiographic provinces — Central Lowland, Ouachita, and the Coastal Plain. Figure 1 shows the physiographic provinces in the area covered by this report.

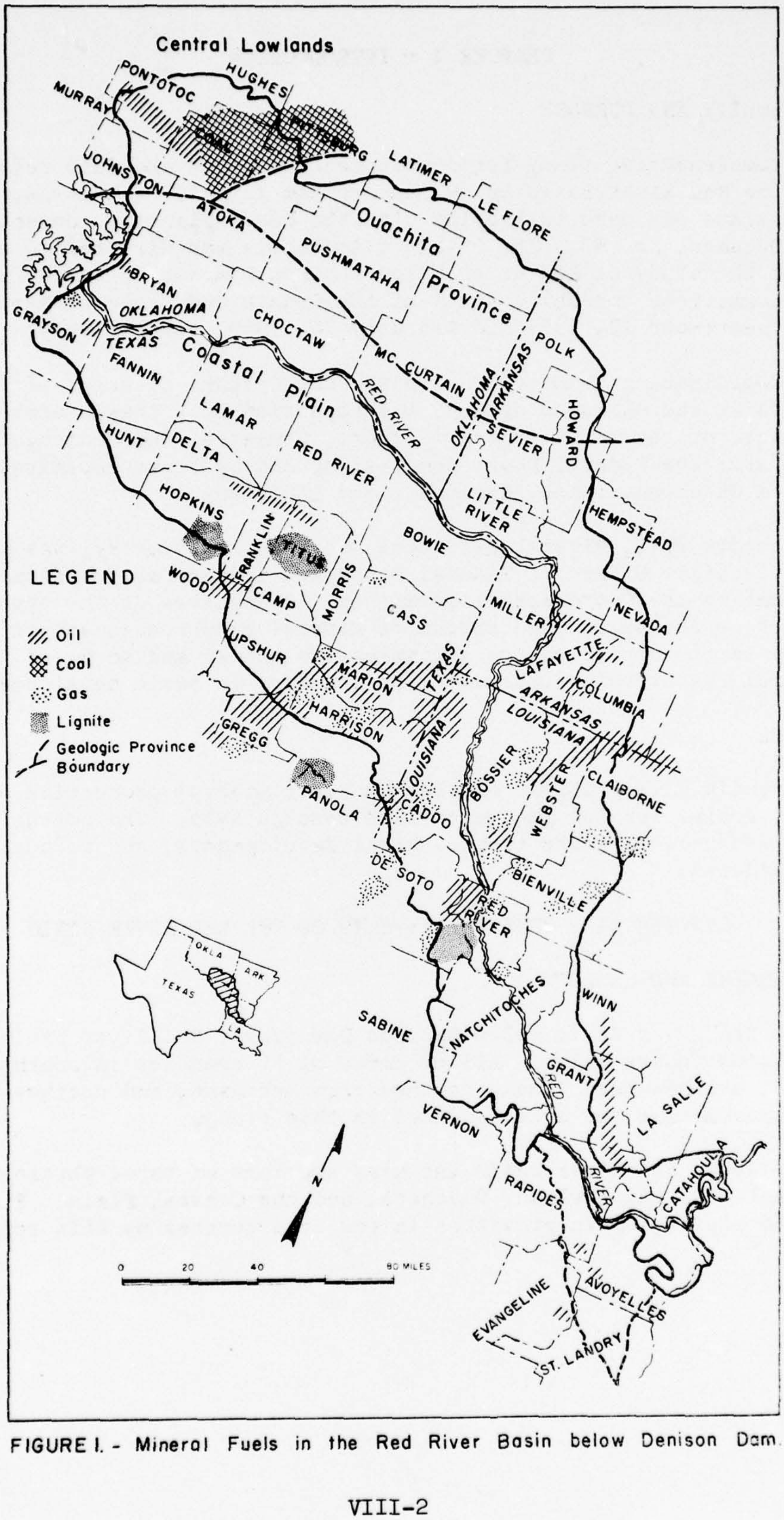

FIGURE I. - Mineral Fuels in the Red River Basin below Denison Dam.

Geologically, Paleozoic formations crop out at the northern end of the basin in Arkansas and Oklahoma, and constitute the Ouachita and Arbuckle Mountains (14).[1/] The formations at the surface consist principally of the Arbuckle Limestone, Bigfork Chert, Arkansas Novaculite, Stanley Shale, Jackfork Sandstone, and Atoka Formation.

The rocks of Paleozoic age extend to the south under overlapping formations of Cretaceous and Tertiary age (tables 1 and 2).

The deposits of Cretaceous age are wedge shaped, thinning to a feather edge to the north against the Paleozoic rocks and thickening rapidly to the south. The Trinity Group, the lowermost group of the Cretaceous System, consists principally of sand, clay, limestone, and conglomerate, and is as much as 5,300 feet thick.

The Woodbine Formation lies above the Trinity Group and is separated from it by as much as 900 feet of the Fredericksburg and Washita Groups. The Woodbine Formation is as much as 600 feet thick and consists chiefly of sand and clay with interspersed lignite. In northeast Texas, units of the Gulf Series overlie the Woodbine and, collectively, are about 3,700 feet thick (table 1).

The rocks of Tertiary age in the Red River basin include, in ascending order, the Midway, Wilcox, Claiborne, Jackson, and Vicksburg Groups, and sandbeds of Miocene age (14).

The formations of Tertiary age crop out in northeast-trending bands, dip to the southeast and east, and thicken down dip. The oldest rocks are exposed in the northern part of the area; progressively younger formations crop out in a southerly direction.

The formations of Tertiary age are composed of a heterogeneous sequence of beds of lignitic sands, silts, and clays. Most of the beds are lenticular.

The Quaternary System alluvial deposits along the Red River are in the nature of terraces formed at different stages of river development; the highest terrace is the oldest and the lowest (the present floodplain) is the youngest. The older terraces serve as sources of sediment recharge to the floodplain deposits.

The alluvium underlying the present floodplain in the Red River is composed of gravel, sand, silt, and clay and grades generally from silt and clay at the surface to sand and gravel at the base. The thickness of the alluvium in the floodplain ranges from about 60 feet in Grayson County, Tex., to about 100 feet in the vicinity of Alexandria, La. (14)

1/ Underlined numbers in parentheses refer to items in the list of references at the end of this report.

TABLE 1.--Generalized stratigraphic column, Mesozoic and Cenozoic Strata, showing stratigraphic units

System	Series	Group	Other units cited in text
Quaternary	Recent		Alluvium
	Pleistocene		Terrace deposits
Tertiary	Miocene		
	Oligocene	Vicksburg	
		Jackson	
		Claiborne	Cockfield Formation Sparta Sand Weches Greensand
		Wilcox[1/]	
	Paleocene	Midway	
Cretaceous	Gulf	Navarro	Nacatoch Sand Saratoga Chalk
		Taylor Marl	Annona Chalk
		Austin	Tokio Formation
		Eagle Ford Shale	
			Woodbine Formation
	Commanche	Washita	
		Fredericks-burg	Goodland Limestone
		Trinity	DeQueen Limestone Ultima Thule Gravel Dierks Limestone Pike Gravel

1/ Eocene and Paleocene in Louisiana.

TABLE 2.--Paleozoic and Precambrian Systems represented in Red River below Denison Dam

System	Formations or groups cited in text	Principal rock types represented in systems
Pennsylvanian	Atoka Formation	Sandstone and shale.
Mississippian	Jackfork Sandstone Stanley Shale Arkansas Novaculite	Sandstone and shale. Conspicuous chert in lower part.
Devonian		Chert, shale, and limestone.
Silurian		Limestone
Ordovician	Bigfork Chert and Viola Limestone Simpson Group McLish Formation Oil Creek Formation Arbuckle Group	Sandstone, shale, chert, limestone.
Cambrian		Limestone, dolomite, shale, and sandstone.
Precambrian		Granite.

The Ouachita and the Central Lowland provinces are characterized by high ridges of chert and sandstone and intervening wide, flat valleys trending in a general east-west direction. Altitudes range from about 600 feet to about 2,700 feet above sea level. The highest point is located in the Ouachita Mountains along the Arkansas-Oklahoma State line (14).

The Ouachita province is bounded on the south by the northern margin of the gulfward-dipping rocks of Cretaceous age of the Coastal Plain. A surface of low relief generally slopes gulfward in the Coastal Plain. Streams have wide, nearly flat floodplains bounded by a series of terraces which in some places are more than 100 feet higher than the present stream channels. Uplands are irregular and rolling to hilly (14).

CHAPTER III - MINERAL RESOURCES AND INDUSTRY

4. SUMMARY

Production of petroleum, natural gas, and natural gas liquids generated most of the value of the mineral output in the lower Red River basin during the period 1958-1966 (table 3) (fig. 1). Cement, sand and gravel, iron ore, and stone provided most of the remaining tonnage and value of mineral production within the counties and parishes of the basin (fig. 2).

The following discourse relates the output and value of individual substances for the period 1958-1966. Source, extent of resources, and future outlook are considered. Lignite is evaluated for its possible future significance in the mineral industry of the basin.

Present and future water problems of the mineral industry are mainly twofold: (1) Protection from encroachment by construction or resulting conditions under the plan of basin development. An example of this is the construction of a levee to protect installations of the Okay plant of Ideal Cement Co. on the east bank of Millwood Reservoir. (2) Availability of water for use in the mineral industry. Water may be used primarily in the extraction and processing of raw mineral materials such as drilling the deposit, as part of the mining process, or washing the product to prepare it for use or further treatment. Preparation of natural gas for use as fuel sometimes involves removal of natural gas liquids. Water is also used in the production of oil and gas in the drilling process and in secondary recovery processes.

TABLE 3.--Value of mineral production in Red River Basin below Denison Dam, 1958-1966

(thousands)

Year	Petroleum	Natural gas	Natural gas liquids	Cement	Sand and gravel	Iron ore	Stone	Clay	Coal and lignite	Salt	Gypsum	Slate and barite
1966--------	440,535	113,312	46,891	24,676	12,551	8,423	6,845	1,011	922	------	882	100
1965--------	403,322	99,062	51,772	22,899	10,194	6,851	5,139	1,048	923	913	841	39
1964--------	401,113	103,157	41,813	23,040	10,246	18,861	6,828	960	824	1,161	850	30
1963--------	389,529	107,816	50,579	22,228	8,057	8,226	5,890	911	1,090	1,253	410	50
1962--------	383,547	103,344	49,420	18,115	7,842	6,523	7,290	833	2,397	1,116	240	-------
1961--------	380,709	96,341	41,490	18,889	7,400	6,504	6,038	1,026	1,700	1,243	224	16
1960--------	363,110	85,239	49,518	16,583	7,700	6,835	3,655	1,046	2,545	1,255	188	-------
1959--------	396,067	70,323	49,104	17,428	8,249	7,872	1,794	786	3,882	1,147	428	-------
1958--------	412,430	72,846	54,574	13,347	9,786	6,207	1,566	458	4,318	1,154	478	-------

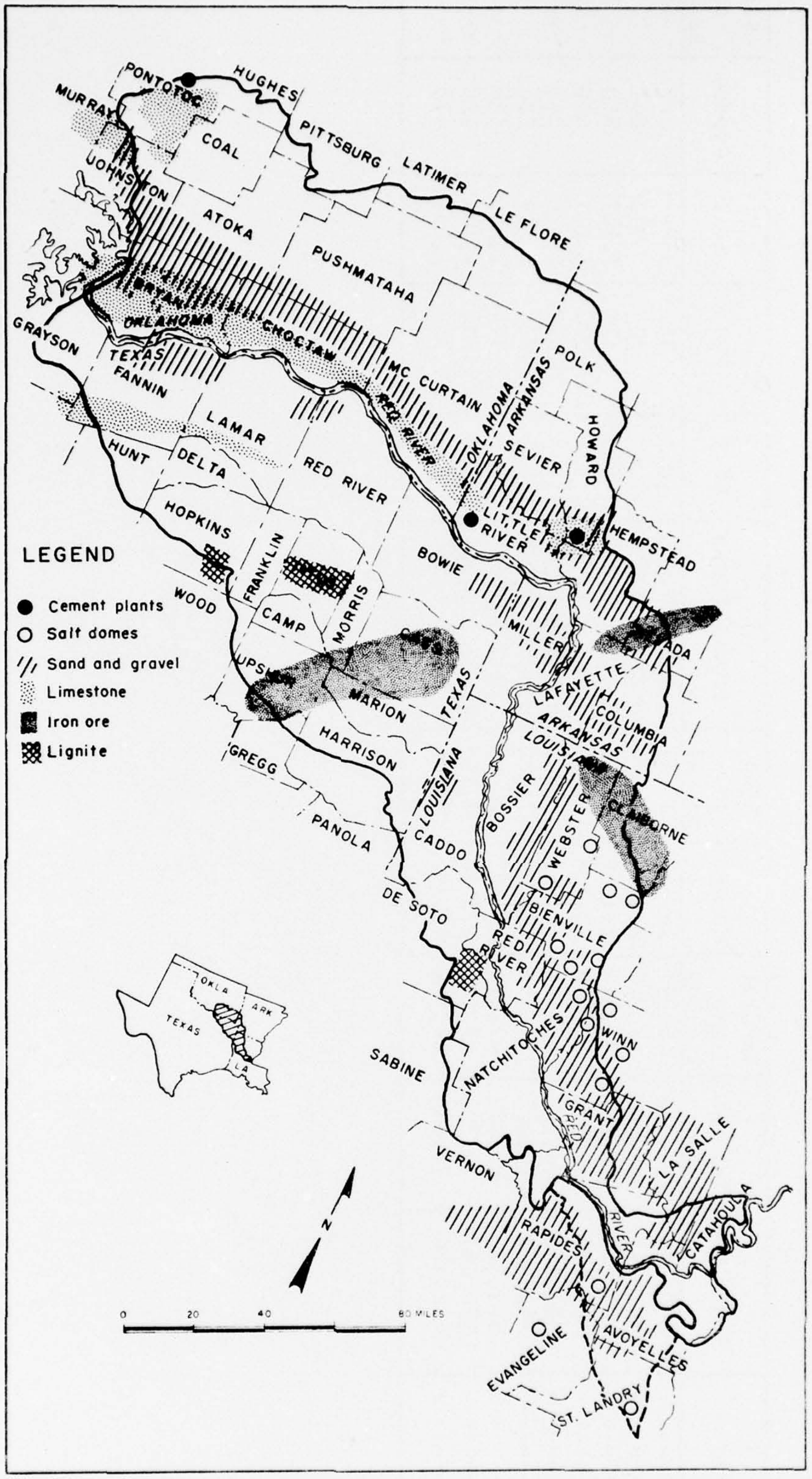

FIGURE 2. - Metals and Nonmetals in the Red River Basin below Denison Dam.

The Bureau's statistics of water use is a result of a national canvass of the mineral industry concerning use of water in 1962 (5) (12). Total quantities of water used annually appear to be relatively large for industry. For example, the mineral industry used 29.6 billion gallons in Harrison County, Tex., in 1962. However, the same year the mineral industry recirculated 29 billion gallons of water in Harrison County. The actual input of new water needed to start and operate the system was only 587 million gallons. Eventual discharge from the water circuits of the mineral industry was 254 million gallons, resulting thus in a consumption or loss of 333 million gallons or 57 percent of the input of new water.

The total input of new water in the mineral industry of the Red River Basin below Denison Dam was about 9.6 billion gallons or 29,500 acre-feet in 1962. The area comprises all counties that lie within or even partially within the drainage basin. Both surface and ground water are included, but not salt water.

The largest input, about 1.3 billion gallons, occurs in Pointe Coupee Parish, La., most of which is outside the Red River Basin. Inputs of more than half a billion gallons, but less than a billion gallons, were reported in Harrison County, Tex., and Bossier Parish, La. Inputs of a quarter to a half billion gallons were required in Hughes County, Tex.; Columbia County, Ark.; and Webster, Claiborne, and Avoyelles Parishes, La. The remainder of the counties and parishes in the Red River Basin had input requirements of less than a quarter billion gallons. Actually the inputs were less than 1 million gallons in each of nine counties located in southeastern Oklahoma, northern Texas along the Red River, and the left bank of the Red River in Arkansas.

Projection of water use to the future cannot be made directly, for there is no time series of industry consumption available in the Red River Basin. Based on the amount of water used nationwide in the mineral industry in 1962, predictions are that in 1985 the industry will have a national total input of new water equivalent to 2½ to 3 times that in 1962. A threefold increase of input water by 1985 would raise the mineral industry's requirements in the Red River Basin to about 90,000 acre-feet per year. When compared with the U.S. Department of Agriculture estimate of maximum requirements for irrigation water in the Red River Basin below Denison Dam of 447,500 acre-feet in 1980, 1,252,300 acre-feet in 2030, and 2,059,700 acre-feet in 2080, quantities of water used by the mineral industry are very small.

Water pollution by the mineral industry within the Red River Basin below Denison Dam has not been a problem. The States have stringent regulations pertaining to sludge pits, salt water disposal, and other waste disposal problems of the petroleum industry. Pollution from acid mine waters, dredging, and washing operations has been minor. The new water quality criteria developed by Texas, Oklahoma, Arkansas, and Louisiana should prevent development of any further pollution problems related to the mineral industry.

5. PETROLEUM AND NATURAL GAS

Petroleum, natural gas, and natural gas liquids account for about 92 percent of the total value of mineral production in the Red River Basin below Denison Dam. Texas and Louisiana are the principal oil, gas, and gas liquids producers in the basin.

The composition of petroleum varies from dark heavy oils with few volatile constituents to green and amber light oils consisting mainly of easily volatile constituents. In its natural underground environment, petroleum is usually associated with hydrocarbon gases which pressurize the liquid petroleum as it comes near the surface to a gaseous liquid state.

Petroleum is used principally as a raw material from which gasoline, kerosene, diesel oil, lubricating oil, fuel oil, and asphalt are separately refined; organic chemicals are also derived for use in medicines, paints, varnishes, and in making synthetic rubber.

Petroleum is recovered from underground reservoirs through drilled wells. When oil-bearing strata are penetrated by a drillhole, the oil may flow to the surface if it is under considerable pressure underground or may require pumping. As the oil is removed from the producing field, the pressure generally declines, and wells that flowed originally may require pumping. When an oilfield nears its final production, 50 to 75 percent of the oil is still underground. Maintaining pressure in the reservoir by returning excess gas or water to the producing formation or flooding it with large quantities of water serve to increase the total recovery of oil from the field. The water pumped into the reservoir is usually salty or otherwise contaminated. This also helps avoid polluting the fresh water streams on the surface.

Crude petroleum is refined principally by distillation processes that involve: (1) Simple distillation, usually called "skimming" or "topping"; (2) vacuum distillation at subnormal distilling temperatures to avoid damaging the distillates, as for lubricating oils; and (3) distillation under high temperatures and pressures to accomplish destructive distillation or "cracking" in the making of gasoline from heavier byproducts of crude oil. Catalysts — substances that promote and accelerate chemical reactions between other substances without being affected themselves — are used extensively in refining processes.

Natural gas is flammable, usually lighter than air, colorless, slightly sweet in odor, and commonly under considerable pressure underground. Impurities may alter the properties of the gas. Natural gas that bears appreciable quantities of hydrogen sulfide is "sour gas" which is unsatisfactory for many uses unless the hydrogen sulfide is removed. Gases containing a relatively small proportion of gasoline vapors are dry gases, while those with relatively large amounts are wet gases. Wet gases while underground are commonly associated with oil, though the two may not be produced from the same well. Gas collected and utilized from a producing oil well is known as "casinghead" gas. The extraction of natural gasoline and other liquid hydrocarbons by collecting the vapors from "casinghead" gas is an important byproduct of the oil production in oilfields of the Texas-Louisiana part of the Red River Basin. Natural gas is used principally for domestic and industrial heating purposes. A substantial amount is utilized in the manufacture of carbon black which in turn is used in manufacturing rubber products. Small natural gas flames deposit black or soot on steel channels from which it is removed at intervals. Natural gas is also used in the petrochemical industry with organic chemicals in making numerous products such as plastics, and great expansion is taking place in the industry as additional methods of breaking down and recombining the constituents of the gases are developed.

Natural gas is transported almost entirely by pipeline, but butane, a liquid petroleum gas (LPG) for use in isolated homes, is transported in pressure cylinders. Natural gas may be used directly as it comes from the pipes or it may be stored for short periods of time in large cylindrical tanks, from which it can be distributed by numerous small pipelines to local consumers. The usual practice is to control the flow of gas from the wells according to the demand. Where gas is collected as a byproduct of oil production, the excess of the immediate demand must either be stored or wasted. Inasmuch as storage above ground in large quantities can be prohibitively expensive, the excess gas is usually pumped back into the underground reservoir from which it came. It thus helps to maintain reservoir pressure and is also available for future use when needed. Gas is also stored underground in depleted reservoirs or specially prepared storage cavities, to be withdrawn at a later date. Thus, the seasonal variations in natural gas consumption can be met by storing excess gas produced during the summer months and withdrawing it during the winter months when demand exceeds supply.

Nearness to markets for many years was the chief factor in determining whether natural gas would be utilized. A network of crude oil lines, natural gas pipelines, and products pipelines service the Red River Basin from its beginning at Denison, Tex., to its end near the Mississippi River in Avoyelles Parish, La. The pipelines distribute the oil, gas, or products to local consumers or to cross-country lines for shipment to the Southwest, Midwest, Northeast, and other parts of the Nation.

6. CEMENT

Cement plants located in Ada, Okla., and Okay and Foreman, Ark., have a combined capacity of 10.3 million barrels of cement a year. Portland cement is the principal product. Annual shipments of cement from the three plants average about 8 million barrels valued at $23 million. The outlook for expansion of the cement industry is excellent and production should increase at a faster rate than that of the increase in population.

Cement has the property of hardening under water and acting as a binder for enclosed substances and bodies. Basically, it is a mixture of limestone or dolomite, silica, alumina, and iron-bearing minerals that has been calcined to a clinker and subsequently ground to a fine powder. The principal cements are "natural" and "portland." Natural cement rock contains limestone or dolomitic limestone with 15 to 40 percent silica, alumina, and iron oxide as an intimately mixed clay or interbedded shale. Portland cement is a prepared mixture blended to about 75 percent calcium carbonate and 20 percent silica, alumina, and iron oxide. Magnesium carbonate, sulfur, and alkalies may comprise the remaining substances. Raw materials (limestone, shale, silica sand, and some form of iron or iron oxide) are mixed dry or ground wet, then calcined. The resulting clinker is finely ground to cement to which raw gypsum is added to act as a retarder in setting. Portland cements are tailored to meet certain constructional needs, by adding a variety of additional substances. The additives to make masonry cements are finely ground limestone and a plasticizer. Finely ground siliceous or aluminous materials such as diatomaceous earth or shale, tuff, and volcanic ash will react with calcium hydroxide and gain cementitous properties. Such substances, including fly ash, are known as pozzolans, and the resulting cements are pozzolan cements.

Cement is used principally in concrete for construction work. Highways, foundations and superstructures of nonresidential buildings including industrial plants, and dams are structures that rely on concrete as the basic high-strength bulk building material. Military construction, sewers, waterworks, public utilities, and oil well drilling create other important markets.

In recent years, the role of concrete in construction has changed markedly. New techniques in casting thin-wall material, manufacturing ornamental precast concrete panels with exposed aggregate, and casting prestressed concrete have created new facing as well as main structural uses. Lightweight aggregate with portland cement is also used in external, internal, and facing construction.

Reserves of raw material for manufacturing cement are as abundant as ordinary rock can be. Estimates made by the Arkansas Geological Survey and Bureau of Mines indicate that the area of outcrop of Annona Chalk in Sevier and Howard Counties, Ark., contains at least 700 million tons. There are no estimates of the amount of Saratoga Chalk or marl in other formations in Arkansas that might eventually be used to manufacture cement.

In Oklahoma, an east-west band of Cretaceous rocks crop out south of the Arbuckle and Ouachita Mountains. The most important cement rock in the area is the Goodland limestone of the Fredericksburg Group. Its outcrop extends from Love County through Marshall, Johnston, Atoka, Bryan, Choctaw, and McCurtain Counties, Okla. In Texas, the Eagle Ford Shale and Austin Chalk of the Upper Cretaceous are present in Grayson, Fannin, and Lamar Counties (18).

Technological problems of the cement industry are generally the same throughout the Red River Basin, namely, that of producing cement of improved quality at lower cost. These problems require additional attention to improve cost of grinding, mixing, firing efficiency, and greater automated handling of materials.

Research is needed to determine the value of volcanic materials in Woodbine and Tokio Formations and Stanley Shale for use as pozzolans.

7. SAND AND GRAVEL

Construction in the Red River Basin below Denison Dam required an average annual output of 6 million tons of sand and gravel valued at about $9 million.

In 1966, the principal producers were in Johnston and Pushmataha, Okla.; Miller and Sevier Counties, Ark.; and Webster and Catahoula Parishes, La. Many large and small plants produce washed and screened sand and gravel throughout the basin and their products are marketed for the most part within the basin or in the adjacent region.

Sand and gravel are unconsolidated granular materials resulting from a natural disintegration of rocks (1). Commercial sand comprises a fine granular material generally less than ¼ inch in diameter whereas gravel is the coarser material, ranging in size from ¼ inch to 3½ inches. The sand in the lower Red River basin is composed predominantly of quartz grains and most of the gravel is composed of quartz, chert, or a mixture of silicates, though residual deposits commonly contain limestone, dolomite, sandstone or other sedimentary rocks as the chief component. Sand and gravel occur in virtually all the counties and parishes of the Red River Basin--as alluvial deposits in the floodplains and beds of rivers and smaller streams, in terrace deposits above present stream levels, or as residual or talus deposits. The talus deposits are composed mainly of gravel on the higher slopes. Inasmuch as sand and gravel are low-priced commodities, commercial production is concentrated largely in deposits that are situated near markets.

The chief use for sand and gravel is as fine and coarse aggregates for concrete in construction of buildings, bridges, dams, and similar structures, in paving, and as aggregates in bituminous mixes for highway and airport construction. Large tonnages of sand and gravel are produced for use as roadstone on secondary roads. Minor quantities of sand are produced for use as molding, grinding, polishing, engine, filter, and railroad-ballast sand.

The outlook for continued high production of sand and gravel is favorable. Building and highway construction will continue to expand in the future with a corresponding increase in demand for sized aggregates. Lightweight aggregates and crushed stone are displacing sand and gravel to some extent for special purposes. Economic and technical problems include encroachment by some suburban communities on the sand and gravel resource and established operations. This results in restrictions on further expansion in those localities, higher transportation costs, and the necessity of moving operations to sites farther from established markets. Rehabilitation of worked-out pits is required by law in some localities. Of the many technical problems confronting the industry, probably the most difficult to solve is that of meeting the various rigid specifications of the consumers.

Despite the problems that must be overcome by the producers in order to meet competition, the sand-gravel industry has grown with the expanding construction industry. The increases in price have been moderate, comparing favorably with that of its principal competitor, crushed stone.

The increasing use of portable plants has become an important factor in the industry, enabling the small producer to move his operation to deposits nearer construction sites and to adapt his plant to production of aggregates that will meet specifications. The markets for sand and gravel products prepared in permanent and fixed plants are generally well established.

8. IRON ORE

The large market for steel products in Texas and the favorable location of deposits near large oilfields and gasfields assure some future interest in East Texas iron ores. Due to the relatively low grade of the ores and the lack of suitable coking coal in the area, future plants probably will utilize direct reduction methods rather than the blast furnace smelting now employed.

The iron ore deposits of the lower Red River basin in Texas are in the northeast part of the State. The main iron ore-bearing area, which is designated "North Basin," lies within the north part of the eastern Texas geosyncline, a troughlike structural feature that borders the Sabine uplift on the northwest. The North Basin, except for the southern end, lies between Sulfur River and Cypress Creek which are easterly flowing streams that join the Red River in Arkansas and Louisiana, respectively.

The area containing the iron ore deposits of present economic value in the North Basin trends southwestward from the northeast part of Cass County into the northwest parts of Marion County, the southeast part of Morris County, and the northeast part of Upshur County. An area of about 15,000 acres in the four counties contains ore of commercial grade and an additional 6,000 acres contains lower-grade deposits.

The most abundant type of ore is limonite, or brown ore. In the North Basin, the ore occurs chiefly in nodular forms or as thin lenticular bodies that are distributed irregularly through the weathered zone in the upper part of the Weches Greensand. The ore-bearing material ranges from 5 to 30 feet in thickness, and the ratio of waste to ore is rarely more than 5 to 1. The best ores occur near the outcrop of the Weches Greensand. Iron carbonate, or siderite, is plentiful in the ore beds, occurring as white or gray, dense nodules on thin beds at or near the ground-water level. The carbonate ores, as mined, contain less iron than the brown ores, but roasting to drive off carbon dioxide will yield a product as high in quality as the best brown ores.

All the iron ore produced in the North Basin is from open-pit mines, and most of the ore requires beneficiation to make it suitable for use in blast furnaces. Virtually all the iron ore mined in the North Basin is consumed in blast furnaces to produce pig iron.

Lone Star Steel Co., the major producer, utilizes ore from the vicinity of Daingerfield, Morris County, where its blast furnace plant is located. Pelletized magnetite from Missouri supplements the local ore to allow capacity operation of the blast furnace.

The estimated iron ore resources of the lower Red River basin in Texas, confined to the limonitic ores of the North Basin, contain 49 million tons of measured ore and 117 million tons of indicated ore having an iron content of 40 to 45 percent (13).

Iron deposits occur in northwestern Louisiana in sufficient concentration to be considered a potential source of iron ore. The area, approximately 20 miles wide by 60 miles long, trends northwesterly in parts of Lincoln, Bienville, Claiborne, and Webster Parishes. Surface indications place another deposit in the vicinity of Rocky Mount and Plain Dealing, Bossier Parish.

The iron ore exposures were mapped, drilled, and sampled in a cooperative project by the Louisiana Geological Survey and Louisiana State University, Geology Department during 1959 and 1960. As the result of this field work, 180 million tons of indicated ore and 135 million tons of inferred ore were estimated. The ore deposits averaged 33 to 42 percent iron.

The iron ore deposits of Louisiana range up to 20 feet in thickness and occur in the Cook Mountain Formation of the Claiborne Group, Eocene Series. Most of the deposits occur at or near the tops of plateaus and ridges under a clay loam overburden ranging from 2 to 20 feet thick. The iron minerals are limonite and goethite overlying glauconite and siderite. Origin of the limonite and goethite is probably the result of weathering of the glauconite and siderite.

The iron-bearing area in Arkansas extends from northeastern Lafayette County northeast into Nevada County (13). Mineralization has occurred in an area of about 90 square miles, averaging 3 feet in thickness — the known maximum thickness is 8 feet. Iron content ranges from 27 percent to 59 percent. The potential tonnage of iron-bearing material in the area is about 100 million long tons with an estimated average grade of 30 to 40 percent. The iron deposits usually are confined to or near the tops of hills. Mineralized zones occur in the Wilcox Formation in a belt approximately 18 miles long and 5 miles wide, trending northeasterly. The iron mineralization occurs as nodules, fragments, and geodes and, in many instances, in well-defined stratified deposits that are interbedded with soft sandstone and shale. Iron minerals are limonite, goethite, and siderite.

The outlook for exploiting the iron ores of Louisiana and Arkansas in the foreseeable future is poor. The market for steel products in the areas does not justify establishment of a steelmaking industry. Technologic gains in beneficiating and pelletizing the Louisiana and Arkansas ore could improve the outlook by making them competitive in cost with other iron ores.

9. STONE

Stone in the Red River Basin below Denison Dam is largely confined to limestone and sandstone, and occurs mainly in southeastern Oklahoma and southwestern Arkansas.

Limestone, widespread and abundant north of the Red River, is quarried extensively for use as aggregate, roadstone, agricultural limestone, and locally for cement manufacture. The Goodland limestone of Cretaceous age is utilized for concrete aggregate and roadstone in Choctaw and McCurtain Counties, Okla. The Viola limestone of Ordovician age is quarried for use in making cement in Pontotoc County, Okla. The Annona Chalk and associated shale of Cretaceous age are used as cement raw material in Howard and Little River Counties, Ark.

Sandstone is quarried from the Jackfork Sandstone of Oklahoma and Arkansas. Crushed sandstone for roadstone and concrete aggregate and broken sandstone for riprap are the chief products.

The abundant limestone and sandstone are ample to supply constructional materials for most future needs in the northern half of the basin; these rocks are the source of stone for the southern half of the basin which has almost no limestone.

The use of sandstone and limestone in heavy construction will increase in proportion to the expected general expansion of the industry. Crushed limestone for cement and aggregate will continue to be the prime market.

10. CLAY

The Red River Basin has large reserves of various clays, some of which are used in large quantities and others in small quantities for specialized uses. Clay is formed by decomposition or disintegration of special rocks through surface weathering, hydrothermal alteration, or chemical action by subsurface waters. Feldspar and feldspathoid minerals and other aluminous silicate minerals in igneous rock commonly yield clay when decomposed. Clay, which is a common matrix in sandstone and limestone and constitutes from less than 50 percent to almost 100 percent of shale, is released by breakdown of cementing agents or by natural disintegration of the rock.

Commonly, clay denotes size of mineral or rock particles being variously defined as less than 1 to 5 microns. Clay also denotes an aggregate of clay minerals (hydrous aluminum silicates) in which the particles are predominantly of clay size, and the substance is commonly plastic when wet. Clay-like aluminum oxides and hydrates are commonly used in conjunction with or as a substitute for clay.

Shale is fine-grained, indurated sedimentary rock that consists partly of clay and tends to form into relatively thin layers. Slate, a product of intense compaction or compression of clay or shale, is a hard rock that can be split into thin slabs. Finely ground shale and some ground slate may exhibit clay-like plasticity when wet.

Various types of tile and other structural materials are manufactured from clay in a wide range of specifications involving dimensional stability, strength, surface texture porosity, permeability, and appearance. The specifications are attained by proper blending of clays.

Clay used for lightweight aggregate in the United States in 1966 amounted to almost 15 percent of total clay sold or used by producers. Any clay, crushed slate, and ground shale that vitrifies and bloats within a limited temperature range when fired can be used. Impurities in clay and shale that may cause bloating and act as fluxes in vitrification are carbon, lime, magnesia, alkalis, alkaline earths, and iron sulfide and oxide, and expelled water of hydration. Expansion is induced by heating the crushed material in a rotary kiln or by sintering a pelletized mixture of clay and coal on a grate that travels through a furnace. Bloating temperatures range from 1,900^{o} to 2,600^{o} F. Expanded materials are either crushed and screened or simply screened to desired sizes.

Most lightweight aggregate manufactured from clay and shale is used in concrete block, precast and prestressed concrete, and as concrete aggregate in constructing multistory buildings. It is also used as loose insulating fill, plaster and stucco aggregate, roofing material, material for septic tank drainage, mulching agent in horticulture, roadway aggregate, and for refractory purposes.

The clay industry in the Red River Basin area is well developed. The types of industrial clays produced are kaolin, fire clay, bentonite, fullers earth, and miscellaneous clays. Both the ceramic and nonceramic clay industries are dominated by a few large producers, and the general trend has been toward expansion of the larger concerns. Special clay industries, such as refractories, are controlled nationally by a few large companies.

Reserves of the various types of clays in the Red River Basin area are considered large. Miscellaneous clays for use in building brick, tile, sewerpipe, lightweight aggregate, and cement are virtually unlimited. Clays suitable for refractories are less available due to the specific properties a fireclay must contain, but techniques for upgrading the refractory clays will effectively keep the reserves ahead of demand.

Problems confronting the clay industry in the Red River Basin are essentially the same as those of the clay industry in general. Intense competition from other construction materials threatens and sometimes replaces structural clay products such as clay brick and tile. Glass, metals, and conventional and special concretes are the principal competing products.

Fire clay and fire-clay-refractories industries have the additional problem of depletion of high-grade fire clay deposits. In some areas where common clays are not readily available or where there is no demand for refractories production, fire clay deposits are being depleted through use in construction products.

Production of clays in general should continue in a gradual but upward trend. The major uses of clay in the Red River Basin area will be for heavy clay products, portland and other hydraulic cements, lightweight aggregate, refractories, and filler.

11. LIGNITE

The Texas and Louisiana portion of the Red River Basin has large resources of lignite. Lignite, or brown coal, is a noncoking, immature variety of coal intermediate between the peat and bituminous coal stage (16). The color may vary considerably from reddish brown to almost black in the better qualities, but the streak is usually brown. Its luster varies from dull to bright, depending on the quality; its texture and hardness likewise are quite variable properties, being hard, firm, and compact in the better grades and soft in those less pure. The original texture of the woody materials is generally well preserved, but in the better grades of lignite this texture may be almost completely obliterated.

The organic portion of lignite contains carbon, hydrogen, oxygen, and nitrogen, the principal element being carbon. In addition to these, there are usually varying amounts of impurities such as sulfur compounds and inorganic mineral matter. When lignite is burned, the sulfur compounds, usually present as the minerals pyrite or marcasite (FeS_2) and commonly occurring in the form of balls, nodules, lenses, flakes, crystals, and microscopic particles, are oxidized to the gas, sulfur dioxide, which gives the bad odor so commonly noted in Louisiana lignites. The mineral matter remains as the incombustible residue known as ash, which is composed largely of compounds of silicon, aluminum, calcium, and iron (16).

When lignite is used as fuel, the heating value is of prime importance. This value, recorded in British thermal units (B.t.u.), is less than that of bituminous coal and usually ranges between 5,500 and 7,500. When lignite is dried before burning, the heating value is considerably greater which indicates the amount of heat necessary to drive off the large amount of moisture so commonly present in all lignites in the natural condition.

The future of lignite production in the Red River Basin depends mainly on the utilization of lignite as a fuel for generating electricity. The principal competitor of the lignite-fired steam-electric plant is the nuclear powerplant.

12. BARITE, SALT, GYPSUM

Barite ($BaSO_4$) serves a wide variety of markets. Chemical inertness, high density, and low cost make barite especially suitable for well drilling needs which is by far its greatest use. Barite is also used as a filler or extender in paint, inks, oilcloth, linoleum, rubber, and other materials. Barite is the raw material used in manufacturing lithopane and various barium chemicals. Crushed barite is used by the glass industry.

Reserves of barite in the Red River Basin are limited to the southwestern part of Arkansas, and those deposits are not currently mined because technological problems forced closure of the operation. The deposits are interbedded sand and gravel, locally cemented by barite, which occurs in upper parts of two low-lying ridges about 2 miles south of Lebanon, Sevier County. The sediments are in the Trinity Group. The deposit, exposed by bulldozer trenches, hand trenches, and test pits, extends over 6 acres to an average depth of 10 feet. One test pit penetrated 15 feet of the deposit. A sample of the lower 11 feet in the test pit contained 25.4 percent barium sulfate. A channel sample from a nearby trench carried 30.5 percent barium sulfate. Development indicates that a total of 150,000 tons of sandstone and pebble ore containing 10 percent barium sulfate is available. The barite deposits are at the southwest end of a string of deposits that extend 12 miles north-northeast into Howard County. The deposits are about a mile west of the Saline River.

Salt (NaCl) is one of the most common nonmetals and plays a part directly or indirectly in preparation, processing, or production of almost everything that man eats, drinks, touches, and sees. The United States has virtually an inexhaustible reserve of salt despite an annual consumption exceeding 31 million tons.

Winnfield salt dome in Winn Parish, La., accounted for production of about 80,000 tons of salt per year from 1933 to 1965. The mine became flooded in 1966 and was abandoned. No other salt mine was operating within the Red River Basin although 15 salt domes are within or very near to the boundaries of the Red River Basin.

Gypsum and limestone formation frequently caps the salt domes and is quarried where the caprock is on or near the surface. In 1966 the only significant quarry in operation was on the Winnfield dome.

Gypsum reserves in the Red River Basin are large enough for many years of operation at a rate greater than reflected by the current production.

CHAPTER IV — GEOGRAPHIC DISTRIBUTION OF MINERAL RESOURCES AND INDUSTRY

13. OKLAHOMA

The Red River forms the southern boundary of Oklahoma. The river flows generally eastward from Denison and leaves Oklahoma at the extreme southeast corner of McCurtain County.

Counties in southeastern Oklahoma included in the Red River Basin below Denison Dam are Atoka, Bryan, Choctaw, Coal, Hughes, Johnston, Latimer, Le Flore, McCurtain, Pittsburg, Pontotoc, and Pushmataha.

Currently exploited resources in order of value are petroleum, natural gas, cement, sand and gravel, stone, natural gas liquids, clay, and coal (table 4).

Low-grade manganese deposits are known at several localities in Johnston and Coal Counties, at the eastern end of the Arbuckle Mountains, and in the Ouachita Mountains in northeastern McCurtain County. However, the deposits are in general too disseminated and/or too small to constitute or capable of economic development.

The continued favorable outlook for the currently exploited commodities in the lower Red River basin counties of Oklahoma is excellent. Reserves of stone, clay, sand and gravel are adequate for many years of operation.

a. Petroleum, natural gas, and natural gas liquids.--Most of the oilfields and gasfields in Oklahoma are outside the boundaries of the lower Red River basin. A small gasfield yields production near Durant in Bryan County. Pontotoc County in the northwestern end of the study area yields substantial oil and gas but, with the exception of the Fitts field, the major oilfields are in the northern part of the county and mostly outside the Red River Basin. Major gasfields in the northern sections of Hughes, Pittsburg, and Latimer Counties are also outside the northern boundary of the Red River Basin. Humble Oil & Refining Co. operates a gas processing plant near Fittstown in Pontotoc County. No other plants or refineries are within the boundaries of the lower Red River basin in Oklahoma.

The production trend in petroleum and natural gas has been generally upward during the past 5 years.

b. Cement, stone, and clay.--Cement processing for the plant at Ada, Pontotoc County, requires a substantial amount of crushed limestone and clay. Atoka, Choctaw, and McCurtain Counties contain limestone quarries that furnish crushed rock for aggregate, railroad ballast, roadstone, and riprap.

Reserves of limestone, clay, and sandstone are virtually unlimited in Oklahoma. Production of cement and related materials will vary with construction activity but should continue a generally upward trend.

c. Sand and gravel.--Operating sand and gravel pits are exploited as near as possible to heavy construction sites. The portable plants are designed for the less permanent type of construction needs.

TABLE 4.--Red River Basin below Denison Dam, Oklahoma, mineral production value by counties, 1966

County	Value	Minerals produced in order of value
Atoka	(1/)	Stone, petroleum.
Bryan	$2,243,730	Petroleum, natural gas, sand and gravel, stone.
Choctaw	(1/)	Stone.
Coal	2,605,382	Petroleum, natural gas, stone.
Hughes	5,496,229	Petroleum, natural gas, sand and gravel.
Johnston	(1/)	Sand and gravel, stone.
Latimer	6,423,722	Natural gas, sand and gravel.
Le Flore	1,680,736	Natural gas, sand and gravel, stone, coal.
McCurtain	874,383	Stone, sand and gravel, petroleum.
Pittsburg	1,398,878	Natural gas, stone, sand and gravel, clays, petroleum.
Pontotoc	20,697,308	Petroleum, cement, stone, sand and gravel, natural gas liquids, clays, natural gas.
Pushmataha	1,421,340	Sand and gravel, stone.
Undistributed	3,394,049	

1/ Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

The Kiamichi River in Pushmataha County is a major source of building gravel, paving gravel, railroad ballast gravel, and filtration sand. Other substantial producers of sand and gravel are in Johnston, McCurtain, and Le Flore Counties. Sand is used in glassmaking and in molding, paving, and building materials.

Reserves of sand are sufficient to meet any future demand. Accessible gravel is not so plentiful. The prosperity and expansion of the sand and aggregate industry depend upon future construction within the marketing area.

Potential resources of high-grade glass sand in the Red River Basin in Oklahoma are in the Oil Creek and McLish Formations of the Simpson Group in Murray, Pontotoc, and Johnston Counties (18). Reserves of sand are large. The sands are of sufficient purity for the manufacture of container and plate glass, and with beneficiation might be made acceptable for optical quality glass. The basal Cretaceous Trinity Sand extends eastward from Johnston County to the Arkansas border, outcropping in Johnston, Atoka, Pushmataha, and McCurtain Counties. The outcrop of the Trinity Sand is from 5 to 20 miles in width but deposits with sand suitable for the manufacture of glass are rare. Much of the Trinity Sand is poorly sorted and contains clay and other impurities.

d. Coal.--Coal production from the Red River Basin is limited to Le Flore County. Pittsburg and Coal Counties have had coal production in the past, but operations currently are idle.

The coal districts in Oklahoma are outside the Red River Basin with one exception. The Coalgate-Lehigh District covers about 400 square miles in Atoka, Coal, and Pittsburg Counties. Two coalbeds, the Lower Hartshorne and the Lehigh, have been mined in the district. The coals from the district are classified as high-volatile bituminous.

Reserve data are not available for the Coalgate-Lehigh District. Production from the Red River Basin counties has trended downward for the past 10 years. The trend probably will be reversed by supplying new markets resulting from recent developments in river transportation.

14. TEXAS

The Red River forms the boundary line between Texas and Oklahoma and part of the boundary between Texas and Arkansas.

Texas counties included in the Red River Basin below Denison Dam are Bowie, Camp, Cass, Delta, Fannin, Franklin, Grayson, Gregg, Harrison, Hopkins, Hunt, Lamar, Marion, Morris, Red River, Titus, Upshur, and Wood, all located in northeast Texas.

Mineral production from the counties has been principally petroleum, natural gas liquids, natural gas, and iron ore (table 5). In 1966 the combined value of oil, gas, and gas liquids was $259 million. Total mineral production value from the basin counties was about $273 million.

a. Iron ore.--The chief metallic resource is iron ore — mostly limonite or brown ore and iron carbonate (siderite). Iron ore currently is mined and used in production of pig iron and steel by Lone Star Steel Co. in Cass County. Reserves of iron ore in the Red River Basin area are 40 million tons measured and 117 million tons indicated. These, of course, are adequate reserves for many years of operating, especially since pelletized magnetite is imported from Missouri as a supplementary raw material for the steelmaking. Iron ore production has increased during the past 2 years and is expected to continue the upward trend.

b. Petroleum, natural gas, and natural gas liquids.--Oil and gas production and processing in the Red River Basin portion of Texas is concentrated in Upshur, Gregg, Harrison, Marion, and Cass Counties (11). A narrow oilfield extends across the northern parts of Hopkins, Franklin, and Titus Counties. The East Texas oilfield covers southern Upshur County and about half of Gregg County. Several smaller fields occur in Marion and Cass Counties.

Petroleum production in the area has been on a general declining trend since 1958. The value of the output has decreased from $227 million in 1958 to $204 million in 1966. Production of natural gas has been on a general increasing trend from $20 million in 1958 to $25 million in 1966. Natural gas liquids output paralleled the natural gas increase.

The possibility that less oil will be found in the future is suggested and crude oil production in the northeast Texas area probably will decrease further by 1975. The downward trend in crude oil output in the lower Red River basin has resulted from a combination of economic and physical factors: (1) Some fields have passed their production peak; (2) output and development are subject to State regulation to prevent overproduction and to protect oil reservoirs; (3) costs of finding new oil reserves are rising; and (4) the oil industry is concentrating its exploratory drilling in more promising parts of Texas and Louisiana, offshore areas, and in foreign countries where oil often is easier to find and cheaper to produce.

Supplies of natural gas appear to be ample although trends in the domestic oil and gas industry caused a drop in the number of exploratory wells drilled (8). Peak production of natural gas probably will be reached about 1990.

TABLE 5.--Red River Basin below Denison Dam, Texas, mineral production value by counties, 1966[1/]

County	Value	Minerals produced in order of value
Bowie	(2/)	Petroleum.
Camp	$3,176,600	Petroleum, natural gas.
Cass	14,842,324	Natural gas liquids, petroleum, natural gas, iron ore.
Franklin	13,781,085	Petroleum, natural gas liquids, natural gas.
Grayson	27,798,085	Petroleum, natural gas, natural gas liquids, stone, sand and gravel.
Gregg	89,832,715	Petroleum, natural gas liquids, natural gas.
Harrison	18,630,930	Petroleum, natural gas, natural gas liquids, coal, clays.
Hopkins	8,916,700	Natural gas, petroleum, natural gas liquids, clay.
Hunt	(2/)	Natural gas, stone.
Marion	5,037,156	Petroleum, natural gas, natural gas liquids.
Morris	(2/)	Iron ore.
Red River	94,320	Petroleum.
Titus	11,851,160	Petroleum, natural gas.
Upshur	10,188,780	Petroleum, sand and gravel.
Wood	60,638,377	Petroleum, natural gas liquids, natural gas, clays, sand and gravel.
Undistributed	7,991,283	

1/ Delta, Fannin, and Lamar Counties are not listed because no mineral production was reported in 1966.

2/ Withheld to avoid disclosing company confidential data; included with "Undistributed."

c. Coal (lignite).--A firm in Harrison County mines and processes lignite to produce activated carbons (9). The only other lignite mined in Texas or Louisiana is in Milam County, west of the basin area, where lignite is burned by a thermoelectric plant supplying power for an aluminum reduction works. Lower Red River basin area counties in which lignite has been produced in the past include Hopkins, Titus, and Panola. Texas lignite production peak of over 1 million tons was reached in the early 1920's. Output has since declined due to competition from oil and natural gas. Lignite has been used as fuel in municipal and private steam powerplants, for the manufacture of producer gas, and as household fuel. By 1946, all the mines in the State were closed, however, the two mines in Harrison and Milam Counties again began operating in the 1950's.

In the future the lignite deposits could become an increasingly valuable industrial resource. Electric power companies have leased large acreages of lignite-bearing lands and plan to mine the lignite as this fuel becomes competitive with natural gas.

The estimated resources of lignite in east-central Hopkins County are 75 million short tons in beds averaging 6 feet thick, containing 40 to 50 percent volatile matter (6). In southern Titus County, estimated resources are 140 million short tons. Workable beds of lignite average 7 feet in thickness and contain more than 50 percent volatile matter. Estimated resources in southern Harrison and northwestern Panola Counties are 260 million short tons of 5 to 10 feet thickness of workable lignite seams, and contain 40 to 50 percent volatile matter.

In the long-range view, increased production of lignite should offset to some degree the decreasing output of crude oil that has been projected for the study area. The initial large-scale use of lignite resources undoubtedly will be in connection with power generation. Other uses, including the production of gas and liquid fuels from lignite, might also become very important before the turn of the century.

d. Stone, sand and gravel.--The principal stone produced in the Red River Basin of Texas is the Austin Chalk. The Austin Chalk, overlying the Eagle Ford Shale in the southeastern part of Grayson County, is composed of white, chalky limestone and interbedded layers of marl and clay that have a total thickness of as much as 1,000 feet. The Ector and Gober tongues of the Austin Chalk occupy parts of Fannin and Lamar Counties. The Pecan Gap and Annona Chalks form a continuous outcrop that extends across Lamar, Red River, and Bowie Counties. Thickness of these chalks ranges from 1 to 120 feet. Reserves of the chalks are sufficient to meet any foreseeable demand.

Sand and gravel deposits are widespread in the drainage basin of the Red River. They occur as Recent floodplain deposits, as terrace deposits of Pleistocene or Pliocene age along the major streams and their tributaries, as unconsolidated sand and gravel deposits capping divides, and as Tertiary or older unconsolidated formations.

Deposits in floodplains, and to a greater extent in terraces, are the principal source of sand and gravel for construction purposes. Current (1966) production is from Grayson, Upshur, and Wood Counties.

Reserves of sand and gravel have not been determined in detail but are considered ample for many years. Consumption will depend upon local requirements which have increased considerably in recent years.

15. ARKANSAS

The Red River enters Arkansas in the southwest section, forming a part of the south boundary between Arkansas and Texas. The river flows generally eastward for about 40 miles and then makes an abrupt turn to the south, forming the east boundary of Miller County, then enters Louisiana as the boundary of Caddo Parish. The Arkansas counties included in the Red River Basin are Columbia, Hempstead, Howard, Lafayette, Little River, Miller, Nevada, Polk, and Sevier, all in southwest Arkansas.

Mineral output from the counties listed, in order of value, is petroleum, cement, natural gas, natural gas liquids, sand and gravel, stone, gypsum, clay, and slate (table 6).

a. Petroleum, natural gas, and natural gas liquids.--Oilfields, refineries, and gas processing plants in Hempstead, Miller, Lafayette, Columbia, Nevada, Ouachita, and Union Counties account for essentially all of the petroleum and related products in Arkansas (Ouachita and Union Counties are east of the Red River Basin boundary). The area within the basin contains both oil and gas. Much of the gas is "sour" and must be processed to remove hydrogen sulfide before it can be marketed. Consequently, a large quantity of byproduct sulfur also is produced. Byproduct sulfur plants are at McKamie, Magnolia, and El Dorado. Five oil refineries with a total crude capacity of 91,000 barrels per calendar day operate in Union and Ouachita Counties, about 30 miles east of the basin boundary. The largest gas processing plant in Arkansas is in Columbia County, three are in Lafayette County, and one each is in Miller and Union Counties. Total capacity as of January 1, 1968, was 432 million cubic feet of natural gas per day.

Production of crude oil has been on a downward trend since 1960 but in 1966 was still sufficient to comprise a third of the State's total mineral production value.

The output of natural gas shows a steady increase over the past 10 years. Output value of natural gas liquids (LP gases, natural gasoline, and cycle products) averaged about $4 million per year during the 1958-1966 period.

At the end of 1966, the estimated proved recoverable reserve of crude oil was 181 million barrels, 10 percent less than at the end of 1965. Reserves of natural gas liquids in south Arkansas gained 10 percent during the same period.

TABLE 6.--Red River Basin below Denison Dam, Arkansas, mineral production value by counties, 1966

County	Value	Minerals produced in order of value
Columbia--------------	$30,492,031	Petroleum, natural gas liquids, natural gas, sand and gravel.
Hempstead-------------	173,360	Sand and gravel, clay.
Howard----------------	6,046,143	Cement, gypsum, stone, slate, clays, sand and gravel.
Lafayette-------------	16,848,222	Petroleum, natural gas, natural gas liquids, sand and gravel.
Little River----------	13,584,212	Cement, stone, clays, sand and gravel.
Miller----------------	6,468,373	Petroleum, sand and gravel, natural gas, natural gas liquids, clays.
Nevada----------------	2,298,853	Petroleum, sand and gravel, natural gas.
Polk------------------	223,507	Sand and gravel, clays.
Sevier----------------	652,000	Sand and gravel.

The outlook for the petroleum in south Arkansas is good despite the decreasing crude oil reserve. Additional oil and gas producing zones are actively sought through exploratory drilling.

Columbia County ranks first in the State in annual production of petroleum and natural gas liquids and second in natural gas output. Eighteen active and six abandoned oilfields are located in the county.

Major pipelines for the transmission of natural gas extend from northern Louisiana to Little Rock, Ark., and pass through Columbia County. Feeder lines from local gasfields in Columbia, Union, and Lafayette Counties join the main lines near Philadelphia and Macedonia in Columbia County.

b. Cement, stone, and clay.--The production value of cement and its related raw materials comprised about 25 percent of the total mineral production value in the Red River Basin in Arkansas in 1966. Cement plants are located at Foreman, Little River County, and at Okay, Howard County. Total production value of cement nearly doubled between 1962 and 1966.

The Annona Chalk of Cretaceous age is quarried over an extensive area and used in the two cement plants. Appreciable quantities of clay that mantle and are interbedded with the chalk are recovered in quarrying the Annona Chalk at Okay and Foreman. The clay is a necessary constituent in the cement-making process. Reserves of chalk and clay are very substantial and will supply the industry for many years.

The other principal use for stone within the basin area is as concrete aggregate and roadstone. Outcrops of the Jackfork Sandstone extend from the Arkansas-Oklahoma border, across the northern parts of Sevier and Howard Counties. Beds are relatively massive, gray, fine to medium grain, hard, and quartzitic. The sandstone, which has a tendency to break from the outcrop in blocks, is relatively hard and brittle, and is suitable for riprap and crushed stone. Reserves which are considered a source for construction materials are virtually unlimited.

Chalk, sandy chalk, and marl, abundant and widespread in thick beds of Cretaceous formations, are potentially valuable for utilization in cement and agricultural limestone (17). Removal of silica from Saratoga chalk by flotation could open a vast new source of raw material for the cement industry.

Most of the clay output is used in processing cement. Miscellaneous clay is mined near Hope, Hempstead County, for use in building brick. Reserves of clay for heavy clay products or for expanding into lightweight aggregate are virtually inexhaustible.

c. Gypsum.--In 1963, Dierks Lumber Co. opened a wallboard plant that utilizes gypsum from a deposit near the east-central part of Howard County. The gypsum occurs in the De Queen Limestone Member of the Trinity Group. Three flat beds of gypsum, separated by thin shale partings, have an average total thickness of about 20 feet. Overburden consists chiefly of clay and shale. Specific estimates of gypsum reserves cannot be made, but the gypsum belt in Howard County extends some 17 miles eastward to the southeastern end of Plaster Bluff in Pike County and total resources comprise many millions of tons.

d. Sand and gravel.--Production of sand and gravel ranks high in the mineral industry of the basin counties in Arkansas. All of the counties have recorded output of sand and gravel, but Miller County ranked first in tonnage and value of the output in Arkansas for 1966. The material is available from alluvial sediments, Quaternary terrace deposits, and residual gravels. Extensive terrace deposits border Day Creek and have yielded much gravel. Beds 3 to 10 feet thick are mined by dragline. Reserves appear adequate for many years.

The output of sand and gravel in Sevier County fluctuates sharply from year to year as dredging shifts to different sites on Little River. Alluvial gravel is also available in the valley of the Cossatot River. Reserves of alluvial gravel of Little River, credited to both Sevier and Little River Counties, are estimated at 25 million tons. Closing of the Millwood Dam on Little River, east of Ashdown, inundated many of the gravel sites. Construction of De Queen Dam and Reservoir on Rolling Fork Creek and Gillham Dam and Reservoir on Cossatot River may restrict natural replenishment of downstream sand and gravel deposits.

Bedded gravel of Cretaceous age is particularly abundant in the south half of Sevier County. The gravel is essentially rounded pebbles of chert and novaculite derived from the Ouachita Mountains to the north. Uses include road construction, railroad ballast, and concrete aggregate. Total reserves and reserves of individual deposits of the bedded gravel are unknown but large. Currently, the Pike Gravel Member, the Ultima Thule Gravel Lentil, the Trinity Group, and the Tokio Formation are mined. The Pike Gravel Member is 20 to 50 feet thick throughout most of its extent. The Ultima Thule Gravel Lentil thickens westward to more than 40 feet along the Oklahoma-Arkansas border.

Thick sand beds in the Tokio Formation, cropping out in 20-foot bluffs in the south-central part of the county, are a potential source of silica sand (17). The sands of the Tokio Formation are mostly quartz with some grains of feldspar, and a few small black grains (probably of magnetite). The high iron and alumina content precludes use of the sand in glass manufacture, but it may be useful for abrasive purposes, for bonding or molding sand, and as runner sand in pig iron casting.

Much sand and gravel has been recovered in the last 40 years from extensive deposits surrounding North Lewisville in Lafayette County. Reserves are probably extensive. In fact, the widespread cover of thick Quaternary gravel and sand hampers exploration and development of other mineral deposits.

Three types of sand and gravel deposits are available in Hempstead County: (1) Terrace deposits found in the uplands in the northern part of the county and near Fulton in the southwestern part of the county are most extensive; (2) less extensive alluvial sands and gravels; and (3) sands and gravels in the basal part of the Tokio Formation, in parts of the Nacatoch Sand, and in the Wilcox Group which are the least extensive.

Sand and gravel is recovered mostly from bars and banks of Little River. Principal production is from a sandbar in the north-central part of the county by dredge pumps. Total reserves of sand and gravel in Little River County are large.

e. Miscellaneous mineral resources.--Several mines were opened before the Civil War to exploit lead and zinc deposits in Sevier County, and intermittent mining continued until 1906. Antimony ore was mined intermittently from 1874 to 1947. The antimony mines and prospects are concentrated in the north-central part of the county. The future prospects for producing antimony are not favorable because exploration and development costs probably would exceed the value of the ore that could be developed.

The Trinity Group in the general vicinity of Lebanon contains lenticular layers of asphaltic sandstone in the section between the Pike Gravel and the Dierks Limestone Members. The greatest thickness of the layers is 1 foot. The asphaltic sands of Sevier County have not been evaluated for utility or quantity.

Iron ore has been mined in southwest Nevada County. Commercially significant deposits are in an area 7 miles long and 2½ miles wide. Iron ore zones occur in the Wilcox Formation. Goethite concretions within a matrix of goethite and clay occur in layers 1 to 3 feet thick. Some ore is exposed but most is interbedded with clayey strata. Overburden is commonly about 9 feet thick. Locally, the topmost iron-bearing bed is separated by 6 to 8 feet of greensand from an underlying ore zone. Iron-bearing nodules or concretions in the lower zone are principally unoxidized to partly oxidized siderite. The ore, reportedly, contained an average of 56 percent iron, no phosphorus or manganese, and very little silica. Most of the ore was shipped to Alabama for smelting and some was used in cement manufacture. The iron oxides and particularly iron carbonate, because of high purity, are considered potentially valuable sources of pigment. Deposits near Rosston and Falcon constitute part of the iron resources of southern Arkansas.

Abundant tuff and tuffaceous sand possibly are useful as natural pozzolans. An area just south of Lockesburg, Sevier County, has been designated as the locus of a buried volcano of Cretaceous age. Phonolite tuff and pumiceous orthoclase trachyte tuff from this volcano and others to the east are spread widely through Woodbine and Tokio Formations. A belt of potential pozzolanic material runs east-west from Horatio to Lockesburg across the center of Sevier County.

16. LOUISIANA

Red River enters Louisiana near the northwest corner of the State and flows south and southeastward to its confluence with Old River, about 8 miles west of the Mississippi River.

The parishes included in the Red River Basin of Louisiana are Avoyelles, Bienville, Bossier, Caddo, Catahoula, Claiborne, Concordia, De Soto, Grant, La Salle, Natchitoches, Pointe Coupee, Rapides, Red River, Sabine, Vernon, Webster, and Winn. The principal mineral industry activities in the Red River Basin of Louisiana are production of the mineral fuels, petroleum, natural gas, and natural gas liquids (table 7).

a. Petroleum, natural gas, and natural gas liquids.--Oil in commercial quantity was discovered in northern Louisiana in 1906 near Caddo Lake when an operator drilled to a depth of 1,556 feet in the Upper Cretaceous rocks of the Sabine uplift (11). After this discovery, oil development in northern Louisiana was extended to Red River, De Soto, Sabine, Claiborne, and Webster Parishes by 1935. Discovery of the additional fields resulted in a rapid increase in rate of oil production. In 1966, the major oilfields within the Red River Basin in Louisiana were, in order of output, Caddo-Pine Island in Caddo Parish, Cotton Valley in Webster Parish, Pendleton-Many in Sabine Parish, Haynesville in Claiborne Parish, Lake St. John in Concordia Parish, and Black Lake in Natchitoches Parish. Total production from these fields in 1966 was 16.5 million barrels of crude oil. Petroleum reserves in north Louisiana totaled about 2 billion barrels on December 31, 1966.

The production of natural gas in most fields of northern Louisiana is associated with that of petroleum. Parishes with major production within the Red River Basin in 1966 were Bossier, Webster, Bienville, De Soto, Claiborne, and Caddo. Between 1960 and 1966, the value of natural gas production from the basin parishes has averaged $82 million a year. Natural gas liquids (LP gases, natural gasoline, and cycle products) are recovered in gas processing plants concentrated in Webster, Bossier, Claiborne, and Caddo Parishes.

TABLE 7.--Red River Basin below Denison Dam, Louisiana, mineral production value by parishes, 1966

Parish	Value	Minerals produced in order of value
Avoyelles	$4,472,578	Petroleum, natural gas, natural gas liquids.
Bienville	10,546,687	Natural gas, petroleum.
Bossier	32,284,023	Natural gas, petroleum, natural gas liquids.
Caddo	32,960,711	Petroleum, natural gas, natural gas liquids, clays.
Catahoula	12,689,962	Petroleum, sand and gravel, natural gas.
Claiborne	27,826,177	Petroleum, natural gas, natural gas liquids.
Concordia	25,983,719	Petroleum, natural gas.
De Soto	11,096,085	Natural gas, petroleum.
Grant	473,310	Petroleum, sand and gravel, natural gas.
LaSalle	23,130,740	Petroleum, natural gas, sand and gravel.
Natchitoches	6,981,203	Petroleum, natural gas, clays.
Pointe Coupee	14,679,283	Petroleum, natural gas, natural gas liquids, clays.
Rapides	7,465,537	Petroleum, sand and gravel, natural gas, clays.
Red River	1,449,752	Petroleum, sand and gravel, natural gas.
Sabine	16,136,833	Petroleum, natural gas, natural gas liquids.
Vernon	8,000	Sand and gravel.
Webster	33,773,362	Petroleum, natural gas, natural gas liquids, sand and gravel.
Winn	3,417,430	Petroleum, stone, gypsum, natural gas, sand and gravel.

According to the American Petroleum Institute, reserves of petroleum, natural gas, and natural gas liquids on December 31, 1966, amounted to 5.4 billion barrels of crude oil, 83.7 trillion cubic feet of natural gas, and 2.3 billion barrels of natural gas liquids. Proved recoverable reserves in the State as a whole attained new highs in 1966 despite record production rates. Reserve data is not available for separate parishes or sections of the State. The ratio of reserves to production in 1966 were 8 to 1 for crude petroleum, 16 to 1 for natural gas, and 31 to 1 for natural gas liquids. The continued search for oil and gas, together with improved recovery techniques, should maintain the potential proved reserves at about the present level during the foreseeable future.

b. Sand and gravel.--Sand and gravel composed mainly of chert, quartz, and related silica rocks occurs widely in northern Louisiana as Pleistocene terrace and Recent alluvial deposits. In terms of both tonnage and value, sand and gravel (collectively) is the second most important mineral commodity (oil and gas being first) produced commercially in the Red River Basin parishes. The annual output from 1960 through 1966 has averaged 2.6 million short tons valued at about $3.3 million. A predominant part of the current production of washed and screened products is sized gravel.

Commercial sand and gravel washing and screening plants are distributed throughout. A major part of the output of sand and gravel is produced by large-scale operations from deposits near the larger population centers of Shreveport and Alexandria in Caddo, Webster, and Rapides Parishes.

The sand and gravel reserves in the basin parishes are estimated to be about 100 million tons. The most extensive deposits of mixed sand and gravel occur in Webster and Rapides Parishes.

c. Stone and gypsum.--Stone production from the Louisiana part of the Red River Basin consists of anhydrite mined in Winn Parish. The Winnfield salt dome is overlain, in ascending order, by 300 feet of anhydrite, 5 to 30 feet of gypsum, and 50 to 75 feet of crystalline limestone. The anhydrite is quarried for use as concrete aggregate and roadstone. Minable reserves in the area where the limestone and gypsum have been quarried are sufficient to sustain operations for many years.

The gypsum, exposed by limestone operations, has been quarried since 1950 for use as a retarder in portland cement; about 1½ million tons of gypsum has been mined. Reserves are not available but are believed adequate to sustain the current output for many years.

d. Clay.--Northern Louisiana contains an abundance of clay in Tertiary and Quaternary Formations and workable deposits occur in most of the Red River Basin parishes. Common red-firing clay is predominant, though semi-refractory buff-firing clays occur in some areas. One deposit of sandy kaolin has been found.

Common red building brick is fired from Wilcox clay in Bienville Parish and Natchitoches Parish and from Recent alluvial clay in Rapides Parish. Buff-colored facebrick is made from semi-refractory Wilcox clay in Caddo Parish. Since 1948, lightweight aggregate has been produced at Alexandria, Rapides Parish, from alluvial clay.

A deposit of sandy kaolin in the northwest corner of Vernon Parish has been delineated by drilling. The clay material, composed of highly colloidal white clay (45 percent) and white sand (55 percent), may be suitable when blended with other clays for the processing of refractories, porcelain, and dinnerware. The deposit averages 10 feet in thickness and covers at least 10 acres.

The reserves of semi-refractory and bloating clays in the productive areas have not been determined but are probably adequate for more than 10 years at the present rate of mining. Reserves of clay suitable for making common building brick are virtually unlimited in the Red River Basin parishes.

e. Salt.--Salt has been produced sporadically on a small scale in northern Louisiana since 1805 by evaporation of brines, from brine springs, and shallow wells. Salt domes are known to occur northeast of the Red River in Webster, Bienville, Natchitoches, and Winn Parishes. Domes are also known south of the Red River in Rapides, Evangeline, and St. Landry Parishes. A salt mine, opened in the Winnfield salt dome in Winn Parish in 1930, operated until the mine flooded in 1966.

f. Lignite.--All of the exposed and potentially commercial lignite in Louisiana is restricted to the Tertiary System and crops out in the northern half of the State. Most of the deposits occur in the Eocene Series, especially in the Midway, Wilcox, and Claiborne Groups. The most important deposits, however, occur in the Midway and Wilcox Groups in northern half of Sabine and Natchitoches, southwestern Bienville, southern Bossier, Caddo, De Soto, and Red River Parishes.

In general, the lignite occurrences in the Midway Formation are concentrated in De Soto Parish. The occurrences range from 1 to 4 miles west of the Red River.

The most extensive and thickest of the lignite strata in Louisiana crops out in the Dolet Hills in the southeastern part of De Soto Parish, 12 to 15 miles southeast of Mansfield (16). The bed is continuous between outcrops in secs. 3, 4, 6, and 7, T. 11 N., R. 11 W., and sec. 2, T. 11 N., R. 12 W., and sec. 26, T. 12 N., R. 12 W. The outcrops indicate that the stratum can be traced for a distance of about 6 miles in an east-west direction and about 2 miles in a northerly direction. Oil well logs indicate that the downdip extent of the bed to the south and west of the outcrops is at least 2 miles. At the outcrop, the lignite is 6 to 7 feet thick, and well logs 2 miles from the outcrop indicate the stratum is 4 to 12 feet thick.

The bed dips to the south and west from the outcrops resulting in a thickening of the overburden in that direction. The sand section that immediately overlies the lignite bed has a maximum thickness in a few places of 125 feet downdip.

In the early 1900's, several attempts were made to mine the lignites, but the operations were economically unsuccessful. The yielding nature of the overlying sands made underground mining extremely difficult because much timbering support was necessary. Similar operations today would face the same problems. Locally, strip mining would be more satisfactory. Strip mining would be limited to places where overburden depths were less than 100 feet.

The information concerning the lignite deposits of Louisiana suggests that it has little apparent use at this time. Louisiana has an abundance of gas and oil which overshadows any possibility of the lignite being used as a fuel in the foreseeable future. It may have importance in chemicals that might be derived from it and, if this possibility materializes, lignite would be produced in large quantities.

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RED RIVER BELOW DENISON DAM
ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS
COMPREHENSIVE BASIN STUDY

APPENDIX IX

ARCHEOLOGICAL, HISTORICAL, AND NATURAL RESOURCES

Prepared by
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under the sponsorship of
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June 1968

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SUMMARY

Archeologically, the Red River has been most noted for being the heartland of the Caddoan archeological area where Southeastern culture reached one of its peaks of achievement in late prehistoric times. Here, complex burial ceremonialism reminiscent of that of Meso-America is evidenced. But the Red River Basin offers much more of archeological importance. Over a span of some 10,000 years, Indian occupation occurred in all ecological zones and on most land surfaces, at times rather intensively; the once widespread evidence of this occupation still remains as a recoverable resource.

Unfortunately, scientific research in this area has been spotty and in many cases centered on the mound and ceremonial centers of the late prehistoric peoples. Around the beginning of the 20th century, George E. Beyer of Tulane University and Clarence B. Moore of the Philadelphia Academy of Natural Sciences conducted separate and unsystematic investigation programs into mound sites along the Red River. Moore is famous for traveling up the river by steamboat, starting from its juncture with the Mississippi and proceeding to 37 miles above Fulton, Arkansas, recording and probing over 40 sites.

The decades between 1920 and 1940 witnessed increased scientific investigations, beginning with the work of Gerard Fowke of the Smithsonian Institution. During this period Walker, Setzler and Ford worked several mound groups near the mouth of the Red, with Setzler administering a WPA program of research in Louisiana. Spanning this same period, the University of Texas was conducting excavations in the east Texas drainages of the Red. As in Louisiana and Arkansas, the Texas work was almost exclusively confined to excavations of large Caddoan mounds and cemeteries, all of which occurred relatively late (ca. 900-1500 A.D.). During the 1940's in Oklahoma, a series of extensive camp and village sites were dug in LeFlore and McCurtain Counties, part of the basin area.

Recent impetus has been given to research in the basin by the Inter-Agency Archeological Salvage Program. Except for Louisiana, where no Inter-Agency Salvage programs have been inaugurated to date, all other areas of the basin have seen archeological survey and excavation in specific reservoir sites. The work is continuing and has resulted in a considerable accumulation of broader knowledge about the basin's archeological resources, including earlier, non-ceremonial sites and complexes. Water development projects investigated thus far include: Millwood and Gilham Reservoirs, Arkansas; Texarkana, Pat Mayse, Cooper and Lake O' the Pines Reservoirs, Texas; and Hugo, Pine Creek and Broken Bow Reservoirs, Oklahoma.

A general picture of some 10,000 years of Red River Basin history is emerging. However, only a bare outline is known of changes, interactions and influences, some of which, like the introduction of agriculture and pottery, were to have far-reaching effects. Meager and scattered evidences of the early hunters of big game have been recovered. More is known of the occupation of the basin by Archaic peoples; evidence from temporary camp sites indicates a greater use of surrounding natural resources and a response to the slow but widespread climatic and ecological changes which were occurring. Comparatively more is known about the following Formative period which extends to historic times. During this period increased population, semi-permanent village life, and a more stable and permanent food supply allowed for a complexity of social and religious life. In this later period a great diversification and elaboration is reflected throughout the basin, with centers in the Alluvial Valley of the Red, the Caddo area of the central portion of the basin, and the Caddo-Plains area of the Texas-Oklahoma portion.

For an area which holds the key to much knowledge of the Southeast as a whole, it is surprising that more concern has not been generated for the preservation or salvage of information. Despite the amount of research being conducted by both professional and amateur investigators, the fact remains that these important and non-renewable resources are disappearing at a greater rate than can be recorded. The total loss is being augmented by pothunting, agricultural practices, water development projects and industrial expansion.

The potential for archeological research in every area of the basin is tremendous, not only for solving chronological problems of human social development but for important ecological problems as well. A review of proposed projects included in the basin development plan indicates that most have either known or potential archeological or historical resources. Viewed against the background of previous archeological work and the acceleration of site destruction in general, the recovery or preservation of these non-renewable resources should be an integral part of any comprehensive development plan.

APPENDIX IX

ARCHEOLOGICAL, HISTORICAL, AND NATURAL RESOURCES

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SECTION I - INTRODUCTION

This assessment of the natural, archeological and historical resources of the Red River Basin is being made with three objectives in mind: to review the history and present knowledge of the prehistoric and historic occupation of the Basin; to comment upon the potentialities of and necessity for salvage, preservation, development, and interpretation of these particular resources; and to evaluate the possible problems and dangers to these resources inherent in a water resources development plan such as is being considered by various Federal agencies and the States in the current study.

Since the days of Theodore Roosevelt, conservationists have championed the cause of preservation and/or conservation of the Nation's natural resources. "Save the Redwood Forest; Save the California Condor." The hue and cry has had public appeal, and the public conscience has heeded the call. The conservationists have divided natural resources into two groups: those which, in the course of natural events if left alone will reproduce themselves (like the Redwood or the California Condor); and those which cannot reproduce themselves (at least not within "reasonable" time periods--like coal or natural gas). These two groups have been termed renewable and non-renewable resources.

When viewed in these terms, the archeological and historical material and information of the Red River Basin are non-renewable resources. Once an Indian site is churned up by the plow or the pothunters; once a Civil War embankment is included in a levee, its original nature and its cultural and scientific value has been destroyed. Since these resources are often our only records of past human activity, if some effort is not made to salvage and make permanent record of the information in these sites, it is like tearing the pages from a history book, a book only one copy of which remains. All that can ever be known of the way of life of the Indians who inhabited North America before European contact must come from the ground; valid interpretations of the material found in the ground can be made only through scientific excavations. Non-scientific excavations or disturbances of the material in the ground by any means, destroys this resource.

It is not within the realm of possibility to preserve every scrap of broken pottery, or even every Indian site. It is within the realm of possibility to make every effort to salvage information and material when it is known that they will be destroyed. The Inter-Agency Archeological Salvage program was developed on this premise and has proved the worth of its endeavors many times over in the past few years. The potential for interpretation of the recovered portions of this resource has not been fully developed, outside of federally owned monuments, national parks, and other areas of chosen national importance. Equally significant and "appealing" areas and information await recognition and development on the local and the State level.

Any Comprehensive Study should take into consideration the development and interpretation of the significant portions of these non-renewable resources--our country's prehistoric and historic heritage.

The nature, kinds, and amount of information contained in this report must be considered with the fact in mind that it has been prepared in six weeks' time. The four archeologists who provided data for their particular states, had, at the most, six weeks from the time they were asked to help, until the report was to be received at the University of Arkansas Museum--six weeks to review and assess their area and to study the effect of the particular water projects proposed. The Comprehensive Basin study has been underway for several years by the Corps; it is unfortunate that the present study of the archeological and historical resources could not have been inaugurated earlier and made under less pressure of time. However, that the government agencies recognize the importance of such resources by including studies such as this in their planning is indeed encouraging. Despite the hasty nature of the review, we feel it fills a definite place in the Comprehensive Basin study. A more detailed analysis and review of each watershed in the Basin is being prepared and will be deposited with the National Park Service.

SECTION II - NATURAL SETTING AND ENVIRONMENT

1. INTRODUCTION

There are two phenomena concerning the natural resources and environment of the area encompassed by the Red River Basin as defined in this study, which are of significance and interest to an assessment of the area. The first is that, although there are no natural phenomena of National importance (such as another Grand Canyon), there are locally extremely important and significant features which may be affected by a Comprehensive Basin development plan. Pockets of floral communities and certain species of animals exist in restricted areas. They are not of interest because they are "unique", but because they are surviving remnants of the "original" natural environment.

Cutting and draining, particularly in the bottom lands, have eliminated certain natural environments; where these have been preserved, the trees, flowers, birds, and animals which remain become "curiosities" because they no longer exist elsewhere in the area. There are two excellent examples of this phenomena: in Beaver Bend State Park, McCurtain County, Oklahoma there is a beautiful cypress forest; at Grassy Lake, a privately-owned preserve in Hempstead County, Arkansas, there are numerous alligators as well as other unusual plants and animals (see Section V).

The cut over areas are in second and third growth; the drained bottom lands and swamps are farmed or in pasture. The River itself, has changed its channel many times. The natural habitat of many plants and animals has also changed, caused them to disappear from the area. Little remains of the "natural" environment as it was in aboriginal times when man had few tools with which to "improve" on nature.

The second phenomena of interest is that, as a whole, the Red River Basin remains a predominately rural area, supporting small farmers, cattle raising, and lumbering. The area included in the Basin has but three urban concentrations, two of them directly on the Red River itself: Alexandria and Shreveport, Louisiana, and Texarkana, Arkansas-Texas. The remainder of the Basin is distinctly rural in character. Its historic and recreational resources constitute its principal attractions to "outsiders."

Aside from these two factors, which hold for the entire Basin, the physiography and local environmental of the Basin differs greatly as one proceeds from west to east--from Denison Dam to the mouth of the Red River.

2. PHYSIOGRAPHY

The Red River Basin is wholly within the Gulf Coastal Plain physiographic province, except for a small portion of the area north of the River where the Ouachita Mountain province extends from northeast to southwest into the Basin. In the Ouachita Mountain province, the tributary streams of the Red run south in relatively narrow, sometimes steep dissected valleys. In the northwest corner of the Basin, in Oklahoma, there is a small section of Cross Timbers country, where there are rolling sandstone hills, densely covered with scrub oak growth. North of the River in Oklahoma and in Arkansas, the Gulf Coastal Plain topography is interspersed with sections of natural prairie land. To the south of the River in Texas, the "Blackland Prairie" stretches from west to east, essentially disappearing, however, where the major eastward-flowing tributaries (the Sulphur River and Cypress Bayou) have cut and eroded major portions of the Basin. East Texas, then, is no longer flat park land, but rolling timbered country. The same is true in northwest Louisiana, where streams, flowing south into the Red, run through gently rolling forested land, the "hills" of northern Louisiana.

As the alluvial valley of the Red River is reached, in Louisiana, the country is flat. The natural levees and backswamps generally are covered with timber--in fact, until the last few years, as little as 20% of the land in the alluvial valley had been permanently cleared for agriculture or settlement. The lower portions of the Red crosses the wide alluvial plain of the Mississippi River. Just south of Alexandria the Red had deposited an unusual amount of sediment, for at one time, when the Mississippi was in a channel far west of its present course, the Red entered the Mississippi in this area.

3. NATURAL GEOGRAPHY

Three major tributaries of the Red River are wholly included within the basin; however, for the purposes of this report, the Ouachita - Black drainage has been excluded. The three major waterways are the Little River in Arkansas, the Sulphur River in Texas and Arkansas, and Cypress Creek in Texas and Louisiana (where it is called Twelvemile Bayou).

The valleys of the streams extending into the Ouachita Mountain province, or the bordering rolling hills, are usually covered with oak-hickory-pine forests. The valleys of the Sulphur and of Cypress Bayou and other smaller tributaries running from the south to the north and east into the Red River generally flow through timbered country, in wide terraced valleys.

The gross differences which can be seen in vegetation in the Basin as a whole can be largely (though not entirely) accounted for by changes in rainfall as one moves from the western to the eastern portion of the Basin. In the western portion, in Texas and Oklahoma, annual precipitation is slightly over 40 inches; when the four-state-corner area is reached, average annual rainfall reaches 50 inches or more, and the growing season averages 240 days (April-September). In the eastern area rainfall generally comes in the winter and spring, adding to the excellent potential for abundant vegetation.

To the differences in climate, forest cover, and topography, can be added considerable difference in the faunal population, particularly prior to settlement by Europeans. Bison were found in herds on the prairie and park land of the western Basin; deer, bear, and puma and wolves roamed the forested mountains. The wild turkey was common in the Ouachita Mountains, and common small mammals still found today were abundant throughout the area (squirrels, raccoons, opposums, rabbits). In the swampy backwaters and deep forests of the central and eastern Basin, snakes of several poisonous and non-poisonous varieties abound. Fish, too, are abundant, particularly in those areas which have been artificially impounded. In the southern portion of the valley, waterfowl are found by the thousands in season, for they cross the eastern and central portion of the Basin on their migrations.

4. MODERN HUMAN GEOGRAPHY

As has been mentioned, except for the urban areas of Alexandria, Shreveport, and Texarkana, the Red River Basin has now and always has had, essentially a rural economy. Because the river valleys were (and are) subject to periodic overflow, little of the unterraced flood plain was used for farming in the past--although now (especially in Louisiana) much of this land and the back swamps as well are being cleared and drained for soy beans and rice cultivation. Use of the land for pasture, and of the forests for lumber and pulpwood is most common in all of the Basin except as it narrows toward its mouth in Louisiana, where there are marginal communities of fisherman-trappers, and stock raisers.

Back from the flood plains, cotton farming was common--of the plantation variety in Louisiana, of the small farmer type in Arkansas and East Texas. The Arkansas and extreme southeastern Oklahoma portion of the Basin has always been economically poor, although lumbering and cattle raising are prevalent. In the past twenty years, however, much land has been put into the soil bank, and even the small farmer is disappearing.

Industry is playing an increasingly important role in all areas of the Basin, as large firms bring branch factories to the small towns (especially those with water resources available). However, possibly the fastest growing "industry" in terms of the economy, is recreation, associated primarily with the development of water control projects but also possibly because of locally attractive natural scenery as in Beaver Bend State Park in Oklahoma and Queen Wilhelmina State Park in Arkansas. Lake O' the Pines, Caddo Lake, Lake Texarkana, and Millwood Reservoir are all impounded lakes providing recreation facilities for rural and town populations alike, particularly for those who like to fish.

Perhaps the greatest influence on the use of the land within the Red River Basin is the development by Federal and State agencies. Changes are already occurring in the economy, particularly in terms of reclaimed land available for agriculture, and in terms of recreation and resort facilities. As the River is stabilized, the chance of flooding lessened, lakes created, and channels made permanent, changes, as yet unforeseen, in the use of the land may come. Since much work on the River itself has been completed in Louisiana, clearing operations are much in evidence along the alluvial valley. Here thousands of acres of former levee and back swamp lands already have been converted for the production of beans.

Approximately 150 river miles of the Red River are to be eliminated with the realigning of the channel--this in itself is a major change in land use and in the potential use of the River, its tributaries, and the Basin. The advantages and potentialities for human use of the resources of the Basin is great; the preservation of equilibrium for the floral and faunal populations must be kept in mind; and the consequences of environmental changes to all ecological relationships within the Basin must not be ignored.

SECTION III - HISTORY OF ARCHEOLOGICAL WORK

1. INTRODUCTION

There is a startlingly similar ring to the history of archeological research in various parts of the Red River Basin. Indians occupied the Basin for at least 10,000 years, at times rather intensively, and yet scientific research on this area has been spotty, and almost entirely centered on the mound and ceremonial centers of the late prehistoric peoples.

There are two consequences of this particular history of scientific investigation: the entire span of 10,000 years of prehistory is only vaguely known; and some important sites which would have filled gaps in our knowledge are now gone--into the river, under a levee, churned by the plow or the relic hunter's shovel. For an area which holds the key to much knowledge of the Southeast as a whole, it is astonishing that more concern has not been evident for the preservation, or at least the salvage of information about this particular area of North American prehistory.

2. FIRST PHASE, 1890-1920

The first Indian sites to be investigated in the Red River Basin were large, obvious, mound sites at the mouth of the River and further upstream near Natchitoches. George E. Beyer of Tulane excavated in a few mounds between 1895 and 1898, but made no attempt to locate village sites (Beyer 1895).

Shortly after the turn of the century, Clarence B. Moore, of the Philadelphia Academy of Natural Sciences, went by steamboat up the Red River to approximately the present Oklahoma border, visiting and excavating in a number of sites along the way. Moore's steamboat was equipped for an archeological expedition, and he carried his crew with him. He, too, concentrated on obvious Indian mounds and located their associated cemeteries with a metal probe. He left a record (Moore 1912) of the burials that he recovered, and particularly fine accounts and drawings of the more artistic artifacts, but he actually visited and described only a very small number of sites in the valley. His was not a systematic survey, but a selecting of sites which would yield artifacts. His descriptions of mounds and cemeteries on the Great Bend in Arkansas are the first for that area.

It is interesting to note, at this point, that throughout Moore's publication (as in his other works in other areas of the southeast) he makes constant reference to the fact that relic hunters were causing extensive destruction of sites all along the River.

Inspired by Moore's findings, the Museum of the American Indian in New York City, sent M. R. Harrington to southeast Arkansas in 1916. It was intended that he continue where Moore left off, investigating the mound sites on Red River, but he reached Fulton, Arkansas when the Red was in flood and as a consequence most of his twenty months in the field were spent to the north and east of the Great Bend and just outside of the Basin as defined in this study. His 1920 publication, however, added considerably to our knowledge of the prehistory of the area, and his description of the Mineral Springs site near Nashville (which is in the Basin) was invaluable to later studies.

3. SECOND PHASE, 1920-1940

The decade of the 1920's brought Smithsonian archeologists to Louisiana, to investigate in the same areas that Beyer had first worked--around the mouth of the Red and near Natchitoches. Gerald Fowke, working in both village and mound sites, excavated a number of sites (Fowke 1928), but again did not investigate the area between Marksville and Natchitoches, nor further up the River towards Shreveport.

For most of the southeastern United States, the Great Depression brought a flurry of archeological activity due to the immense labor force available. The prehistory of the Basin benefited by this fact, but only to a limited degree and in certain areas, i.e. the mouth of the Red, southeast Oklahoma, and to a lesser extent, East Texas. Walker, Setzler, and Ford worked in several large mound groups at the mouth of the Red. Walker alone moved out of the lower portion of the valley to excavate at the U.S. National Fish Hatchery site at Natchitoches and to publish on late prehistoric ceramics from the area (Walker 1932, 1935, 1936). Setzler came to the Marksville area in the midst of the W.P.A. operations. Local legend has it that Walker could not eat 'Cajun food nor imbibe enough to suit the natives. Louisiana at that time was a hot bed of local partisan politics and such gourmet talent was necessary to the furtherance of local diplomatic relations and archeological research as well. Setzler was well equipped to administer the W.P.A. program. His excavations at the Marksville site itself led to further work in that area by his crew leaders (James A. Ford, Stewart Neitzel, and Gordon R. Willey). Setzler (1933a, 1933b, 1934) and Ford and his associates (1940, 1951, and 1952) laid the groundwork for a relatively detailed chronological framework of occupation for the area, but this was limited in scope to the Red River mouth and the adjacent areas of the Lower Mississippi Valley.

In other parts of the Basin, the 1930's saw a considerable increase in investigations. Ford, the first to survey the area between Natchitoches and Shreveport, recorded a number of village sites (1936), but his attention soon shifted back to the mouth of the River (Ford and Quinby 1945). Further up the River, in Arkansas, local amateurs were beginning to be active, amateurs who published on their work (Lemley 1936, Dickinson 1936). These two reports on work at the Crenshaw site, a large ceremonial center in the River valley itself, served as a major source of information on the late occupations around the Great Bend of the River for many years.

Beginning in 1930, the University of Texas sent crews into East Texas almost every year until the Second World War. Floods seemed to have disturbed most of the sites along the Red itself, so the work was begun along the middle and upper drainage of Cypress Creek, and later was shifted to the middle Sulphur River and finally the Red. Two sites excavated during this decade of work, produced significant bodies of data: the Sanders site at the mouth of Bois d'Arc Creek in northwestern Lamar County (Krieger 1946: 171-199), and the Hatchel site northwest of Texarkana on the flood plain of the Red in Bowie County (Suhm et al. 1954: 203-204). The Hatchel site was extensively excavated with a large W.P.A. crew.

As in Louisiana and Arkansas, this work in Texas was almost exclusively confined to excavations of large Caddoan mounds and cemeteries, all of which occurred relatively late in terms of the occupation of the Basin (ca. 900 - 1500 A.D.). The work seemed bent on first acquiring specimens, and only secondarily on recovering coherent information on the prehistoric occupations. Pearce, in a summary of the first season's work by the University of Texas (1932b: 51-52) emphasized that in 1930 alone more than 1,000 specimens were brought into the laboratory. Landowners, were, in fact, compensated two dollars for each vessel found, a practice which caused difficulties in later years because it produced inevitable confusion between commercial worth and scientific worth.

Although this work in Texas was variable in quality and limited in usefulness, it did (like that in Louisiana) produce results which Krieger was able to use in defining a series of burial complexes which still represent most of what we know about this part of the Red River drainage (Krieger 1946: 205-216; Suhm et al. 1954: 151-227).

Recorded investigation into the prehistory of the Basin north of the Red in Oklahoma began during the second decade of what we are calling the Second Phase of research. Beginning in 1935, H. R. Antle, working for the Oklahoma Historical Society, investigated and reported upon several sites (including a small shelter) in Potontoc County, at the northwest edge of the Basin (Antle 1935a, 1935b, 1939). It was W.P.A. activity, however, which gave the first real boost to knowledge of prehistoric occupation in southwest Oklahoma, and in 1940, 1941 and early 1942 a considerable amount of work was done in that portion of the State included in the Basin. A series of extensive camp and village sites were dug in central LeFlore County (Newkumet 1940, Proctor 1957, Sharrock 1960); two village sites, one with a mound, were excavated in central McCurtain County (Bell and Baerreis 1951; 53-56), and both historic and prehistoric sites were excavated in western Bryan County (Kassel 1949, Bell and Baerreis 1951: 43-44, Ray 1960).

In contrast to this scientific work, site destruction, particularly in the cemetery sites which were known to produce pottery vessels, was heightened during the Depression, because of the market value of these artifacts. Sites throughout the Basin were unsystematically looted, causing untold amounts of damage. Pearce, working in Texas, noted (1932a: 687) that:

> The prevalent depression has set tenant farmers, commercial pothunters, and even unemployed geologists from the closed down oil fields to digging into and destroying our precious records of the past. This is going on in a way and to an extent that is heartbreaking to any <u>bona fide</u> archeologist.

4. THIRD PHASE, 1940-1967

Other than the work by Krieger, based on the Texas excavation of the 1930's, our knowledge of the late prehistoric, or Caddoan, occupation in the Central portion of the Basin is largely the result of work by non-professional archeologists, begun just before the beginning of World War II.

Under the leadership of Dr. Clarence H. Webb (a physician), a cultural sequence for the northern Louisiana area of the Red has been firmly established, based on considerably more work and detail than either the sequence in the lower Red valley or that in Texas (Webb 1940, 1945, 1948a, 1959, 1961, 1963, Webb and Dodd 1939a, 1939b, 1941). Dr. Webb was also the first person to investigate and report on Paleo-Indian and Archaic occupations anywhere in the Basin, his work being done along the Red River's tributaries in the hills of northwest and north central Louisiana (Webb, 1946, 1948b).

Once the W.P.A. work came to an end with the Second World War, scientific archeological work by professionals in most areas of the Basin came to a standstill. Following the end of the War, interest in the prehistory of the area was renewed. In 1947, Bell worked at the Scott site in LeFlore County, Oklahoma (Bell 1953), and in 1948, Krieger directed work at the Battle site in Lafayette County, Arkansas (Krieger 1949).

The real impetus to archeological research in the Red River Basin came with the establishment of the Inter-Agency Archeological Salvage Program in proposed federal reservoirs. Except for Louisiana, where no Inter-Agency Salvage programs were inaugurated, all other areas of the Basin have seen archeological survey and excavation in the specific areas which will be (or in most cases, now have been) flooded by reservoirs. This work is continuing at the present time and has resulted in a considerable accumulation of knowledge of the archeological resources in the Basin, despite the fact that these projects must confine themselves within the reservoir limits.

Two of the first projects in the Basin, begun in 1952, were the survey of the proposed Millwood Reservoir in southeast Arkansas, carried out by Jelks and Moorman from the River Basin Survey office in Austin, Texas (Jelks 1954), and survey and testing in Texarkana Reservoir (Jelks 1961). Since that time most major reservoir areas in Texas, Oklahoma, and Arkansas have been surveyed and salvage work either completed or in progress. This Inter-Agency Salvage work can be summarized briefly as follows:

Texas: In the Red River valley itself, reconnaissance has been carried out by the University of Texas at two small water control projects: a private power reservoir in Grayson County (W.A. Davis et al. 1963) and the Logan-Slough Watershed Project in Lamar County (Jelks 1965). Southern Methodist University carried out survey and limited excavations in Pat Mayse Reservoir on Sanders Creek in 1967 (D. Lorrain, personal communication). In the Sulphur River Valley, there were limited excavations by the University of Texas in 1959 in the area of the future Copper Reservoir (Johnson 1961: 234-268) and the work by Jelks in the basin of the Texarkana Reservoir. In Cypress Creek valley there was excavation by the University of Texas in the basin of the Lake O' the Pines--then called Ferrells Bridge Reservoir--in 1957-1958-1959 (E. M. Davis 1958, Jelks and Tunnell 1959, W. A. Davis and E. M. Davis 1960, E. M. Davis and Gipson 1960, E. M. Davis and Golden 1960).

Oklahoma: Survey and limited testing in proposed watershed and flood control projects began in 1960 and was done either by amateurs or by the University of Oklahoma. Hugo Reservoir was surveyed and a few sites were tested, in eastern Choctaw County (Lawton 1960, 1962); and Broken Bow Reservoir in east central McCurtain County was surveyed (Wyckoff 196[illegible]). To cope with the increasing problem of salvage archeology in proposed reservoir and watershed areas, the Oklahoma River Basin Survey Project was organized in 1962 to act as a contracting agency for this work. Surveys have been carried out in Pine Creek Reservoir (Wyckoff 1963), and Frogville Watershed Project (Bastian 1967), and a resurvey of Hugo Reservoir (Wyckoff 1967). Intensive excavations have been carried out in Broken Bow Reservoir (Wyckoff 1965, 1966a 1966b, 1967a, 1967b), and in Pine Creek Reservoir (Barr 1966).

Arkansas: Beginning in 1961, the University of Arkansas Museum, began test excavation in Millwood Reservoir, based on the recommendations made by Jelk's survey. Work was carried out there each year until the reservoir flooded late in 1965 (Hoffman 1965a, 1965b, 1967; Thomas 1966). In addition, the National Park Service did a seasons work in the reservoir area, at the Mineral Springs site (Bohannon, 1966), and made a survey of Gillham Reservoir (Wilson 1963).

During this period of activity in two-thirds of the Basin area, the Louisiana portion has been relatively neglected. Some recent work has surveyed for historic sites (Williams 1961, 1962; Gregory and Webb 1965) clustered in the vicinity of Natchitoches. Webb continues to be the most active person in Louisiana archeology, and archeologists at Northwestern State College have initiating some small scale surveys and excavations but are hampered by lack of funds.

Outside of the federal reservoir areas, archeological work since the War has been carried out to a considerable degree by amateurs, and to a far lesser degree by professionals. Organized societies of amateurs in Texas, Oklahoma, and Arkansas, have not only done a considerable amount of good archeology, but have been of inestimable service to professional work where salvage funds were not available. The information accumulating from this source of work is filling in gaps which might otherwise remain blank.

5. PRESENT STATUS OF ARCHEOLOGICAL WORK

Salvage archeology, as the term implies, works against time to save what can be excavated from the ground in two, three, sometimes as many as five seasons of work before a reservoir is flooded. All archeological information and materials which will be covered by the lake waters cannot be salvaged, so a choice must be made, and the choice is usually made to "salvage" the most significant or the most important sites. Less often it is possible to have the time and opportunity to choose sites to be salvaged because they will, hopefully, provide some answers to certain problems. The situation is complicated by the fact that the flood plain of river valleys were often not as popular for village sites because of frequent flood--although this is by no means always the case. No site investigated under the Inter-Agency program has been excavated as intensively as were many of the sites worked on by W.P.A. crews. There was both time and plenty of labor then; now there is usually little of either. In the literal sense of the word, salvage archeology never excavates a site in a reservoir area, it only tests. As a consequence, although the situation is somewhat better now than it was in the 1930's, we still are largely ignorant of the village life of the prehistoric inhabitants in the Red River Basin.

Despite the amount of research made possible through the Inter-Agency Salvage Program, and despite the work outside of reservoir areas by knowledgeable amateurs, the fact remains that sites and information are disappearing at a greater rate than they can currently be recorded. Throughout the area, destruction of sites by pothunters and untrained persons continues (Wood 1963a). In point of fact, the antiquities of much of this area have been unexplored except by citizens bent on week end relic collecting. In recent years this loss of information has been greatly augmented by the accelerating pace of site destruction caused by agricultural, urban, and industrial expansion, water development projects (particularly in Louisiana, but also those over which the Inter-Agency program does not have control), highway construction, to say nothing of many, many other projects which are changing the face of the land.

We would do well here to reiterate the point made in the Introduction. Archeological and historic sites constitute a non-renewable resource. Once destroyed without record, they cannot be recreated. The public has a right to the information contained in these sites, and the need for systematic investigation in the Red River Basin is considerably more desperate today than it was when Clarence B. Moore complained about extensive pothunting in 1912. After 35 years of continuing destruction, by various means, the situation has now become truly acute.

SECTION IV - SUMMARY OF HISTORY AND PREHISTORY

1. INTRODUCTION

A summary of the human occupation of the Red River Basin can best be viewed by setting it in the perspective of prehistory in North America as a whole. Speaking in very general terms there are three continent-wide cultural stages: Paleo-Indian, Archaic, and Formative. Archeologically, the Paleo-Indian stage is characterized in North America by large, skillfully made projectile points used for hunting big game. The flaking is often done by a distinctive parallel-flaking technique, and in some areas a channel or flute was removed on each side of the projectile point. In some parts of the United States, these points are quite early in time (older than 10,000 years ago), and have been found associated with bones of animals now extinct, such as mammoth and long-horned bison. In many areas these distinctive projectile point flaking traditions lasted until as recently as 4,000 B.C., when geographical conditions and animal life were much the same as they are today. The Paleo-Indians were nomadic hunters, following herds. They undoubtedly traveled in very small groups, but they eventually spread over the whole continent.

The Archaic stage was also characterized by a nomadic way of life, the wandering groups essentially living off the land. However, the variety of tool types, was much greater during this stage, and there are more signs of gathering and grinding of seed and berries, and other exploitation of plant foods. Groups were probably larger than in the Paleo-Indian stage, and seem to have returned, perhaps at certain times of the year, to favorite (or favorable) camping areas. This stage ended at different times in different areas: in parts of the southeastern United States it ended between 1000 and 500 B.C., but in the Great Basin it continued into the 20th century.

The Formative stage was characterized by a livelihood based on a combination of agriculture and hunting, with groups now living in permanent or semi-permanent villages. Agriculture, the major difference between the Formative and Archaic stages, had spread north from Mexico. Pottery and the bow and arrow are also primarily associated with this stage. The Indians of the Red River Basin were living a Formative way of life when the Europeans first appeared, established in villages and obtaining their subsistence by growing corn, beans, and squash, and by hunting game.

The following summary of human occupation in the Red River Basin will be presented in terms of these three general stages, as well as touching upon the opening of the historic period.

2. PALEO-INDIAN

Evidence that these early hunters of big game were in the Red River area is present, but it is meagre and scattered. Surface finds of projectile point types associated elsewhere with the Paleo-Indian have been found in a few places in the Basin, mainly outside of the alluvial valley of the Mississippi, in the uplands or terraces of the Red River's flood plain. In northwestern Louisiana a recent intensive study of artifacts in the possession of local collectors and others (Gagliano and Gregory 1964) has revealed several types of Paleo-Indian projectile points, and has suggested the presence of some local varieties. No actual Paleo-Indian sites are known in the Basin, although one site in northern Louisiana is currently being excavated which contains tools of one of these possible local varieties of the Paleo-Indian tradition (C. H. Webb, personal communication). None of the finds have ever been made in association with extinct mammals in the Basin as has been the case further to the west.

3. ARCHAIC

More is known of the occupation of the Basin by Archaic peoples, although here again, evidence is scant as compared to the later Formative cultures. This is partly due to the nature of the sites--temporary camp sites rather than semi-permanent villages. The dart points used by these people for hunting are found all over the Basin, and this kind of artifact, along with other stone tools are common in the collections of amateurs. Scientifically excavated sites, however, are few and far between--in fact, excavated information on Archaic occupation most often derives from the lower levels of sites upon which later Formative peoples also lived.

As was mentioned in the initial statement in this Section, the Archaic stage ended at different times in different parts of the continent, and this same statement can be made for the Basin itself. Near and into the area of the Ouachita Mountain province, the Archaic group continued to live by hunting and gathering probably well into the Christian era, while in Louisiana pottery making and possibly agriculture had been introduced into at least the southern portion of the State prior to that time. Some of these differences, and changes in the tool assemblages in the different areas can be accounted for by slow but widespread climatic and therefore ecological changes occurring throughout the southeast. Different adaptations were made in different areas to these changes, and to the influences felt by local groups from neighboring areas.

Several sites in Oklahoma and Texas have revealed large enough numbers of a variety of stone tools that it is obvious that people were making greater use of the natural resources around them, and producing a greater variety of objects. Some were burying their dead in a flexed position, and in addition to chipped stone tools for hunting and processing of hides and meat, they were producing ground and polished tools as well, such as axes and celts. Projectile point types indicate that there was a relationship of some kind between some of the Archaic groups in Oklahoma and Arkansas and similar groups on the Great Plains.

In northern Louisiana, but outside of the Basin area itself, is one of the most interesting and unusual Archaic sites known in America--the Poverty Point site. The time period of its occupation is contemporaneous with Archaic occupations elsewhere, and it was primarily a non-pottery making, and perhaps largely non-agricultural people who lived there. But this site was, nevertheless, a large village (not a temporary camp site); there must have been a relatively complex social organization because there are earthworks at the site which are not known elsewhere in the Mississippi valley until much later in time; and there is a tremendous variety of utilitarian objects, as well as a sophisticated and highly artistic lapidary industry present at the site. Very slowly evidence is coming to light of similar artifacts on an Archaic time level in other parts of the lower Mississippi valley, and into the hills of north central Louisiana within the Basin. There are no sites yet known in the Basin itself which reflect more than a weak influence from this large village, and it seems to have had no effect on what must have been contemporary Archaic sites in the Basin in Texas and Oklahoma. The enigma of the Poverty Point "culture" of northern Louisiana is one of many fascinating problems to be solved in the Basin area.

A topic of an argumentative nature (to archeologists) in the Basin is that of the dividing line between the Archaic and the beginning of Formative times. It is easy enough to say that when pottery is found on a site, people were living in the Formative stage. This is a very arbitrary and easy line to draw, but it is becoming evident that it is an unrealistic one. There is good evidence in southern Arkansas and especially in the Ouachita Mountains of southeast Oklahoma that pottery was being used by peoples who were living essentially by hunting and gathering. This "transitional" period, between Archaic and Formative stages is poorly defined and provides the basis for Hoffman to state that the Archaic "ends" in southwest Arkansas somewhere between 1000 and 500 B.C., and for Wyckoff to state that the stage "ends" in southeast Oklahoma somewhere between A.D. 500 and A.D. 700. Such disparities in opinion exist only partly because of differences in the definition of terms, but are primarily the result of there being so little information available from excavated sites upon which to base firms conclusions.

4. FORMATIVE

As is indicated in the introduction to this Section, the Formative Stage brought some significant changes to the way of life of the aboriginal inhabitants in North America. In the Red River Valley, new ideas came into the area, probably from the North and East as well as up the Mississippi Valley which caused a basic change in the subsistence patterns of the Archaic peoples. None of the changes were abrupt or drastic, but occurred very gradually, possibly over generations. The rate of change is difficult to detect archeologically; the ground reveals only changes in the inventory of material goods, and differences in ways of living brought about by concentrations of populations in villages. The idea of pottery was probably introduced first into the area of the mouth of the Red River from the East, for it is known to have appeared in the Atlantic coast considerably earlier. The advent of agriculture is less easy to identify, but must be partially assumed from the settled village life--some permanent food supply must have been available.

Increased population, semi-permanent village life, and a more stable and permanent food supply allowed for a complexity of social and religious life which was not possible to the hunting and gathering peoples of the Archaic. An elaboration in the kinds and amount of material goods was possible, and it is upon the occurrence of these objects that archeologists depend for most of their interpretation of development and change of the various groups who occupied the Red River Basin. This diversification and elaboration in the Formative Stage is reflected in the Red River Basin in the kinds of sites found there and in the artifacts associated with them. In addition, different cultural traditions arose in different areas of the basin--different traditions which are all, nonetheless, based on semi-sedentary village life. It is possible, therefore, to discuss the Formative Stage in the Red River Basin in terms of three different areas: the Alluvial Valley of the Red River, the Caddo area, and the Caddo-Plains area.

In order to be able to discuss the differences which appear in the archeological material from each of these three areas, archeologists have given different names to the regional developments and elaborations over time and space. No political or tribal relationship is suggested when two sites are said to be of the Tchefunte culture, for example; this just means that the traits found on these two sites are more similar to each other than they are to sites of the Ichula or Baytown culture. It must be remembered also that most of the information we have for the various groups in the Red River Basin during the Formative Stage comes from ceremonial sites or cemeteries.

a. Alluvial Valley. Through the W.P.A. work, reviewed earlier, at the mouth of the Red River, a chronological sequence was established for the Lower Mississippi Valley. The names of the cultural groups distinguished as a result of these excavations were (from oldest to latest): Tchefunte, Marksville, Troyville, Coles Creek, Plaquemine, and Historic. Sites near the mouth of the Red are some of the first in the alluvial valley to show evidence of pottery. In fact, some Tchefunte sites seem to differ from the late Archaic groups only in the respect that a well-developed ceramic complex was added to a basic Archaic stone tool inventory.

The Mississippi River was obviously a great artery of communication, and certainly ideas and influences were felt all up and down its course. The Marksville culture, for example, shows a marked relationship to the Hopewell culture which is only slightly earlier in time in the Ohio River Valley. This influence, possibly even a colonization from one group to the other, is shown by similarities in elaborate burial practices and mound building, and in well-made distinctively decorated pottery, as well as other ceremonial and non-utilitarian objects. The importance of the Marksville sites located at the mouth of the Red cannot be overemphasized, for it well may be that here is the largest single concentration of sites of this culture in the Mississippi Valley. More problem-orientated excavation should reveal the extent and nature of contact between these people and those living in the Ohio Valley.

The Troyville and Coles Creek people, again differentiated and defined upon differences in treatment of the dead and styles and decoration of pottery, are found over a wider area in the alluvial valley, and a major Troyville site occurs well up the Red River, at the Fredericks site in Natchitoches Parish. Enough archeological work has been done to suggest that influences from Mexico were being felt at the end of Troyville or beginning of the Coles Creek period--particularly evident in the appearance of truncated, flat-topped mounds upon which religious structures were built, and the advent of well developed agriculture. Just exactly when these two traits appeared and from where and how is a subject of considerable controversy among archeologists working in the area a controversy which can only be settled, or at least toned down, by more research.

By the time of the Plaquemine period, some of the elaborate ceremonialism of the earlier periods had disappeared, but there are definite indications of influences, probably even trade, with groups living further up the Red River valley above Natchitoches. Distinctive pottery types and decorative motifs show this influence well, but very little is known of the occupation of the lower Red River valley during this time period, because no Plaquemine site has been adequately investigated as yet in this area.

b. Caddo Area. The central portion of the area considered in this study of the Red River Basin is known archeologically as the Caddoan area (Fig. 1). Nearly all the sites in this general area seem to represent the ancestors of the Caddo tribes who were still living here when the first Europeans appeared on the scene. The establishment of a chronological sequence of Formative Stage cultures for the Caddo area is not as firm as is that in the alluvial valley, but certain changes have been observed which make it possible for the archeologists to talk about early Caddoan groups (Gibson Aspect) and later Caddoan groups (Fulton Aspect). Within each of these arbitrary and generalized time periods archeologists have recognized localized areas of related villages--which may or may not represent "tribes"--which are also given names. These groupings are based mainly on differences in artifact styles, but again, artifacts which come from ceremonial and cemetery sites, rather than from village sites.

There were pottery making groups in this area prior to the establishment of what can be recognized as Caddoan, but the relationship of these groups to Caddoan groups is not well understood. The artifacts from these pre-Caddoan or Early Ceramic sites indicate influence from Marksville and/or early Coles Creek groups down river, as well as possible influence from pottery making groups to the north. The origin of Caddoan culture itself is one of the major problems of the prehistory of the Red River Basin and is as yet unsolved. As we know it now, the Caddo culture seems to have dropped out of the blue, full blown as it were, with developed ceremonialism and a social organization which provided the man power (or women power) for building large ceremonial mounds. This picture is certainly an illusion resulting from inadequate research. Many of the early Gibson Aspect traits resemble contemporary styles in the Mississippi Valley, and some resemble styles in Mexico; much of the stonework is the same as is found in preceding Archaic and earlier ceramic cultures. How and why the distinctive Caddo complex of traits formed, we have as yet little idea. The information is waiting in the ground.

The "heartland" of the Caddoan culture is along the Red River in northwest Louisiana and southwest Arkansas. The major ceremonial centers of the Gibson Aspect, and there are several, occur only in this area. There are ceremonial mounds, built for burial or for putting a structure upon, away from

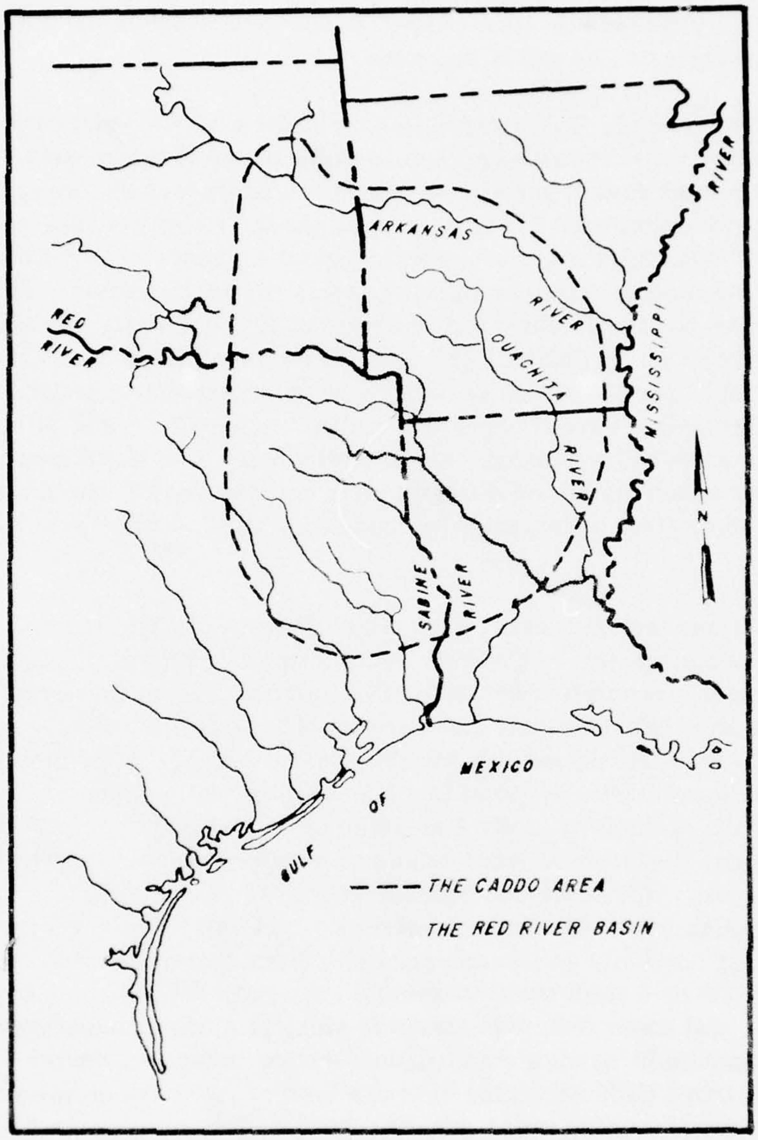

Fig. 1. The Caddoan Archeological area in relation to the Red River Basin. (Map adapted from Bulletin of the Texas Archeological Society, Vol. 31, p. 5).

this "heartland" but none of the large complex mound groups are found anywhere in the Basin except around the Great Bend of the Red. There are almost none of them left that have not been extensively damaged by pothunting. These ceremonial centers date from around A.D. 900 to A.D. 1300. It is interesting to note, however, that Gibson Aspect people also were building single ceremonial mounds along the Red River well into the prairie country, in both Texas and Oklahoma. The Caddo were basically a woodland people, and these western sites apparently represent a penetration into the prairie along what was essentially a woodland habitat of the river valleys.

Information on the growth and spread of Gibson Aspect peoples is meagre and what is known has not been well tied together as yet. There are, for example, two ceremonial centers of Caddoan culture along the Arkansas River in east central Oklahoma, far from the major concentration of occupation on the Red. Work in southeastern Oklahoma shows very little occupation in early Gibson Aspect times, and in the Sulphur and Cypress valleys in Texas small Gibson Aspect sites are known to exist but almost none have been excavated. It may well be that in these small village sites, as yet uninvestigated, lies buried the clue to the origin of Caddoan culture.

Fulton Aspect sites also occur in large numbers in this "heartland" of the Caddoan area, and there seem to be more of them than of the previous Gibson Aspect sites, although here again, this statement may be based purely on a lack of complete investigation of Gibson sites. Certainly one thing is obvious--the Fulton Aspect people did not build large ceremonial centers, or even large ceremonial mounds. They did not practice the same form of elaborate ceremonialism as the Gibson groups, although ceremonialism of some sort is indicated in burial of the dead with abundant grave goods during this period. In fact, more Fulton Aspect sites are known probably because of this very fact--large numbers of fine pottery vessels can be found in these cemeteries, and they are being looted at a great rate.

There are several regional subgroups of the Fulton Aspect, and relatively speaking, a good deal of archeology has been done on Fulton Aspect sites in southeast Oklahoma and northeast Texas as a result of River Basin salvage work. It is known that these sites date no earlier than around A.D. 1350 and that they extend into historic times. While these people did not build ceremonial mounds as did the Gibson Aspect people, it has recently become evident that they did build small mounds over burned structures--structures presumably ceremonial in nature. Some of these mounds have been excavted in Lake O' the Pines, in Texas, in McCurtain County in Oklahoma, and in Millwood Reservoir in southwest Arkansas.

Although burial practices differed in different localized areas, the general way of life of the people was probably the same throughout the area (although this has not been verified archeologically as yet), if we may judge from the accounts of the European who appeared on the scene at the end of the 17th century.

c. Caddo-Plains. As is mentioned above, there are definite indications that the horticultural Caddoan Indians had expanded their territory into the prairie lands in the western portions of the Basin. Scattered sites have been found on the south side of the Red River in Texas, and several late Gibson sites have been excavated on the north side of the River in Bryan County, Oklahoma. The relationship of these groups with the Plains Indian groups just to the west is poorly known. The Wichita, relatives of the Caddo, were known in the western portions of the Basin.in historic times. What the dynamics of the movement of these groups was, and whether the influence and movement was from west to east or east to west is yet to be determined.

It is obvious, however, that the western portion of the Basin is the least well-known of the three areas discussed, and research would reveal important movement of ideas or groups between those Indians whose cultural traits were oriented toward an eastern woodland ecology, and those who were oriented toward the prairie plains.

5. HISTORIC

When and where history begins and prehistory ends is usually not a cut and dried question. European objects can appear in the inventory of an Indian site without there having been any actual contact between the two peoples. Shortly after the Spanish reached Mexico, horses began to trickle up into the North American plains; news if not objects must have reached the Indians in the Red River Basin area by the same routes that influences from Mexico had been felt for several hundred years. Presumably Cabeza de Vaca's presence was heard of, and in fact he may have traveled into the western portion of the Basin in the late 1520's (Covey 1961: 18-19).

It is difficult to precisely follow the routes of these early explorers, but general routes can be estimated. The DeSoto expedition, following the death of its leader, tried to reach Mexico overland. This party, under the leadership of Moscoso, went well into present day northeastern Texas in 1542, before giving up the attempt and returning to the Mississippi. Swanton (1939) believes that Moscoso and his men crossed the Red River near present day Shreveport, where the Spaniards reported agricultural villages of the Naguatex, a Caddo tribe.

Following these brief encounters, the Basin area slipped back into "prehistory" for almost a hundred years, although European trade goods were appearing in the area by A.D. 1600 by which time there were Spanish settlements near the Rio Grande. There is abundant documentary evidence for widespread native trade across Texas from the Rio Grande to the Caddo country in the 17th century (Swanton 1942: 35ff; Kelley 1955).

The end of the 17th and the beginning of the 18th century finally brought the Basin into the full historic record, as both the French (from the east and southeast) and the Spanish (from the southwest) began to trickle into the area. The frontier between the Spaniards in Mexico and the French in Mississippi crystallized along the Neches and the Red Rivers, most significantly, perhaps, near Natchitoches. In 1714, Louis Juchernau de St. Denis founded the western extension of French Louisiana there, and nearby the Spanish established an administrative post at Los Adeas. The Caddo found themselves the objects of continuing political, military, and commercial maneuvering. This area on the Red River in central Louisiana holds some of the most fascinating pages of history in the struggle between two European nations for holdings in the New World. The ground still holds much of this story. There are, however, beginning with the account of the LaSalle party through this central portion of the Basin in 1686 (Swanton 1942: 38 ff), many useful records of the countryside and its inhabitants.

There are several known Indian sites of this period which indicate the nature of the material traded to the Indians, and the change in some of their customs as a result of contact with the Europeans. An historic Tunica village is located near the mouth of the Red River, which was occupied around 1706 (Ford 1936: 131). Glass beads, guns, lead shot, a halbred blade and other European and Indian objects have been found at this site (the Angola Farm site). In 1719 Bernard de la Harpe built a post on the south side of the Red in what is now Bowie County, Texas (possibly at Roseborough Lake (Harris et al. 1965: 359)). This post was in the territory of the Kadohadacho, of whom the Nassonites (Nasoni) were a component tribe. As has been mentioned, sometime in this era Wichita groups were coming into the area, and in the 1700's they became the principal middlemen in the trade between the then flowering Southern Plain equestrian groups (Comanche, Kiowa, and others) and the French and woodland Indians to the East.

European and American appearance in the northern portions of the Basin came much later than in Louisiana and Texas. Influences were felt, nonetheless, and by the 1770's, the Kahahadacho villages in Arkansas had been abandoned because of smallpox. By 1820 a short-lived American Factory and military post was established at the mouth of the Sulphur River in Arkansas; and by this time southeast Oklahoma was occupied only by hunting parties from further west. Oklahoma, or Indian Territory, has its own unique "historic Indian" sites; the Basin portion saw the settlement of Choctaw groups in the 1830's, groups which had been moved from the lands in Alabama and Mississippi.

In summary then, up to around 1720 there was only scattered and intermittent European influence in the Basin. After that date, up to 1803 and the purchase of Louisiana territory by the Americans, there was considerable contact, mostly commercial and military (and some missionary) activity in support of trade. By the late part of the 18th century, Indian groups in all parts of the Basin were suffering a marked population decline. Between 1803 and 1830, the native Indian population was sharply reduced, and the Basin saw the movement of numbers of groups from the east into Texas and Oklahoma, as pressures from settlers forced them from their homelands further east.

Unlike the French and Spaniards, the Americans who moved into the area were not scattered official military and commercial representatives of powerful nations located elsewhere. They were common citizens bent on settlement and direct exploitation of the land. In general, they were not interested in Indian trade as a commercial venture; in fact, they were little interested in the Indians at all. By 1840 all Indian groups had been moved to Oklahoma.

Our review ends here, when the historic documentation of settlement and growth of the Basin can take over. It would seem interesting to note that since the beginning of Formative times, the valley of the Red and of its major tributaries has seen a constant and sometimes concentrated occupation of peoples, the knowledge and history of which will be affected by long range Basin development plans of the Federal agencies and the States.

SECTION V - ASSESSMENT AND RECOMMENDATIONS

A. ARCHEOLOGICAL AND HISTORICAL RESOURCES

The general summary of the history and prehistory of the Red River Basin indicates that there has been continued occupation in the area for at least 10,000 years. But details are scant. An adequate knowledge of this unique culture history is critical to our understanding both of this particular segment of human history and to our comprehension of the forces and factors at work in human cultural development throughout the southeastern United States.

Occupation over this 10,000 year span occurred in all ecological zones and on all land surfaces, although some were more favored during one period of history than another. This study has shown that many factors are changing these land surfaces, and thereby destroying the particular "resource" which lies buried in the ground. Not only is this a nonrenewable resource, this archeological and historical information, but it is one that, when properly preserved and interpreted, has great public appeal.

1. KINDS OF SITES IN THE BASIN

a. Habitation. Camp or village sites of the Indians doubtless are the most numerous kinds of sites in the Basin, but are the least well-known or documented. Nothing is known of Paleo-Indian daily life, and it is presumed, from evidence further west, that these big game hunters never remained long in one spot. The possibility of finding a campfire here or there is slim but not impossible, for Paleo-Indian and Archaic hunters seem to have frequented the same advantageous camping (or hunting) areas often. The wandering Archaic hunters and gatherers returned frequently to favorable camping spots, so that accumulated debris reveals considerable information on their way of life. Archaic camp sites are usually found on the terraces and uplands, away from the lands subject to flooding, but near a constant source of water. Such scattered sites are known to occur from the prairie lands in Texas and Oklahoma, to the southern portions of the rolling hills of northern Louisiana. Almost all of these sites are known only from surface collections, except for testing of several camp sites on terraces above the narrow flood plain of the proposed reservoirs of southeastern Oklahoma.

In the northwest corner of the Basin, in Pontotoc County, Oklahoma there occurs another kind of habitation site. In these hilly areas, the Indians of

Archaic and early Formative times lived in the shelter of overhanging bluffs. Several such inhabited shelters have been reported in that area, but none occur, as far as is known, in the Ouachita Mountains.

Outside of alluvial valley itself with the advent of agriculture, semi-permanent and permanent villages came into being not only on the terraces, but occasionally (perhaps only as scattered farmsteads) in the flood plain. In the alluvial valley of the Red and the Mississippi Rivers there was little flood free land, and villages are scattered along the natural levees close to the streams or what are now old sloughs. Village sites of agricultural or horticultural people contain considerable debris and information concerning everyday life of the inhabitants. It is often possible to find, not only broken pottery and tools, but also evidence of house patterns, storage pits, and similar features. No village site in the Red River Basin has been extensively excavated; portions of village areas associated with mounds were investigated during the W.P.A. work at the mouth of the River and in the Texas and Oklahoma work, but these are but a drop in an ocean compared to the number of village sites which have not been explored at all.

Historic Indian and white settlements are found on the natural terraces, and sometimes the flood plain--close, at any rate, to the navigable waterways.

b. Burial sites. When people congregated in villages, and population increased, burial areas (or cemeteries) are often found in association with habitation areas. Sometimes graves were dug under individual house floors; sometimes a separate area away from the houses was set aside for burial. The number of people in Archaic camp sites was small, and although burial was usually near the living area, they were fewer in number than with village sites, and therefore less frequently found. The vageries of preservation of skeletal material are also a consideration, of course. The agriculturalists usually placed material goods with their dead, and even though the bones themselves may have disintegrated, the pottery, pipes, tools, and ornaments remain. The Archaic people seldom placed artifacts with their dead.

c. Mounds. Artificial mounds constructed by the Indians following the Archaic are found throughout the Basin. They occur in or close to the valleys, on terraces, and less occasionally in the uplands. Some mounds were used for burial, some as the bases for ceremonial structures, and some for both; recently it has been discovered that some mounds in very late prehistoric times were built over burned structures. Some mounds were relatively small, some were extremely large, reaching a height of 30-40 feet. Some early mounds, built for one purpose by one group of people, were used by later people for another purpose.

d. Ceremonial centers. From the time that agricultural peoples began congregating in villages, and more complex social and religious practices developed ceremonial centers grew up which served as "community" centers for surrounding villages. At these centers are usually found several mounds (of varying sizes and sometimes arranged around a plaza), several burial areas, and sometimes village debris and house patterns. These centers of the Coles Creek and Caddoan peoples are scattered along the alluvial valley from the mouth of the Red to just west of the Great Bend. None occur in the Basin area in Oklahoma, and only one or two occur in East Texas.

e. Historic Indian sites. From the time of the first penetration of Europeans into the Mississippi valley, European material can be found on Indian sites. The Indians seen by the first Europeans (the French) were no longer building mounds, but their village life was much the same as that just prior to White contact--with the addition of some European trade items. With French settlement in the alluvial valley (at Natchitoches in 1714), and the establishment of the Spanish provincial capitol at Los Adaes. European and Indian goods and traits are found intermixed on Indian village sites in a good part of the Basin. In the western portion of the Basin, Caddo and Wichita villages are found in which the European influence is seen. These historic Indian villages are found in the same kinds of locations as are earlier Indian sites, although often, as White settlement increased, some Indian settlement moved closer to these sources of trade goods and supply.

f. Historic White sites. Except for the administrative and missionary settlements in Louisiana there was little White settlement in the Basin during the the 18th century. However, some of the earliest and most important historic sites, important to the whole opening and development of the southwest are located within the Basin area. Without exception the 18th and early 19th century sites are on the Red River which was the mainstream of communication with the outside world, as far as the Europeans were concerned. Later communities were located away from the River which could wreak such havoc in flood time. In fact, the Louisiana portion of the Red River valley contains one of the most diverse concentrations of historic European sites in the nation: French, Spanish, and American influence, settlement, and interaction are all to be found in this portion of the Basin.

2. THE ARCHEOLOGICAL AND HISTORICAL POTENTIAL

In terms of recovery of information about the human occupation and use of the Red River Basin, the potential is great. What is known now of this 10,000 years of history gives only a bare outline of changes, interactions, and influences, some of which, like the introduction of agriculture and pottery, were to have far reaching effects.

There are presently huge gaps in this chronological picture. This is due to two principle factors: prior to the Inter-Agency Salvage Program, the sites which were investigated were the large ceremonial centers and burial areas which generally produce quantities of artifacts. The Inter-Agency Salvage Program brought to light other kinds of sites, but again within sharply delimited bounds, for such salvage work is confined to the limits of the reservoir areas. As a consequence sites located in the uplands, away from the flood plain, or away from construction activity altogether, have generally not been investigated. The potentiality for archeological research in every area of the Basin is tremendous, not only for solving chronological problems of human social development, but for important ecological problems as well. For example, the western portion of the Basin represented in prehistoric times (as it does now) the ecotone between the southeastern woodlands and the southern plains. The establishment of Indian horticulture along the streams of this border region and the functions of this activity as an economic base may well be related to the world-wide climatic changes which are known to have been occurring during the past 1,000 years. In addition, relationships between different groups of people living in the Basin at the same period of time (and at any given time in the history of its occupation) are extremely important to the understanding of each successive cultural development. The relationship and influences of the cultures of the Mississippi Valley with those in the "heartland" of the Caddoan culture area have only been suggested by research to date; the influence of Plains culture from the west has barely been touched upon. On a larger frame, it has been suggested by some that influences from Mexico came through this area in prehistoric times, and certainly if any answers to this puzzle are to be found in the Red River Basin, as well they might, they would have a major influence on the interpretation of the prehistory of the whole United States.

In historic times, the role of the Red River in the development of the United States was certainly considerable. The French settlement at Natchitoches (1714) literally opened up the interior of the Louisiana Purchase, and the Spanish provincial capitol at Los Adaes initiated the first contacts between the Spanish and Colonial America. After Louisiana passed into American hands, traders moved up the Red River, following the path of the French and Spanish, to open up the southern Plains and the present state of Texas.

Knowledge of this long time span of human occupation of the valley is slipping away, but the possibility of preserving large quantities of information and in some cases the more significant or typical sites themselves must not be overlooked. Where destruction will occur because of Basin development work of any kind, it goes almost without saying that survey for location of prehistoric and historic sites is an absolute necessity. This must be followed by testing and occasional large scale excavations. Preservation or reconstruction of sites or portions thereof on or near these development projects is another matter, but one of considerable worth. The Marksville site, where so much W.P.A. work was concentrated, near the mouth of the River, is one of the ceremonial centers which has been saved from further destruction by the State as a part of the State Park System. At the present time there is no Caddoan ceremonial site (no Caddoan site of any kind, for that matter) which has been preserved or developed in any way. Several occur close to proposed areas of Corps or Soil Conservation Service development. If no effort is made to preserve them, we may salvage some information, but there will be no examples for future generations to learn from and enjoy.

The location and preservation of historic Indian and white settlements is of equal interest and importance. The location of some of the early French settlements in Louisiana are known, but none have been extensively investigated; and some, which are well documented historically, have not been located. The amount of information awaiting recovery in these sites is *unquestionably* considerable, and would constitute an invaluable addition to the documentation of the period, one about which all too little is know.

The possibility of combining preservation and interpretation of this country's past with recreation facilities normally associated with water development projects is one which will pay great dividends in terms of public interest--public interest in both water development and the past. It has been demonstrated over and over again in this country, that the General Public is extremely interested in the past, and will visit in great numbers interpretive exhibits and restored buildings, communities, or sites. The public is more appreciative of this heritage, more concerned with its preservation, and has more leisure time to enjoy it now than ever before. The information potentially available in the historic and prehistoric sites in the Basin belongs to everyone, and no one individual or cooperate body has the right to destroy that information without an effort being made to see that the public has access to this part of our past.

3. PROBLEMS

There are several problems of greater or lesser magnitude concerning the recovery and interpretation of what remains of the evidence of the occupation of the Red River Basin. Greatest of these is destruction of sites. While this destruction has been going on for at least seventy-five years, it has actually accelerated in the last ten years.

The Coles Creek and Caddoan ceremonial mounds and burial areas have suffered most. It is in these sites that the most artistic of the prehistoric art-facts are to be found, often in considerable quantity. In one Caddoan grave it is possible to find anywhere from two to twenty pottery vessels, pottery and stone pipes, projectile points, ear spools, celts, beads--a happy reward for the relic hunter. We know most about the location of these sites, and the kinds of material they contain, but little about the method of construction of the mounds or association of burial areas or burials not in mounds with the village life. The number of enthusiastic collectors is now considerably more than the number of ceremonial sites, and the number of such sites which have not been severely damaged can be counted on one hand.

Added to this destructive enthusiasm is the fact that throughout the southeastern United States there are persistent reports that gold is to be found in Indian mounds (either the gold that DeSoto was looking for, or that he found and buried because he couldn't take it all with him!). No one has ever found gold in an Indian mound, but the belief still holds firm. It is a relatively common feature, particularly out of the alluvial valley, to find a large hole dug through the center of a mound to subsoil. Such holes, of course, are likely to destroy structural information, or to intercept and destroy portions of burials.

Mounds on flood plains often have farmhouses built on them to be above the floods. Mounds that have not been so "protected" in the bottoms are generally leveled either because they are nuisances to farming operations, or because they are a convenient source of fill for roads or levees. Even more frequently, mounds, especially the smaller ones are simply plowed over until, after many years, there is nothing left.

Burial areas are perhaps an even more popular source of artifacts for relic hunters than mounds, perhaps because there is not as much dirt to move as in a mound. Individual Caddoan and Coles Creek burials often contain numerous artifacts, and finding a cemetery is indeed a bonanza for the collector. In recent years some collectors are realizing the usefulness of maintaining records of burials and their associated material, so that some good information is available on this one particular aspect of Indian life. The number of burial sites which have been excavated by modern scientific methods in the Red River Basin can also be counted on one hand (see Thomas 1966; Miroir 1964; E. M. Davis and Golden 1960, as examples).

Where burials are shallow, plowing and erosion has destroyed many. Mule farming didn't do too much damage; modern California plows can turn a whole cemetery upside down in an afternoon. The same is true, of course, of village sites. In fact, farming operations have been the greatest destructive agent to village sites. Both Archaic camp sites and village sites in plowed fields are usually picked over by collectors for the whole projectile points and other tools which may be found on the surface. This type of activity causes only superficial damage, but the vast majority of these sites await scientific excavation.

The fact that farming operations generally churn up at least the upper portions of village debris deposit, is a coin with two sides--difficult for the archeologist to call a choice on. If there has been no distrubance through farming, if land is in pasture or timber--the sites may not be discovered; when they are found because of farming operations, they are already disturbed. On the rolling hills of east Texas and northern Louisiana, in the mountains at the southern portion of the Ouachitas, in the scrub oak Cross Timber country--sites doubtless are present but are as yet unknown. Whenever archeological reconnaissance has taken place, in a determined and systematic effort to find sites in reservoir areas, on almost all areas of the bottom lands, terraces, natural levees and uplands sites are found. Even the alluvial valley has problems of location of "undisturbed" sites--for sedimentation and flooding have covered sites deeply in places, and it is only the water development and channel work which is revealing their existence.

A major problem in assessing the potential of the archeological and historical resources of an area in which considerable development work is in progress, is that so much work could be done, needs to be done, and construction schedules leave too little time. Given nothing but a scientific problem before him, the archeologist would give himself several years to excavate one large village or ceremonial site. There has never been an instance in the Red River Basin when this has been possible. Salvage archeology must sample and work ahead of the construction schedule.

B. RECOMMENDATIONS CONCERNING ARCHEOLOGICAL AND HISTORICAL RESOURCES

1. INTRODUCTION

The reviews and recommendations which follow are as specific as it is possible to be at this time as to what salvage work should be done and where and what effect proposed projects will have on archeological and historical sites. It is obvious that where survey work has not been done that is a basic necessity. Levee building and channel straightening are equally destructive of information as are flooding of bottom lands. It is equally obvious that no recommendations can be made as to specific sites which could best be developed for preservation and or interpretation, until an area survey of each local project has been made. There is no project in the Basin where this does not need to be done, and no area where there is not excellent potential for the recovery, preservation, and interpretation of this, a fascinating segment of human endeavor to adjust to the environment.

However, not only human history and adjustment must be taken into account. The changes which comprehensive water development plans inevitably make in the ecology of the country can be adjusted to by modern man--the faunal and floral populations have a more difficult time. Changes in their habitat can bring extinction; a little planning can preserve them, not only to the benefit of the balance of nature, but for the enjoyment of the human population who have air-conditioners and frozen food to aid in their own adjustment process.

2. EVALUATION OF THE BASIN'S RESOURCES IN TEXAS
by E. Mott Davis

a. Red River. Much of the information reported here derives from a recent reconnaissance of a portion of the Red River valley by R. K. Harris of Southern Methodist University (Harris ms.). Between Denison Dam and eastern Fannin County there has been almost no archeological activity on the south side of Red River. It is known, however, that there are Archaic sites on the terraces of tributary valleys (W. A. Davis et al. 1962).

In Fannin County, on Bois d'Arc Creek, Archaic sites are known and some of them have a small proportion of Paleo-Indian points. None of them has been studied. One early Caddo ceremonial mound, the Harling site, was formerly on the first terrace above the Red River flood plain in northeastern Fannin County. It was tested by an archeological field party (E. M. Davis 1962) and has since been leveled to improve the drainage in a peanut field. The work there produced indications of an early penetration of Caddo Indians up the Red River valley into the prairies, possibly around A.D. 1300. At least one non-mound Caddo site is known on the same terrace two miles to the east.

In Lamar County, the valley terraces of the Red and its tributaries have Archaic camp sites as well as sites of the Gibson and Fulton Aspect Caddo and the historic Wichita. There are a number of Paleo-Indian points found on the Archaic sites. Recent excavations by Southern Methodist University in the basin of the Pat Mayse Reservoir on Pine Creek (D. Lorrain, personal communication) indicate that there was a late Paleo-Indian occupation there, as well as occupations through all the later periods into historic times. Unfortunately, neither the reservoir construction schedule nor available funds permitted extensive investigation. Several mound sites are known along Red River, notably the Sanders site at the mouth of Bois d'Arc Creek (Krieger 1946: 171-199) which was occupied in early Caddo and historic Wichita times. The Womack site near Garrett's Bluff on Red River (Harris et al. 1965) is a historic Wichita site close to the eastern edge of the range of that prairie people in the seventeenth and eighteenth centuries. The situation in Lamar County, then, indicates an early penetration of Caddo people westward, followed some centuries later by an eastward or southeastward movement of Wichita. It is possible that the early westward movement of the Caddo along the valley played some part in the development of the later Wichita culture.

The only systematic excavations in Lamar County have been brief projects at the Sanders and Womack sites, and the recent limited excavations at the Pat Mayse Reservoir. An archeological reconnaissance of Logan-Slough Creek watershed which led to the discovery of two Archaic sites (Jelks 1965) is the only survey of a Soil Conservation Service watershed project which has yet been made in the Texas portion of the lower Red River basin.

In Red River County, fewer details are known about archeological sites than in Lamar County. Archaic sites are known on the eroded valley terrances, there being an extensive one along Big Pine Creek near Blakeney. Surface finds on this site indicate there was probably some Paleo-Indian occupation there, earlier than Archaic times. At least four Caddo mound sites have been recorded, the one best known being the Sam Coffman (or Kaufman) site, a late prehistoric and early historic mound, burial, and village site part of which is being destroyed by the Red River (Harris 1953). There are three important historic

Anglo-American sites along the river: the original site of Paris, abandoned in 1844, in the northwest corner of the county; the site of Jonesborough, at the present community of Davenport; and Pecan Point farther downstream. Jonesborough and Pecan Point were the first Anglo-American settlements in Texas. They were important river crossing points from about 1815 on, and Jonesborough was a river port until the river moved to a new channel in 1843.

Members of the Dallas Archeological Society have worked at the Sam Coffman site, but otherwise no systematic work has been done on the Red River in Red River County. Southern Methodist University is planning an excavation at Sam Coffman in the near future.

In Bowie County, no systematic archeological survey has been carried on, but it is known that Caddo sites are common. This was the territory of the Kadohadacho confederation in early historic times. Three middle prehistoric and late prehistoric Caddo sites, in particular the well-known Hatchel mound (Suhm et al. 1954: 203-209) were dug on the Red River flood plain northwest of Texarkana in the 1930's, and other Caddo and Archaic sites are known to be in the vicinity. There are reports that some sites have been dumped into the levees in the course of river control projects. One historic site is known, on Roseborough Lake, which may be the site of La Harpe's 1719 post.

Of the Red River valley in Texas below Denison Dam, it can be said in general that wherever archeological reconnaissance has taken place along the main valley and the valleys of its southern tributaries, sites have been found ranging from Archaic (and perhaps Paleo-Indian) times into the days of the Spaniards, French, and Anglo-Americans. Any engineering work along the southern tributaries of the Red River will affect evidences of this history.

b. Sulphur River. Archeological knowledge of the Sulphur River basin is limited to the Cooper Reservoir basin near its headwaters, the Texarkana Reservoir basin near its mouth, and a short stretch of its middle course. Throughout, there appear to be sites ranging from Archaic into Formative times. Archeological salvage in the Cooper Reservoir basin produced evidence of Archaic and Formative materials (L. Johnson 1961: 234-268). An early Caddo site has been excavated by members of the Dallas Archeological Society farther downstream (Gilmore and Hoffrichter 1964). Along the middle Sulphur, Titus Focus (Fulton Aspect Caddo) sites are known (Goldschmidt 1935), and there are also Archaic sites and signs of some possible Paleo-Indian sites. In the Texarkana Reservoir basin, sites of Archaic and Caddo peoples underwent limited salvage excavation in 1952 (Jelks 1962), and even today relic hunters and amateur archeologists continue to find Caddo burials eroding out of the banks. There is every indication that any significant engineering work along the Sulphur will affect archeological sites.

c. Cypress Creek. The basin of the Lake O' The Pines was the scene of the most extensive archeological salvage work that has so far taken place in the Red River Basin in Texas, but even there the excavations were limited. In addition burial grounds were excavated in the Cypress basin in the 1930's, and other information on burials has been accumulating from the work of a few amateurs, from studies of the collections of relic hunters, and from some reconnaissance in the vicinity of Caddo Lake on the Louisiana border.

The basin of Cypress Creek, from its headwaters to Caddo Lake, is very rich archeologically. The most numerous known sites are burial grounds of the Titus Focus, around A.D. 1500. Some small-mound sites of the early Titus Focus were found on the valley floor in the Lake O' The Pines basin. No one had known that such sites existed in this area before the Lake O' The Pines salvage work. There may well be others near by. Archaic sites are also known on the uplands at the edge of the valley. A few burials with European trade goods have been found in the northern part of the Cypress basin near Atlanta (Suhm et al. 1954: 225-27). All around Caddo Lake are archeological sites, including more than one mound site, which represent both the Gibson and Fulton Aspects. A rise of even five feet in the lake level would probably affect a number of these sites. Some of them have already been extensively damaged by relic hunting. There are reports that Indian pottery vessels have been fished up from the shallow lake bottom, and one assumes that these vessels represent Indian occupation of the valley before the lake was impounded by the Red River raft. If such sites ever could be investigated, we might learn something about the age of Caddo Lake.

To judge from the work in the Lake O' The Pines and the materials found in and around Caddo Lake, the creation of a navigation channel along Cypress Creek is almost certain to affect prehistoric sites. In addition, historic sites will be affected, because it was up and down this stream that goods flowed in the early days of settlement of northeastern Texas. The early river ports below Jefferson and the port facilities at Jefferson itself deserve some investigation. For four decades Jefferson played a key role in the opening of a hinterland which extended west for two hundred miles, to Dallas and Fort Worth, and it is worth recovering some of the information that is to be found by detailed investigation of the hundred-year-old ruins along the bayou at the edge of the town.

3. EVALUATION OF THE BASIN'S RESOURCES IN OKLAHOMA
by Don G. Wyckoff

a. Boswell Dam and Reservoir, Choctaw County. There has been no archeological survey or excavations within the confines of the proposed Boswell Reservoir so it is impossible to make any conclusive statements on the locale's archeological potential. There has been very little archeological study in this portion of the Grand Prairie province so even an estimate on such potential may be grossly wrong. Archaic and early Caddoan (Gibson Aspect) sites are known from work in eastern Choctaw county (Bell and Baerreis 1951: 48-53; Lawton 1960 and 1962); it might be suspected that such cultures may be represented in the Boswell locality. This reservoir area must be surveyed before its construction. Such work will determine the nature of sites present and whether any such sites merit excavation. In terms of archeological research, this locality should be important in several respects: potential Plains cultural influences to the east during prehistoric times, data on the possible extent of early and late Caddoan cultures, and the nature and extent of prehistoric and early historic cultural sequences in the Grand Prairie.

b. Broken Bow Dam and Reservoir, McCurtain County. An archeological survey of this reservoir was conducted in 1961 at which time a series of 56 prehistoric sites was found (Wyckoff 1961). Limited test work that year was the basis for recommending varying degrees of excavations at six sites. Actual excavations commenced in 1964 and were again continued in 1967, resulting in seven sites receiving varying amounts of salvage work. These excavated sites contained occupations relating to several phases of the Archaic tradition, to late Gibson and early Fulton cultures of the Caddoan tradition, and to early historic, Choctaw culture (see Wyckoff 1965, 1966a, 1966b, 1967a, and 1967b). A time range of around 6,000 B.C. to A.D. 1860 is indicated.

Most of the excavated sites were open camp or village locations situated on terraces next to streams; all of these sites will be inundated when the dam is completed. There were, however, two sites which had series of small, substructure mounds; both of these sites are believed to date around A.D. 1400. One of these sites, Woods Mound Group (see Wyckoff 1967b), is on a picturesque bluff which will be along the edge of the lake. Except for its isolated location, Woods Mound Group could easily be developed (excavated mounds restored and stabilized, etc.) into a scenic park with an informative, interpretive exhibit.

c. Clayton Dam and Reservoir, Pushmataha County. An archeological survey has not been conducted with the Clayton Reservoir locale. Such a survey, and its associated testing, must be conducted to allow some preliminary statements on an area that is otherwise a void in prehistoric study. Such a survey will form a basis for any recommendations of salvage work which will in turn, hopefully, provide a framework of the archeology of the locale.

There have been some archeological studies in the Ouachita Mountains (see Bell 1953; Williams 1953; Proctor 1957; Sharrock 1960; Shaeffer 1965: 87-97), and these works have indicated intensive and extensive occupations of people oriented towards hunting and gathering. Salvage work in the Clayton Reservoir may amplify our understanding of the extent and nature of such occupations and cultures in this mountainous province.

d. Hugo Dam and Reservoir, Choctaw County. In 1960, an extensive archeological survey was completed in this reservoir area. This survey resulted in the locating of 94 sites of which 15 were recommended for salvage excavations (Lawton 1960). Most of the sites in this area represented small, lithic working stations and temporary camp spots, but more intensely occupied camp and village sites were also present. The cultures manifest are primarily Archaic (Lawton 1960 and 1962) and early Caddoan (Lawton 1960), but a few early Choctaw sites are also present. Surface collections from the Archaic sites suggest that an extended time span (5,000 B.C. to A.D. 500 ?) may be represented.

Salvage excavations for this reservoir are planned within the next two to three years and should provide a useful summary of the prehistoric cultural sequence, of varying land use by prehistoric peoples(the early Caddoan sites tend to occur mainly on sandy terraces which parallel creeks), and, perhaps, of the reason for the apparent lack of late prehistoric (A.D. 1400 to 1600) cultural remains.

e. Lukfata Dam and Reservoir, McCurtain County. There has not been any previous archeological study within the confines proposed for the Lukfata Reservoir. An archeological survey, with associated testing, must be undertaken to allow decisions about further salvage work and the nature of the archeological record in the area.

Sites with late Caddoan (Fulton Aspect: McCurtain Focus) occupations have been dug on Glover Creek but in an area five or six miles south of the proposed reservoir locale (see Bell and Baerreis 1951: 53-61; Wilson 1962).

Surface collections from the Glover area also indicate Archaic sites with occupations relating to several temporal phases. This is a fairly wide valley area with sandy terraces, a topographic situation which, in adjacent river valleys, has demonstrated intensive utilization during early and late Caddoan times. Archeological work in the Lukfata area should provide useful, additional data on the nature and extent of these Caddoan cultures and may provide evidence concerning a transition from early to late Caddoan cultures. There is also considerable likelihood that early (A.D. 1832-1850) Choctaw homesteads may be found in this locale.

f. Pine Creek Dam and Reservoir, McCurtain and Pushmataha Counties. An archeological survey was conducted in this area in the spring of 1963 (Wyckoff 1963). This survey located 30 sites with Archaic, early Caddoan, and late Caddoan cultures being represented.

Archeological salvage excavations were undertaken at four sites in August and September of 1964 and in August of 1965. These excavations revealed excellent stratigraphic sequences of occupations dating from around 6,000 B.C. to perhaps A.D. 1500 (Barr 1966: 1-84; Rohrbaugh 1967). These occupations were usually temporary in nature. This reservoir locale is typified by a narrow valley with little terrace development; this lack of good terraces apparently was the cause for rather minimal occupation during the Caddoan cultural period (circa A.D. 1100 to 1500). All of the excavated sites will be flooded once the reservoir construction is completed; these sites will thus not lend themselves to future recreational-educational development.

Although none were excavated, there are some early Choctaw sites in this locale. One of the more interesting of such sites is Alikchi which, in the Choctaw constitution revision of 1857, was made a county seat of the old Choctaw nation (Gibson 1963). Although the site of Alikchi will not be flooded by this reservoir, there are few surface features which could be restored and developed.

g. Tuskahoma Dam and Reservoir, Pushmataha County. There has been no archeological survey or salvage excavations in this reservoir locale, and data on the archeology of the area is meager. Amateur archeologists in the vicinity of Talihina have surface collections which point to several phases of Archaic occupations. In general, these collections are similar to the Fourche Maline Focus material reported (Bell and Baerreis 1951: 19-27; Newkumet 1940; Bell 1953; Williams 1953; Proctor 1957; Sharrock 1960) for LeFlore county which is to the east. Choctaw settlements are probably present too; the nearby town of Tuskahoma was the capitol of the Choctaw nation in 1834 and from 1883 to 1907.

A survey of the Tuskahoma Reservoir must be conducted prior to construction. Such work will provide data on the nature of the cultures and their sequence and may indicate a need for further salvage work before inundation.

h. Waterfall-Gilford Watershed Project, McCurtain County. There has been no archeological survey of this watershed area but some sites are known for the locale. There are only surface collections from these sites, but these collections suggest the presence of camp and village locations relating to Archaic and late Caddoan (Fulton Aspect) cultures as well as early historic homesteads (Shawnee or Choctaw ?). Mound groups have not been reported for this locale but then an intensive survey has not been conducted. It is probable that early Caddoan occupations are present; if such components could be found their nature would be very interesting. A survey and possible salvage work needs to be undertaken in this area.

i. Whitegrass-Waterhole Watershed Project, McCurtain and Choctaw Counties. There is no information on archeological materials in this specific locale. Some inference could be drawn from sites found along the Kiamichi River which is a short distance to the west (Bell and Baerreis 1951: 48-53; Bastian 1967). Sites along the Kiamichi consist of Archaic camp and workshop areas and small villages with early Caddoan affiliations. There is considerable likelihood that early Choctaw homesteads occur in this locale. This project area should be intensively surveyed prior to any construction.

j. Lower Clear Boggy Watershed Project, Atoka and Bryan Counties. There is no archeological information directly relevant to the area encompassed in this watershed project. Sites with Archaic and early Caddoan (Bryan Focus) occupations might be expected since such sites do occur in the western part of Bryan county (see Bell and Baerreis 1951: 43-48; Bell 1958; Ray 1960; Wyckoff 1964). It is likely that early historic Chickasaw settlements and homesteads may also be in the area (Kassel 1949). This project area needs an intensive archeological survey. Salvage work may provide important information on Plains-Caddoan area relationships as well as on prehistoric and early historic man's utilization of the area.

k. Caney Creek Watershed Project, Atoka County. There is no archeological information on this area, and such data would be very important and interesting. An intensive archeological survey is needed; such work may reveal occupations comparable to the Archaic, early Gibson, and early historic Chickasaw components found along the Red and Washita rivers to the southwest (see Bell and Baerreis 1951: 43-48; Kassel 1949; Bell 1958; Ray 1960; Wyckoff 1964).

l. Upper Blue River Watershed Project, Johnston and Pontotoc Counties. Archeological data for this locale is rather meager. Bluff shelters in southern Pontotoc county have contained rock paintings (of unknown affiliation) as well as refuse of hunting-gathering people of the Archaic tradition (see Antle 1939; Borhegyi 1955). Extensive prehistoric lithic working areas (cultural affiliations uncertain) have been reported (Evans 1958) for southwestern Pontotoc county. In the historic period of around 1840 this area was a part of the Chickasaw nation, and settlements relating to the Chickasaws could be expected. Needless to say, archeological studies in this locale should be useful and informative.

m. Caney-Coon Creek Watershed Project, Atoka and Coal Counties. There is no archeological data for this locale. Such data is needed, and an intensive survey should be conducted. Prehistoric and early historic cultures in this province are poorly known; studies could provide much useful information concerning prehistoric and early historic man's utilization of the southern portion of the Cross Timbers region.

n. Delaware Creek Watershed Project, Atoka County. Again, archeological information is lacking for this locale. While Archaic and possibly later cultures may have used the area, an accurate assessment of the archeology cannot be given until a survey and, possibly, salvage work have been conducted.

o. Leader-Middle Clear Boggy Watershed Project, Atoka and Coal Counties. Information directly pertinent to the prehistory and early history in this local is lacking. An intensive survey is merited and could provide data on the cultural sequence as well as on prehistoric and early historic man's relationship to the ecology in this border area between the Grand Prairie and the Cross Timbers.

p. Upper Clear Boggy Watershed Project, Coal and Pontotoc Counties. There have been no archeological studies conducted in this particular drainage locale, but prehistoric lithic workshops and Archaic cultural materials have been reported (Evans 1958; Antle 1939) from adjacent vicinities. An intensive survey should be undertaken in this drainage area, and it may provide information of the nature and sequence of cultures that were once present.

4. EVALUATION OF THE BASIN'S RESOURCES IN ARKANSAS
by Michael P. Hoffman

a. Red River Levee and Bank Stabilization. This work is nearly complete so comments concerning its potential site destruction are dated. The Red River is notorious for its meanderings and it has destroyed or partially destroyed several important Caddoan sites since Moore's 1912 work. Sites like the Friday site, the Foster site, and McClure are examples. At the Haley site, Mound A (the temple mound) is now incorporated in a levee. Evidently another mound which Moore mentioned was destroyed in levee building. The whole area to be stabilized or built over with levees should have been surveyed. An initial study conducted with the aid of topographic maps and aerial photographs along with detailed plans of the work to be done would have been valuable. At the present time sites like Friday and Foster which are still being affected by the action of Red River should be excavated before they are completely lost.

During 1967 a $129,000 contract for bank stabilization on Swan Lake has been let. Swan Lake is one of the many old channel lakes of the Red River. Its southwest bank has a high natural levee of land on it that should be walked for site locations. The west end of Swan Lake is less than one half mile from the Egypt site, an important Caddoan ceremonial center.

Some 1967 channel work will be done at Spirit Lake near the Battle site. The University of Arkansas Museum has some Caddoan pottery vessels which state "Spirit Lake, Arkansas" as their provenience, but from where in this large lake area is not known. A topographic map shows the upstream end of Spirit Lake (where the work will go on) is lowland and probably no site is located there. However a short check through walking the surface is suggested.

b. Garland City. Work is going on at the present time to realign the Red River channel and protect the railroad and highway bridges at this location. Probably no further archeological work will be required because a topographic map shows that the land there is low and already considerably disturbed by river improvements.

c. Maniece Bayou. Channel and bank stabilization work on Maniece Bayou is in progress at the present time and is scheduled for completion in September 1968. The Bayou is a meandering stream which flows westward in the Red River bottoms in Lafayette County. Along portions of the stream it is bordered by an old terrace. One site is known from this terrace, the Cap Black Ridge site (3LA3) which seems to have Middle and Late Archaic and early

Formative occupations. Plans should be obtained for the Maniece Bayou work and the area intensively surveyed.

d. McKinney Bayou. Levee and outlet channel construction are projected along McKinney Bayou which flows southeastward into the Red River in Miller County. This Bayou goes through the heart of the Red River valley and when plans of the construction are obtainable the country should be surveyed. A good deal of the present day land around the Bayou is in deep woodland and survey would be difficult but the possibility of finding an unknown Caddoan or earlier site would make it worthwhile.

e. Posten Bayou. A plan to divert Posten Bayou in Arkansas (along the Arkansas-Louisiana state line) is projected. No sites are known along the Bayou but diverting its flow to the Red River in Arkansas would mean a lot of earth moving and judging from topographic maps, some of the channel excavation would be through fairly high bottom land where sites unquestionably exist so the area should be surveyed to locate them.

f. Millwood Reservoir. A good deal of archeology has already gone on in Millwood Reservoir and it has produced at least the beginnings of a sound archeological sequence there. The most pressing need for continuing archeological work in the reservoir is the survey of public use areas, all of which are located on high ground that presumably would have been attractive to aboriginal inhabitants.

g. Dierks Dam and Reservoir. The Dierks Dam and Reservoir on the Saline River will affect an area of about 3000 acres. The land to be flooded is a portion of the Basin which falls within the Ouachita physiographic province and the location and excavation of sites endangered by this reservoir will contribute to our archeological knowledge of this interesting region. No formal survey work has been conducted in connection with this reservoir although a local amateur archeologist has attempted to locate some sites there. The area is extremely difficult to work in because it is all heavily timbered and roads are almost non-existent.

h. Gillham Dam and Reservoir. The Gillham Dam and Reservoir on the Cossatot River will cover 1370 acres. The reservoir has been surveyed (Wilson 1963a and 1963b) and excavation based on Wilson's recommendations will take place in the summer of 1967. Public use areas have yet to be surveyed.

i. DeQueen Dam and Reservoir. The DeQueen Reservoir will be located on the Rolling Fork River and will cover, at the top of the flood control pool, an area of about 4000 acres. No formal archeological survey has taken place at the reservoir but it should occur in the near future. Like the Dierks Reservoir almost the whole area to be flooded is in heavy woodland and survey work will be difficult.

j. Walnut Bayou. A Corps of Engineer's Project on Walnut Bayou to clean and divert its channel was finished in 1962. As the project has been finished for five years, no archeological work is recommended.

k. Bayou Dorcheat. A reservoir which may be built on Bayou Dorcheat in Louisiana would extend some distance into Arkansas. Almost nothing is known of the archeology of the Bayou and certainly if the reservoir is to be built a survey of its archeological resources should be undertaken and sites endangered should be excavated. The Bayou flows through rolling hills and one would expect Archaic and early Formative sites along its banks.

5. EVALUATION OF THE BASIN'S RESOURCES IN LOUISIANA
by Hiram F. Gregory

a. Posten Bayou Project. A number of prehistoric sites are known from this area. The Byram Ferry Site (Moore 1912: 525-526) is located very near Posten Bayou, but on the Red River itself. Moore reported two mounds here but subsequently one has been bulldozed down. A local amateur salvaged one burial with Haley Focus-like Caddoan ceramics (C. H. Webb, personal communication 1967). This site could provide much needed information on the relationship of Louisiana Caddoan sites to those in southwestern Arkansas. Also a number of Archaic sites and one Bellevue Focus site are reported from the hills west of Posten Bayou. A minimal recommendation for this area would be an archeological survey with attendant salvage excavations.

b. Caddo Lake - Black Bayou - Twelve Mile Bayou Projects. This area has a large concentration of prehistoric sites, which have yielded surface materials ranging from Paleo-Indian almost to historic occupations. The hills flanking the lake and the islands in it are the location of several large sites. Consequently almost any work on Caddo Lake will affect sites. Three sites are located in the immediate vicinity of the Caddo Lake dam (Webb 1959: 8-9). One is on a hill adjacent to the present dam. This site and its neighbors should definitely be investigated. A careful survey of the project areas should be conducted and attendant testing and excavation is recommended in the light of the concentration of known prehistoric sites.

Local collectors also pay close attention to the hills along Twelve Mile Bayou and Paleo-Indian tradition points have been reported there. It therefore seems imperative that project planners also pay attention to the area.

It should be borne in mind that these areas are very close to the city of Shreveport, actually providing that city with its municipal water supply, and that this places it almost within the limits of the largest urban center in northern Louisiana. Also it is in easy driving range of Bossier City, Shreveport's urban neighbor with its large military installation, Barksdale Air Force Base. Due to its location, this area would seem to be an excellent area for building a series of parks with boat launches and other facilities. It would also be a fine area for a series of interpretative exhibits on the history and prehistory of the area concerned. There are parish parks on Caddo Lake, but others would be useful. These parks could be extended onto Black and Twleve Mile Bayous as well.

c. Bayou Dorcheat Reservoir Project. Due to an almost complete lack of survey, either professional or amateur, the bottoms of the Bayou Dorcheat area are an archeological *terra incognita*. Recent activities by local amateurs have brought to light several large middens in that drainage, but none have been adequately investigated. Local agencies have been requesting a survey of the area to be contained by the project. Aid has been requested from local, state, and federal agencies, but to date no financial aid has been provided.

The relationship of sites in this area to those in the alluvial plain of the Red River and the area of southwestern Arkansas is extremely important. A minimal recommendation would be a survey of sites with testing and some salvage archeology. In the light of strong local interest in prehistory, it might be logical to place a number of interpretive exhibits in this area. Due to the proximity of this area to the expanding Shreveport-Bossier City area, some recreational facilities should be considered here as well.

d. Cypress Bayou Project. This area is practically unknown archeologically although Dr. Webb (personal communication 1967) notes a number of Archaic to Bossier Focus sites in the immediate vicinity. Additional surveying and testing are desperately needed here to clarify the development of the Caddo area. Local agencies, especially the Soil Conservation Service District board have again requested aid in conducting surveys and other archeological investigations of these areas. To date no such action has been taken.

As this area is again very close to the Shreveport-Bossier City urban area it would seem reasonable to build both recreational and educational areas near this project. Should surveys and salvage be conducted the local people will demand that interpretations of local prehistory and history be made available here.

The recreational facilities here will serve Ruston and Minden, Louisiana as well as the urban areas further west. Consequently a minimal recommendation for this project would be archeological investigations and some recreational facilities.

e. Red Chute-Loggy Bayou Projects. This area has a number of important archeological resources, ranging from the Archaic to Bossier Focus Caddo. One of these sites, the Jim Sinner site, may have connections with the Poverty Point culture and another, the Pease site, is a definitive site for Bossier Focus Caddoan developments (C. H. Webb, personal communication 1967). Loggy Bayou drains Lake Bistineau where some 40 sites have been recorded by local amateurs in the last year and there is little reason to doubt that this wealth of sites is not duplicated further downstream. Care must be taken to survey this area and to salvage any important sites.

f. East Point Project. This area has been only partially surveyed, mainly by Dr. Clarence Webb of Shreveport. Moore listed one site, Sunnyland Plantation, near here on Red River (Moore 1912). Dr. Webb and his associates later tested this mound and think it a Gahagan-Alto component site (C. H. Webb, personal communication 1967). Additional archeological investigations are strongly recommended.

g. Bayou Pierre Project. This former Red River channel is very important from both an archeological and historical standpoint. A number of important archeological sites are recorded. Jim Island in Natchitoches Parish may be one of the largest Archaic sites in northwestern Louisiana and Webb (1965) has reported on a number of Alto Focus Caddoan sites on the upper portion of the stream where it hits Wallace Bayou and Chamarre Lakes. The relationship of these valley margin Alto sites to more riverine centers like Gahagan has long been an archeological problem. The job of clarifying Coles Creek-Alto relationships also involves sites along Bayou Pierre.

As this area was the "coast" for French settlers from Natchitoches and Spanish families moving from Los Adaes it becomes one of the areas of the United States where documented sites of Franco-Hispanic settlement can be sought (D'Antoni 1961). These settlers intermarried, both with themselves and Caddo neighbors, and founded numerous rural agglomerations or "rancherias;" although many were of French descent their ties were to Spanish Texas. It was in this neighborhood that tribes like the Adaes and Yatasee finally located (Webb 1963: 146-147). Attempts to locate these sites should be made.

Further down Bayou Pierre, near its junction with Red River, the first American Indian Factory was built shortly after the Louisiana Purchase. A possible site representing this factory and an American military camp of the War of 1812 period have been located at Grand Ecore near the junction of the two streams. These sites should both be investigated.

Grand Ecore bluffs, just south of the Bayou Pierre on Red River, would make a fine park area. These bluffs show indications of occupation ranging from Indian times to a steamboat landing town of the Civil War period. Large numbers of southern and northern troops were billeted here during the Civil War and remnants of Civil War earthworks are still seen at the site. This area, near the city of Natchitoches and already a tourist center, should be developed as an interpretive exhibit area. Recommendations for this project should include exhibits at Grand Ecore and an archeological survey of the area.

h. Bayou Dupont Watershed Project. This area, like Grand Ecore and Bayou Pierre, is very important from an archeological viewpoint. It contains the site of the presidio and mission at Los Adaes established by the Spanish in 1720. Excavations in progress at the Los Adaes Park site document the occupation of this area by both Indians and Europeans between 1720 and 1820. This site seems to represent the mission to the Adaes and the site of a later Spanish-American community occupied as late as 1820. The site of the presidio is still indefinite, but it must fall within the limits of the project under construction here. The importance of these sites to the history and archeology of the southeastern United States cannot be overestimated. Numerous rancherias satellite to the major sites also have not been located, but are of extreme importance archeologically. The Los Adaes Park is owned by Natchitoches Parish, but other than a grassy meadow, a polluted well and a historical marker it is undeveloped. No interpretive exhibits exist nor any facilities for visitors to the site.

Sites other than those mentioned above ranging from Paleo-Indian to historic times have been reported. Two of these, the Freeman site (Fowke 1928) and the Wilkinson site (Ford 1936) are threatened by flooding. Every effort should be made to survey this area for both historic and prehistoric sites. Exhibits and further excavations at the Los Adaes Park as well as some recreational facilities there would also seem attractive.

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COMPREHENSIVE BASIN STUDY. RED RIVER BELOW DENSION DAM, ARKANSA--ETC(U)

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i. Cane River Project. This stream, a former Red River channel, is now a dammed area which forms a long lake. Improvements along this old channel system will definitely endanger a number of known archeological sites. Unfortunately most of the excavated Glendora Focus (historic) components are on this system; the Fish Hatchery site at Natchitoches, the Southern Compress and Oil Mill at Natchitoches, and the Lawton Gin site just below Natchitoches are all on the bank line of Cane River. An additional historic site, Fort St. Jean Baptiste (1714) at Natchitoches, is about to be replicated with local funds. Unfortunately the actual site of this French frontier post has not been identified, but according to both maps and historiographic materials it was on the bank of the Cane. Dredging and bank line earth moving may uncover portions of this settlement. Additional work on all these sites would be of extreme value in terms of our picture of the French colonial occupation at Natchitoches and their neighbors at the time of contact. Interpretation of Fort St. Jean Baptiste would be an invaluable asset to the local region.

Also present along the Cane River are a number of sites of French homesteads built between 1776 and 1850. Some of these sites are occupied by the original plantation houses and/or the less pretentious houses of the region's petits paysans. To date no archeology has been done on these later sites. Excavations here would doubtless give us much information about French, English, Spanish, and American ceramics in the transitional period in which the Louisiana Territory passed from European to American hands. This information would be extremely valuable in aiding the interpretation of historic sites in the American West. Attempts to salvage these sites if they are to be affected would seem requisite.

Older prehistoric sites are also known in this area. Some of these sites, like the Fish Hatchery #2 site at Natchitoches, pose a special archeological problem. The Fish Hatchery #2 site was buried under two and a half feet of sterile overburden deposited by the Red River subsequent to the site's last occupation. These deeply buried sites probably account for much of the enigma concerning the lack of villages in the alluvial plain of Red River. Usual survey techniques will probably miss these sites. There is absolutely no surface expression nor can they be detected on aerial photos of the area. Rather than see these undisturbed sites lost to earth moving activities special funds for their rapid salvage must be set aside and the archeologist must be ready to act should the contractors uncover another such site. Additional work at the Fish Hatchery #2 site would also be a probability as it is on the Cane River bank line. Considerable additional information concerning the Haley-Belcher-Bossier Foci could be gleaned from this site alone.

As this area is already very popular with tourists, primarily for its antebellum homes, it might be well to plan some archeological exhibits in this area. The Natchitoches National Fish Hatchery with two separate components would seem a logical place for interpretive exhibits.

Recreational areas are already maintained here by the Parish and State.

j. Bayou DuGrappe-Rigolettes (Row Gully). This area should be carefully surveyed for historic sites and Indian sites as well. The American State Papers note a large settlement in this area of French-Irish and Indian families. These sites obviously relate to the Colfax Ferry site on Red River and would help to document that site further. To date no work has been done in this area. Sites ranging from Archaic to historic should be here, but none are reported. A careful survey and necessary salvage seem to be a minimal recommendation.

k. Kisatchie Bayou Project. This project will cover a number of terrace surfaces which are known to have Archaic and/or Paleo-Indian sites to the west and east of this reservoir. As no archeological reconnaissance has been conducted in this area it seems requisite that a survey be made.

The Cotile Bayou area, just north of Kisatchie Bayou or Creek, has some known Coles Creek-Alto-Bossier sites and a local collector has a Baytown Plain pipe excavated from a deeply buried midden where these streams join the Red River alluvial valley.

Work in this area seems in order and possibly an interpretive exhibit or two could be planned as this area provides the major recreational facility for the military installation, Fort Polk, at Leesville, Louisiana.

l. Bayou Rapides Project. This Soil Conservation Service project is finished and no evaluation of its historical or archeological resources was made. The stream known as Bayou Jean de Jean is nearby, however. This stream was the locale settled by a band of Choctaw and Biloxi in the 1760's. Any work near this stream's junction with the Red River will doubtless uncover the remaining portion of this site; it is badly pothunted by local treasure seekers. No other recommendations other than concern for the Bayou Jean de Jean areas need be made here. Doubtless a number of sites have already been destroyed in the area, but no estimate can be made as a survey was not made.

m. Campti to Clarence Levee Project. This seemingly simple project has involved at least three known sites to date. There are three middens located in the eastern portion of this project on Saline Bayou: the Lemoine, Roshto, and Chivary Dam sites all in Natchitoches Parish. The levee rights-of-way have cleared and destroyed portions of the Lemoine and Roshto sites. These sites seem to be on the Coles Creek-Alto time levels. Both are riverine middens with abundant surface materials. A large area of both these sites remains. The Chivary Dam site is a spoil situation in the bottom of Bayou Bourbeaux. This spoil will be eroded away when the levee system planned is finished. This deposit represents a Bossier-Belcher and Troyville site that was graded away to build Chivary Dam several years ago. This spoil contains an abundance of sherds and bone.

A minimal recommendation for the Campti-Clarence area would be testing of known sites and an additional survey of the area involved in both the levee project and the Red River channel plans.

n. Red River Navigation and Bank Stabilization Plan. The Red River region as a whole will be affected by this larger Army Corps of Engineers project. As the aims of this project are quite different from those of the Soil Conservation Service they deserve a different treatment here. In the first place the six locks scheduled for the Louisiana portion of the river are all in areas not adequately covered by survey at this point. Also the areas where the channel of the present active stream will be realigned are not adequately surveyed either. To date there has been no systematic survey of Louisiana archeology. Attempts at getting funds for this sort of thing have all met defeat, both on the state and federal level.

Obviously a number of sites will be affected by the present plans but the present study can do no more than list known sites and make a few recommendations. How many sites are actually in the area is not known nor do we have any idea how many archeological remains lie buried in the bed of the river. A number of known sites are known to have been eroded away by the stream and others are presently being eroded. Dredges in certain areas of the Red River valley might yield archeological remains. However, it should suffice here to note the loss of these sites, as sites so near the river are bound to be damaged by the presently planned activities.

In the immediate vicinity of Lock and Dam No. 1 is the Moncla Mound, a nice Marksville - Troyville Period mound. A portion of this mound has already been destroyed by existing levees and any additional work in this area will probably affect it. Any work on the lower Red River should include the salvage of this site.

A number of sites also are known to either exist or have existed along the Red River below this point. C. B. Moore noted the L'eau Noire Bayou site in Avoyelles Parish, a Plaquemine Period mound with burials, and the Keller Place in Pointe Coupee Parish near the Old River Locks Project (Moore 1912: 489-492). Additional work on the Plaquemine Period would be invaluable but it is feared that the Keller Place site has been destroyed. No attempt at survey or salvage was made for the Old River Project.

Also in this vicinity are the Saline Point sites and the Norman Landing site (Moore 1912: 495-501). These are all important Marksville Period sites. Recently a local pothunter has been busy digging at the Norman site, but the other sites are still relatively intact.

Above Moncla the river has never been surveyed. W.P.A. surveys by James A. Ford dealt primarily with the areas of site concentration and for this area these were Marksville Prairie, Catahoula Lake and Lake Larto (Ford 1936: 32). Moore also reports a dearth of sites for this area (1912: 507-508). Moore seems to have concentrated on the area around the Red River mouth and listed only two sites between there and Alexandria: the Johnson Place and the Rodriquez site. The former site is a Troyville-Coles Creek site and the Rodriquez site yielded a number of red jasper beads and heavy points. This site may well represent a late Archaic or Poverty Point component site. If the site is still extant additional work there would seem imperative.

The strip of river from Alexandria north is slightly better known. At Alexandria there exists a portion of Bailey's Dam, a structure built by Union naval engineers to facilitate the retreat of northern forces down the Red River during the War between the States. This is but one of many Civil War sites in the valley and a number of wrecked ships are reported, especially between Alexandria and Natchitoches, Louisiana. One has definitely been seen at low water near Montgomery Landing. Any channel activities will definitely destroy these sites. The loss of Bailey's Dam would seem irreparable.

At about Mile 100 on the realigned channel, on the west bank are the Colfax Ferry and Bayou Jean de Jean sites. These 1763-1820 contact sites are very valuable resources. The Colfax Ferry site has suffered considerably from the depredations of pothunters, but a sizable portion of it is intact. That the Bayou Jean de Jean site is mainly midden is a fortunate accident. On the bluffs here is also a large French cemetery started in the 1760's also. It, too, has been badly looted by treasure seekers.

From the mouth of Cane River to Grand Ecore Bluffs no sites are known along the active stream. Most known sites are back, on the older abandoned channels like the Cane River. However, there are doubtless a number of sites here and an attempt at survey should be made before the channel area is worked on.

A mound formerly existed at Campti (Beyer 1899) but it is now eroded completely away by the river. Traces of this site should be sought as it seems to have been a late burial site representing Fulton Aspect Caddoans. No sites are known along the active channel between here and Coushatta, but only because the area is still wooded and no attempt at survey has been made.

Just above Coushatta a trace of the Gahagan site remains. A portion of one mound and a thin midden deposit buried under alluvium can still be seen. However, the portion of the site excavated by Moore (1912: 511-524) and Webb (1939: 92-127) are all in the river now. Any bank stabilization is bound to destroy the remaining portion of this important site. More work is recommended for the portion of the remaining site.

The Briear Bend site worked by Moore (1912: 510-11) is still extant, but no other information is available about it. This area is all in woods or pasture at the present time.

From this area to Shreveport, Louisiana are scattered a number of rather important sites, the most important of which are contained in our discussion of the East Point to Loggy Bayou and Bayou Pierre Projects. However, three sites: Taylortown, Sunny Point (Moore 1912) and an historic Coushatta site are in this area. The latter site is well documented, but has not been found.

Webb (1959) lists a number of sites in the alluvial valley between Shreveport and Belcher, Louisiana. A number of these sites have already been discussed in the Black Bayou and Caddo Lake or Posten Bayou Project evaluations. The most important site here is probably the Mounds Plantation site near Dixie, Louisiana. This large Alto Focus site with its Coles Creek component would possibly be damaged by the channel operations. It should be carefully considered for salvage or other investigation. The park area noted on the Corps of Engineers' plan would be near there and a possible interpretive exhibit could put that area to good use.

Other sites in this area include the Belcher, Kelley Bayou, Huckaby, Thompson Mound, and Cd-37 sites all of which could conceivably be included in the immediate area of the project planned. These are the most definitely well organized Caddoan sites in Louisiana and any loss of information here would be grievous. Additional work is recommended for this whole area, that is the Shreveport to Hosston, Louisiana, reach of the Red River.

Above the latitude of Hosston, Louisiana, local amateurs report several sites, but present information cannot be any more definite than that. The situation described for the Posten Bayou Project will probably be representative for this reach of the river as well.

In the light of the comparative dearth of information on sites in the Louisiana portion of the Red River valley, and the importance of those that are known and reported, it seems imperative that these recommendations end by advising a detailed archeological survey of the entire valley of that stream. This survey should begin near where the Red River enters Louisiana and cover all the project areas in its alluvial valley. Additional surveys of borrow pits and access routes to parks, locks and dams, and other areas to be affected are also deemed necessary. On the basis of this survey more detailed information as to kind and nature of sites should lead to a salvage program. This plan of action is needed desperately before the state of Louisiana loses some of its most important archeological and historical sites.

C. NATURAL RESOURCES AND RECOMMENDATIONS

In the course of this study, we have emphasized the natural setting in which the human inhabitants of the Red River Basin have lived. The factors which can cause destruction (or "extinction") of the evidence for this human occupation, can be equally destructive to the natural environment. The non-renewable natural resources of the area, such as oil, iron-bearing gravels, geological outcrops containing evidence of former plant and animal life in fossil form, all are matters which must be considered in basin development, but which are outside the scope of this particular paper. These are resources which are useful, in some cases vital, to us in the 20th century, but with which the prehistoric and early historic inhabitants had little concern. This fact does not make them the less important; it only makes the present authors less qualified to speak about them.

Other resources, however, which form a part of our present environment as it did that of the Indians, constitute an important element in our understanding of how people lived in the past, as well as our understanding and enjoyment of the present. Certainly as the present population of the United States grows, this natural environment is changing. In many respects we control our environment, and this control can be and has been an extremely destructive device. With no thought to the consequences, both human and animal populations have been exterminated. This extinction can be so far removed from its cause that most of us are unaware of the possibility--lumbering, for example, or draining of swamps, can eliminate animal and plant habitats practically over night. We are at the point where some thought must be given to preservation of some areas, not only for the "balance of nature" but for the sake of future generations. The potentialities of development or the "non-disturbance" of various areas of the Basin, in relation to the overall development plan, are as great in this realm as in that of the archeological resources. We reiterate that there may not be a Grand Canyon in the Red River Basin, but there are unusual and unique areas in the Gulf Coastal Plain and Ouachita Mountain provinces which may be drastically effected by elimination of natural flooding, and by drainage, to say nothing of inundation. The appeal of such preserved areas to the general public can be witnessed anywhere in the country where such areas exist--on a large scale, this is exactly the appeal of our National Park System. A few examples will help point out the potential--both for possible elimination of these natural resources if they are not considered in the planning stages, and for their preservation and development in relation to a Comprehensive Basin plan.

The rich bottom land forests of the Red River valley in McCurtain County, Oklahoma, and the five southwestern counties of Arkansas are beautiful examples of the value of well-developed wetlands, and the unique fauna and flora now present there,exist because much of the area has not been cleared or drained. One of the best examples of bottom land woods is in Beavers Bend State Park in McCurtain County, where there is a beautiful cypress swamp. Indeed, the famous "big tree" there is reported to be the largest cypress in the world. This area contains the only cypress woods in the State of Oklahoma, the only rich breeding populations of wood warblers in Oklahoma, and the only palmetto.

In Arkansas, the nearly extinct red wolf population, which once occupied all of the Gulf states (Canis major) still remains in the bottom lands of the Ouachita and most possibly the Red Rivers. The animal is becoming increasingly rare because of the destruction of its bottom land habitat by drainage and cutting. The Mountain Lion (Felis concolor) has been almost exterminated in this area, although one was killed in Shreveport very recently. The fact that it is now unusual is attested to by the acquisition of this animal's skin by the museum at Louisiana State University.

In Hempstead County, Arkansas, very near Millwood Dam itself, there is a large privately owned preserve of thousands of acres of bottom lands. It is possible to take a boat through the shallow waters in this area and see virgin cypress swamps where, in April and May, thousands of waterbirds nest: Little Blue Herons, Snowy Egrets, Great Blue Herons, Black crowned Night Herons, Purple Gallinules, Common Gallinules, Pied-billed Grebes, Least Bitterns. This is the second largest rookery for nesting herons and egrets in Arkansas. The owners of this area, which is called Grassy Lake because of the many stands of thick high southern wild rice which grows there, have protected it from surrounding land use practices, and thus preserved an example of a type of habitat which formerly was widespread in the southern and eastern parts of the State and in northern Louisiana. Alligators still exist here as a relict population, and an unusual and strictly southern (Gulf Coast) swamp orchid (Habenaria quinqueseta (Michx.) Sw.) has been found on half-submerged logs.

In Polk County, Arkansas, in the Ouachita Mountain area and within the northern edge of the Basin, Rich Mountain contains one of the richest floral associations in temperate North America. Receiving over 60 inches of rain per year, Rich Mountain qualifies as a true rain forest. Two species of salamanders (Plethodon ouachiti and Plethodon caddoensis) are endemic to this small area and occur nowhere else in the world.

The ox-bow lakes of the Red River Valley in Arkansas support high populations of valued game animals such as mink and muskrat. Wood ducks nest here in abundance. The Paddlefish (Polyodon spathula), which formerly was abundant in the larger streams, is now so reduced as to need protection if it is not to become extinct.

These examples could be repeated over and over in all areas of the Basin. They are examples of natural resources the existence of which depends upon the undisturbed natural habitat. Any disturbance to this habitat must take into consideration the consequences to these resources.

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RED RIVER BELOW DENISON DAM
ARKANSAS, LOUISIANA, OKLAHOMA, AND TEXAS
COMPREHENSIVE BASIN STUDY

APPENDIX X

HYDROELECTRIC POWER

Prepared by
Federal Power Commission
U. S. Department of the Interior, Southwestern Power Administration
and
U. S. Army Corps of Engineers

June 1968

APPENDIX X

HYDROELECTRIC POWER

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APPENDIX X

HYDROELECTRIC POWER

SECTION I - INTRODUCTION

1. SCOPE

A logical market area for hydroelectric power developed in the Red River Basin below Denison Dam was determined and factors related to power marketing were analyzed. This analysis included past power requirements and estimated future requirements in the market area for the years 1970, 1980, 2000, and 2020; existing power supply facilities, scheduled changes in existing facilities; and additional generating capacity, including hydroelectric capacity, required to meet the estimated future demands in the market area. In addition to the presentation for the market area in its entirety, similar data applicable only to preference power users were extracted by the marketing agency and presented separately.

2. OBJECTIVES

The objective of this appendix which includes a presentation of existing power supply and the need of additional power supply sources to serve the estimated future power requirements, is to determine if the potential hydroelectric development in the Red River Basin below Denison Dam is feasible and would be usable in serving the estimated future power loads in the market area while adhering to the long-range basin plans for developing the water and related land resources.

3. RELATIONSHIP TO OTHER APPENDIXES

This report on the Red River Basin below Denison Dam deals with a multiple-purpose development of the remaining undeveloped water and related land resources in the basin. Hydroelectric power development in the basin is primarily associated with multiple-purpose reservoir development and is therefore subject to priorities of water use as well as to economic and financial considerations. It follows that close coordination with project purposes described in the other appendixes is necessary.

4. PREPARATION AND COORDINATION OF APPENDIX

The inventory of power resources and needs in the market area was compiled by the Fort Worth regional office staff of the Federal Power Commission with specific data for preference power users being supplied by the Southwestern Power Administration. Screening of potential hydroelectric projects in the Red River Basin below Denison Dam and study of projects for power in the basin plan was the joint responsibility of the Tulsa and New Orleans Districts of the Corps of Engineers. There was considerable exchange of ideas in all phases of the compilation, particularly in the selection of projects for the 10- to 15-year program. Participants included representatives of the States involved, the Corps of Engineers, Southwestern Power Administration, and the Federal Power Commission. Although the Report is dated June 1968, a cutoff date of December 31, 1965 was used in this Appendix for load experience and for projects in operation. Selection of projects for immediate consideration was made within the limitations imposed by other basin developments.

5. TYPES OF POWER DEVELOPMENTS CONSIDERED

a. Conventional plants. Studies of the development of additional hydroelectric power in the basin centered on the inclusion of power as a function in multiple-purpose reservoir development. The available power heads and streamflow patterns preclude consideration of economical development of single-purpose hydroelectric plants. The inclusion of power in a multiple-purpose development depends on its economic and financial feasibility, applicability to the area power load, and adaptability to the requirements of all water uses.

b. Reversible unit installations. A power installation with a combination of conventional and reversible units was considered at one site. The results are highly encouraging.

c. Pumped-storage installations. Six sites met the criteria for pumped-storage hydroelectric power development. All these sites were screened and the results indicated that detailed studies were warranted. These studies were made for two of the sites, with significantly higher heads, with favorable results for one of the sites.

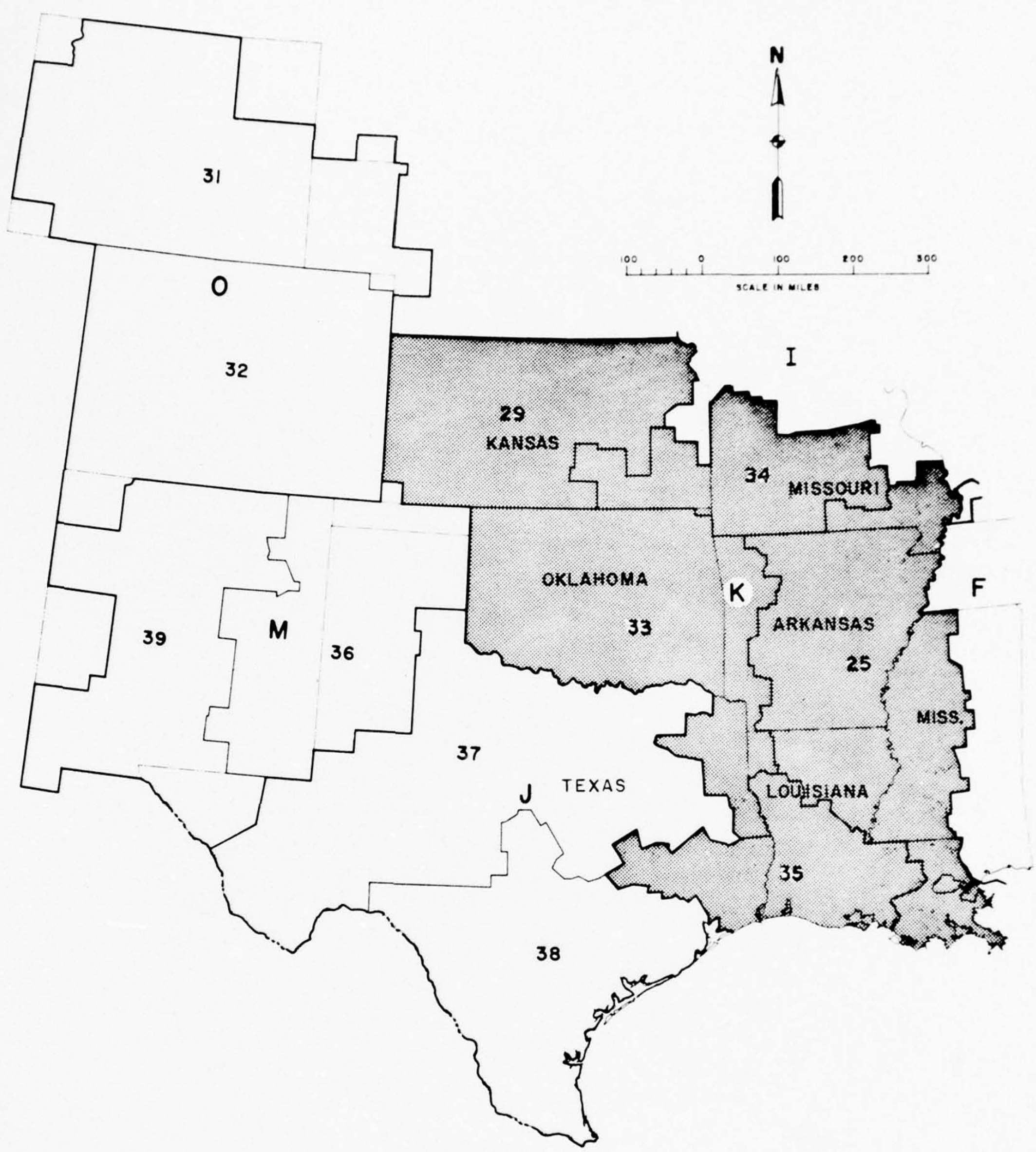
SECTION II - DESCRIPTION OF POWER MARKET AREA

6. GENERAL DESCRIPTION OF MARKET AREA

Power supply areas as established by the Federal Power Commission for power market surveys, hydroelectric power need and utilization studies, and other analyses of power supply and requirements comprise geographical areas substantially representing the electrical service areas of major electric utilities. Usually a power supply area encompasses a combination of utilities that operate in close coordination under a common holding company or under other pooling arrangements. In the development of the National Power Survey, power supply areas were combined into coordination study areas to facilitate studies of extra-high-voltage transmission, coal-field steam-electric generating stations, the more adequate utilization of hydroelectric capacities, and other broad factors affecting the future development of the electric utility industry.

Coordination Study Area K; which includes Power Supply Areas 25, 29, 33, 34, and 35; is a logical combination of power supply areas inasmuch as it substantially represents the area covered by the Southwest Power Pool and associated systems. Through varying degrees of coordinated operations, these systems share reserves, provide mutual assistance in emergencies, stagger construction of new generating capacity, participate jointly in the financing and construction of large sized units, construct long EHV transmission facilities, jointly arrange large seasonal diversity interchanges, make maximum utilization of peaking hydroelectric capacity, and improve service reliability. Coordination Study Area K, therefore, is the logical market area for future hydroelectric power development in the Red River Basin Below Denison Dam. Plate 1 shows the location and extent of Coordination Study Area K.

Study Area K in itself represents an adequate and suitable market for determination of needs for future hydroelectric capacity that may be constructed in the Red River Basin Below Denison Dam. The export and import of electric power made available by seasonal load diversity with TVA and by both seasonal load diversity and hydraulic diversity between the Missouri River and Arkansas-White-Red Basins are recognized in need and utilization studies. Other exports and imports affecting Study Area K are approximately offsetting.



LEGEND

K	COORDINATION STUDY AREA K
33	F.P.C. POWER SUPPLY AREAS

COMPREHENSIVE BASIN STUDY
RED RIVER BELOW DENISON DAM
LOUISIANA, ARKANSAS, OKLAHOMA, TEXAS

COORDINATION STUDY AREA K

SCALE AS SHOWN

PREPARED BY
FEDERAL POWER
COMMISSION

PLATE X-1

7. ADJUSTMENT OF MARKET AREA FOR PREFERENCE POWER USERS THROUGH THE MARKETING AGENCY

Congress, which authorizes the construction of Federal multipurpose projects, has provided a preference in the sale of hydroelectric power from such projects to certain types of power users. The principal "preference" power marketing agency in Study Area K is the Southwestern Power Administration (SPA). It is considered that hydroelectric power produced at the multiple-purpose projects in the Red River Basin Below Denison Dam can be marketed to "preference" power users anywhere within the interconnected service area of SPA, and is not limited to marketing within the basin. This marketing area includes both the area served by the SPA transmission system and areas in which SPA service may be provided through system integration contracts with others.

The marketing area for preference power users for the Red River Basin Below Denison Dam, shown on plate 1a, consists basically of Coordination Study Area K, excluding that part which is in Mississippi and excluding all of Kansas except Kansas City and that part of the eastern one-fourth that is south of Kansas City; but including the north half of Missouri for service principally to cooperatives.

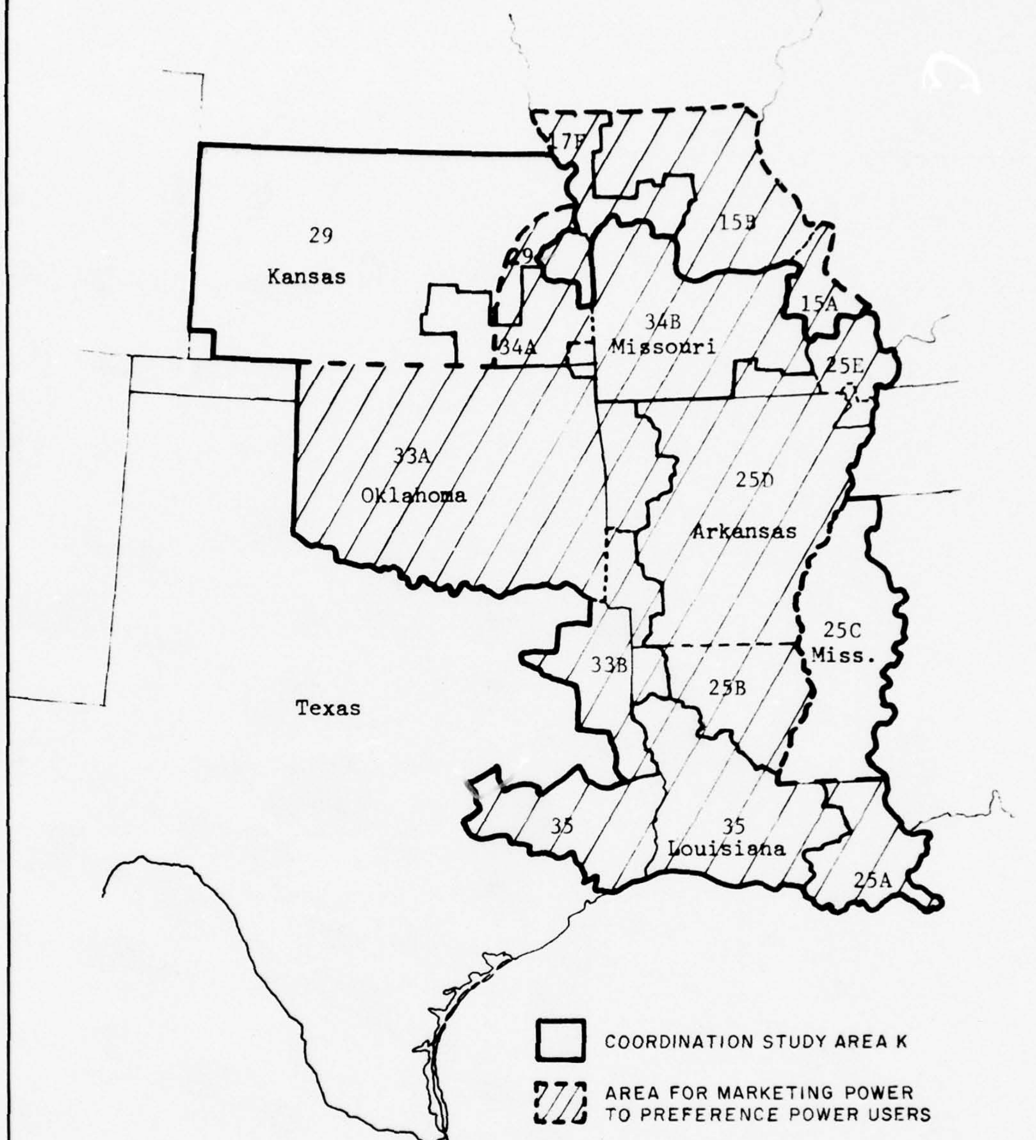
8. POPULATION IN THE MARKET AREA

The population in the power supply areas comprising Coordination Study Area K, the designated market area, is an important factor in electric energy consumption and according to the July 1960 Census is as follows:

Population in Thousands of Persons

Power Supply Area	Farm	Non-Farm	Total
25	803	3,787	4,590
29	247	882	1,129
33	452	2,855	3,307
34	282	1,184	1,466
35	213	1,678	1,891
Coordination Study Area K	1,997	10,386	12,383

Population estimates prepared by the Bureau of Census were adapted to power supply areas and utilized extensively in the development of the electric load forecasts prepared for the National Power Survey which are a basis of the load forecasts presented in this report. Actual and estimated farm and non-farm population as related to other multiple purposes in the Red River Basin Below Denison Dam comprehensive study are presented in the economic base study prepared principally by the Corps of Engineers, U. S. Department of Agriculture, and Bureau of Mines.



COMPREHENSIVE BASIN STUDY
RED RIVER BELOW DENISON DAM
LOUISIANA, ARKANSAS, OKLAHOMA, TEXAS

MARKETING AREA
PREFERENCE POWER USERS

PREPARED BY
SOUTHWESTERN
POWER
ADMINISTRATION

PLATE X-1a

Concentrations of population and industrial loads centralize electric loads in various areas. These load centers are often located along major water routes and at tidewater. The principal load centers in Study Area K, along with their actual 1960 and estimated 1970 and 1980 megawatt-load requirements including 12 percent reserve, are as follows:

Power Supply Area	Load Center Area	Capacity Requirements (mw) (Peak Load plus 12% Reserve) 1960	1970	1980
25	Jackson, Miss.	325	704	1,404
	Little Rock, Ark.	644	1,395	2,782
	Monroe, La.	226	489	976
	New Orleans, La.	964	2,085	4,161
29	Great Bend, Kan.	272	538	952
	Topeka, Kan.	393	773	1,378
33	Oklahoma City, Okla.	771	1,624	2,766
	Shreveport, La.	588	1,243	2,117
	Tulsa, Okla.	637	1,344	2,296
	Fort Smith, Ark.	237	493	851
34	Springfield, Mo.	394	805	1,456
	Wichita, Kan.	486	995	1,803
35	Baton Rouge, La.	511	1,429	3,191
	Beaumont, Tex.	408	1,146	2,556
	Lake Charles, La.	263	732	1,636

9. ECONOMIC FEATURES OF THE MARKET AREA

The comprehensive economic base study, as noted previously, presents a detailed analysis of the many factors which affect the multiple-purpose river basin development. Presented herein are some of the economic highlights that affect the electrical load growth in the designated market area. The energy requirements for farms ranged from 3,532 kwh per customer in PSA 25 to 6,509 kwh per customer in PSA 29 in 1965. This variation is closely related to the productivity of the soil, the type of farm, climate, characteristics of the farm population and price of competing fuels. Non-farm residential electric energy consumption in 1965 ranged from 3,909 kwh per home in PSA 29 to 5,261 kwh in PSA 35. Recent gains in residential consumption can be attributed to increasing acceptance of all types of refrigeration, air conditioning, and heating equipment, as well as to more extensive use of other appliances. Electric energy consumption per commercial outlet ranged from 20,998 kwh per customer in PSA 34 to 26,392 kwh per customer in PSA 35. Commercial utilization of electricity per customer is affected by the present high saturation of air conditioning, diversification of retail outlets, the advent of shopping centers, the expansion of electric cooking, and increasing recreational activities.

The industrial development and associated electric growth in Study Area K has been principally affected by the phenomenal growth of the petrochemical industry along the Gulf Coast where plentiful raw materials, water, pipelines, low fuel costs, lower construction costs, lower labor costs, and water transportation are available. Petroleum refining is growing moderately but is substantially stable. The continued development and diversification in chemicals and plastics presents a bright future, patricularly in the southern portion of Study Area K. The growing need for pulp and paper is expected to enhance electric load growth due to the primary and secondary influences of the development of new paper processing industries in the forested regions of Study Area K. The mineral industry in many areas provides a growing demand for power although in some areas the deposits are marginal or limited. It is not expected that the light metal industries will greatly expand future electric load growth due to the limited supplies of bauxite for the aluminum industry and the general practice of self-generation in the magnesium industry. Growth is expected in the aircraft industry, space industry, and in food processing, cement, fertilizer, and small appliance industries.

SECTION III - PAST AND ESTIMATED FUTURE POWER REQUIREMENTS

10. STUDY AREA POWER REQUIREMENTS

a. Annual power requirements. There is presented in table 1 historical and estimated future data on energy for load, peak demands, and annual load factors for the power supply areas encompassed by Coordination Study Area K. It is to be noted that the peak demand for Area K increased from 2,890 mw in 1950 to 13,070 mw in 1965. Estimated future load growth as developed for the National Power Survey, issued in 1964, is expected to reach 35,900 mw by 1980. This estimate has been trended to the year 2020 for the Red River Basin Below Denison Dam comprehensive study and the expected load at this time is estimated at 182,000 mw.

Table 1 also demonstrates the decrease in annual load factors between 1950 and 1965 due principally to the advent of residential and commercial air conditioning. This trend appears to be reversing at this time and moderate increases in load factors are expected in the future due partly to load building activities of the electric utility industry.

The estimated power requirements shown in table 1 are closely related to many of the economic factors of the market area. The power requirements are developed by classes of sales and combined into a total area requirement. The classes of service projected separately are farm, non-farm, residential, commercial, industrial, irrigation, street lighting, electrified transportation, other sales, and losses. Expected farm usage is related to trends of cash receipts from farm marketings, expected trends in numbers of farms, and consideration of the types of farms, including commercial farming. Residential load projections, in addition to being closely related to population, are determined on the basis of the appliance saturation factors, average annual energy consumption of appliances and other home uses of electrical energy.

Area economics, such as income guidelines, provide correlative data in establishing residential growth. Commercial sales projections are mathematically related to population projections and past trends of energy consumption. General area development guides help establish future expected commercialization. Industrial projections are predicated on a judgment basis after careful consideration of the value of mineral products, mineral reserves, value added by manufacture, industrial growth, electric loads as reported by the electric utilities, and the area potential for future industrialization.

TABLE 1

STUDY AREA K - ENERGY FOR LOAD, PEAK DEMAND, AND ANNUAL LOAD FACTOR

Power Supply Area	Energy for Load (million kwh)	Peak Demand (mw)	Annual Load Factor (%)	Peak Month	Energy for Load (million kwh)	Peak Demand (mw)	Annual Load Factor (%)	Peak Month
		1950				1955		
25	5,438	995	62.4	Sept.	10,332	1,886	62.5	Sept.
29	1,467	304	55.1	Dec.	2,437	519	53.6	Aug.
33	3,846	751	51.2	Aug.	6,911	1,477	53.4	July
34	1,955	379	58.9	Dec.	3,384	672	57.5	Aug.
35	2,696	461	66.8	Sept.	4,455	793	64.1	Aug.
Area K	15,402	2,890	60.8		27,519	5,347	58.8	
		1960				1965		
25	13,222	2,688	56.0	July	21,049	4,318	55.7	July
29	3,563	793	51.2	Aug.	5,235	1,196	50.0	July
33	10,456	2,353	50.6	July	15,833	3,642	49.6	July
34	5,017	1,056	54.1	Aug.	7,285	1,570	53.0	July
35	7,949	1,462	61.9	July	13,285	2,344	64.7	July
Area K	40,207	8,352	54.8		62,687	13,070	54.8	
		1970				1980		
25	30,800	6,390	55.0	Aug.	60,000	11,610	59.0	Aug.
29	7,320	1,580	53.0	Aug.	12,850	2,770	53.0	Aug.
33	22,360	5,000	51.0	Aug.	37,850	8,470	51.0	Aug.
34	10,440	2,250	53.0	Aug.	18,200	3,920	53.0	Aug.
35	22,350	4,080	62.5	Aug.	50,000	9,130	62.5	Aug.
Area K	93,270	19,300	55.2		178,900	35,900	56.7	
		2000				2020		
Area K	462,000	93,000	56.7	Aug.	904,000	182,000	56.7	Aug.

There is presented on figure 1 a graphical representation of the actual and estimated future classified sales projections from 1950 to 1980 with the total requirements extended from 1980 to 2020. The "all other" category includes irrigation and drainage pumping, electrified transportation, street lighting, and other minor uses. These data are related to historical trends that have been recorded by the Federal Power Commission since annual electric utility reporting was initiated prior to 1940. The future trends are predicated from historical data with careful observation of the various area and economic factors discussed in previous sections. Consideration is given to other sources of energy and their price relationships. Table 2 presents tabular data supporting figure 1.

TABLE 2

STUDY AREA K - CLASSIFIED SALES

	Year					
	1950	1955	1960	1965	1970	1980
			(million kwh)			
Farm	860	1,321	1,507	1,783	2,285	3,150
Irrigation and Drainage Pumping	12	71	214	163	262	370
Non-Farm Residential	2,453	5,039	9,364	15,737	23,290	46,500
Commercial	2,673	4,412	7,482	11,576	16,170	28,040
Industrial	6,391	12,031	15,419	24,277	37,670	76,440
Street Lighting	148	250	379	552	841	1,540
Electrified Transportation	58	47	36	7	6	0
All Other	708	1,140	1,557	2,641	3,396	5,570
Total to Ultimate Customers	13,303	24,311	35,958	56,736	83,920	161,610
Losses	2,099	3,208	4,249	5,951	9,350	17,290
Required Energy for Load	15,402	27,519	40,207	62,687	93,270	178,900

	Year	
	2000	2020
	(million kwh)	
Required Energy for Load	462,000	904,000

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PAST AND ESTIMATED FUTURE ENERGY REQUIREMENTS
(NPS STUDY AREA K)

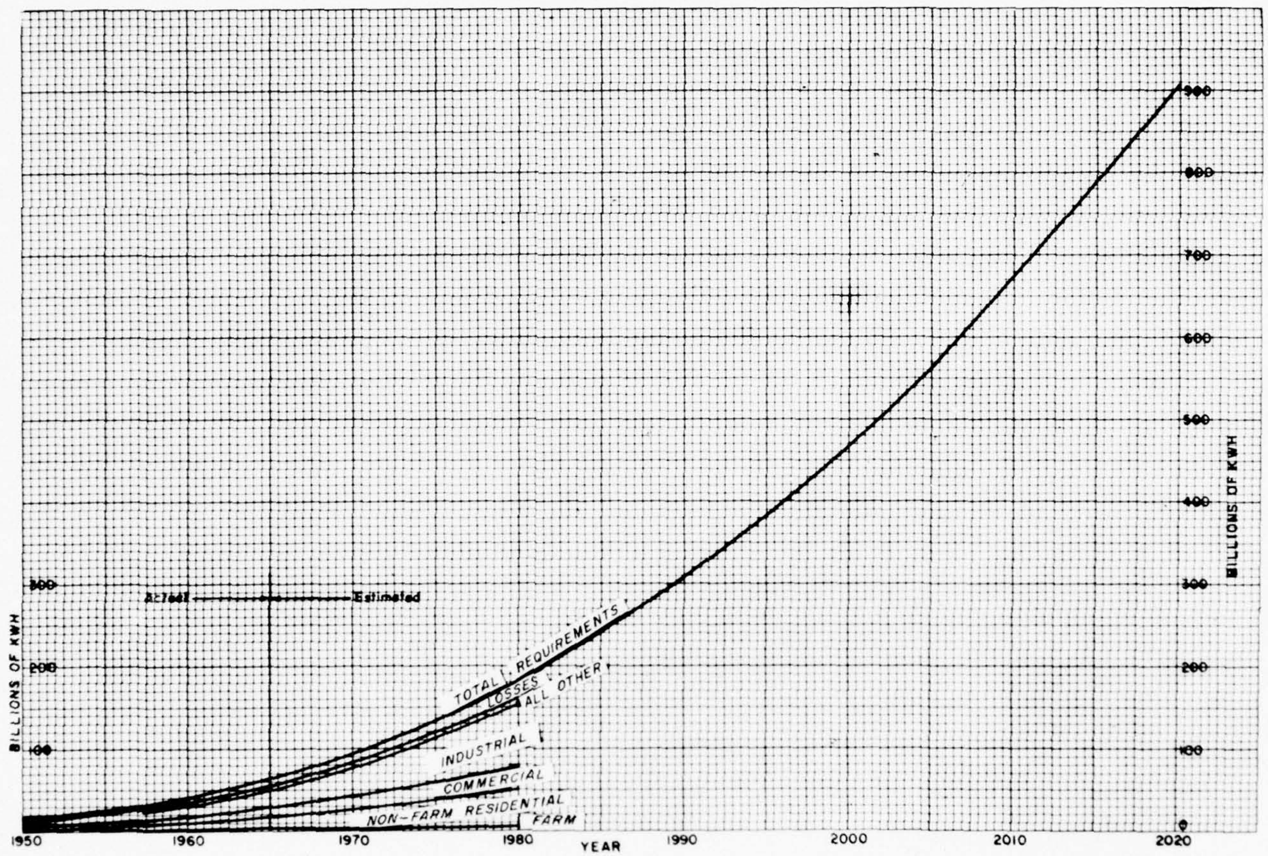


FIGURE I

b. Monthly power requirements. The estimated 1980 monthly energy requirements, peak demands, and load factors in the market area are as follows:

Month	Energy Requirements (million kwh)	(%)	Peak Demand (mw)	(% annual)	Load Factor (%)
Jan.	14,250	8.0	25,940	72.3	73.8
Feb.	12,350	6.9	24,660	68.7	72.0
Mar.	12,890	7.2	23,240	64.7	74.5
Apr.	12,580	7.0	24,250	67.5	72.1
May	14,310	8.0	28,370	79.0	67.8
June	16,210	9.1	33,410	93.1	67.4
July	18,280	10.2	35,400	98.6	69.4
Aug.	18,610	10.4	35,900	100.0	69.7
Sept.	16,370	9.2	33,690	93.8	67.5
Oct.	14,570	8.1	28,600	79.7	68.5
Nov.	13,530	7.5	26,440	73.6	71.1
Dec.	14,950	8.4	28,140	78.4	71.4
Annual	178,900	100.0	35,900	100.0	56.7

Air conditioning loads cause a peak season of power requirements in June, July, August, and September and the annual peak demand usually occurs in the first week of August. Daily peaks occur in the early afternoon as shown on the weekly curve illustrating the operation of pumped-storage projects. Growing loads will create a demand for large amounts of peaking capacity which hydroelectric plants are admirably suited to supply. A few plants having large amounts of storage can be operated at annual plant factors as low as five percent, provided water can be used as needed during the peak-load season.

11. PREFERENCE POWER USERS REQUIREMENTS

a. Annual power requirements. The historical and estimated future annual data on energy for load, peak demands, and load factors for the preference power users portion of the load encompassed in this study (the counterpart of table 1, for the total Area K load) is presented in table 1a.

TABLE 13

LOADS - PREFERENCE POWER USERS
ENERGY FOR LOAD, PEAK DEMAND, AND ANNUAL LOAD FACTOR

Year	Power Supply Area	Energy For Load (million kwh)	Peak Demand (mw)	Annual Load Factor %	Peak Month
	15&17	1,138	242	53.8	Aug.
	25	1,283	282	51.9	July
	29	36	9	45.2	Aug.
1958	33	1,511	374	46.1	July
	34	1,033	249	47.4	Aug.
	35	808	226	40.8	Aug.
	Total	5,809	1,382	48.0	
	15&17	1,391	292	54.3	Aug.
	25	1,577	436	41.3	July
	29	42	10	46.1	Aug.
1960	33	1,870	457	46.7	July
	34	1,267	309	46.9	Aug.
	35	1,017	282	41.1	July
	Total	7,164	1,786	45.8	
	15&17	1,543	327	53.8	Aug.
	25	1,963	536	41.8	Aug.
	29	48	12	43.5	July
1962	33	2,252	559	46.0	Aug.
	34	1,498	363	47.0	Aug.
	35	1,264	361	40.0	Aug.
	Total	8,568	2,158	45.3	
	15&17	1,766	377	53.5	Aug.
	25	2,376	662	41.0	Aug.
	29	57	14	46.2	July
1964	33	2,777	702	45.2	Aug.
	34	1,732	442	44.7	Aug.
	35	1,577	436	41.2	Aug.
	Total	10,285	2,633	44.6	
	15&17	1,777	397	51.1	July
	25	2,557	709	41.2	Aug.
	29	60	14	48.9	July
1965	33	2,989	738	46.2	Aug.
	34	1,833	442	47.4	Aug.
	35	1,772	488	41.4	Aug.
	Total	10,988	2,788	45.0	
	15&17	2,602	560	53.0	Aug.
	25	3,615	750	55.0	Aug.
	29	78	17	53.0	Aug.
1970	33	3,990	895	51.0	Aug.
	34	2,455	530	53.0	Aug.
	35	2,650	485	62.5	Aug.
	Total	15,390	3,237	54.3	
	15&17	4,470	965	53.0	Aug.
	25	6,730	1,300	59.0	Aug.
	29	120	25	53.0	Aug.
1980	33	6,320	1,415	51.0	Aug.
	34	3,970	855	53.0	Aug.
	35	5,370	980	62.5	Aug.
	Total	26,980	5,540	55.7	
2000	Total	62,700	12,620	56.7	
2020	Total	112,300	22,610	56.7	

The projection to 1980 is based on a composite of the load growth by class of service for each power supply subarea (as established by the National Power Survey) in accordance with the 1964 Load Growth Forecast of the Federal Power Commission. The composite trend was extended to the year 2020. The over-all result is shown graphically on the chart, figure 1a. Table 2a presents tabular data supporting figure 1a.

TABLE 2a

CLASSIFIED SALES - PREFERENCE POWER USERS

	Year 1958	1960	1962	1964	1965	1970	1980
	(million kwh)						
Farm	1,523	1,886	2,263	2,727	2,875	3,640	5,100
Residential	1,120	1,387	1,663	2,006	2,156	3,260	6,520
Commercial	1,108	1,373	1,646	1,853	1,958	2,910	5,120
Industrial	1,177	1,427	1,687	2,128	2,358	3,170	5,980
All other	341	422	507	607	634	890	1,460
Losses	540	669	802	964	1,007	1,520	2,800
Energy for load	5,809	7,164	8,568	10,285	10,988	15,390	26,980

	Year 2000	2020
Energy for load	62,700	112,300

In 1960 the preference power user loads, in the marketing area considered, represent about 21 percent of the capacity and 18 percent of the energy shown in table 1. Because of the difference in class of service being considered, the load growth of the preference power users is at a rate less than that for all power users in Study Area K. The preference power user portion of the load is expected to drop to about 15 percent for both the capacity and energy in 1980, and to about 12.5 percent by the year 2020.

ENERGY REQUIREMENTS OF PREFERENCE POWER USERS

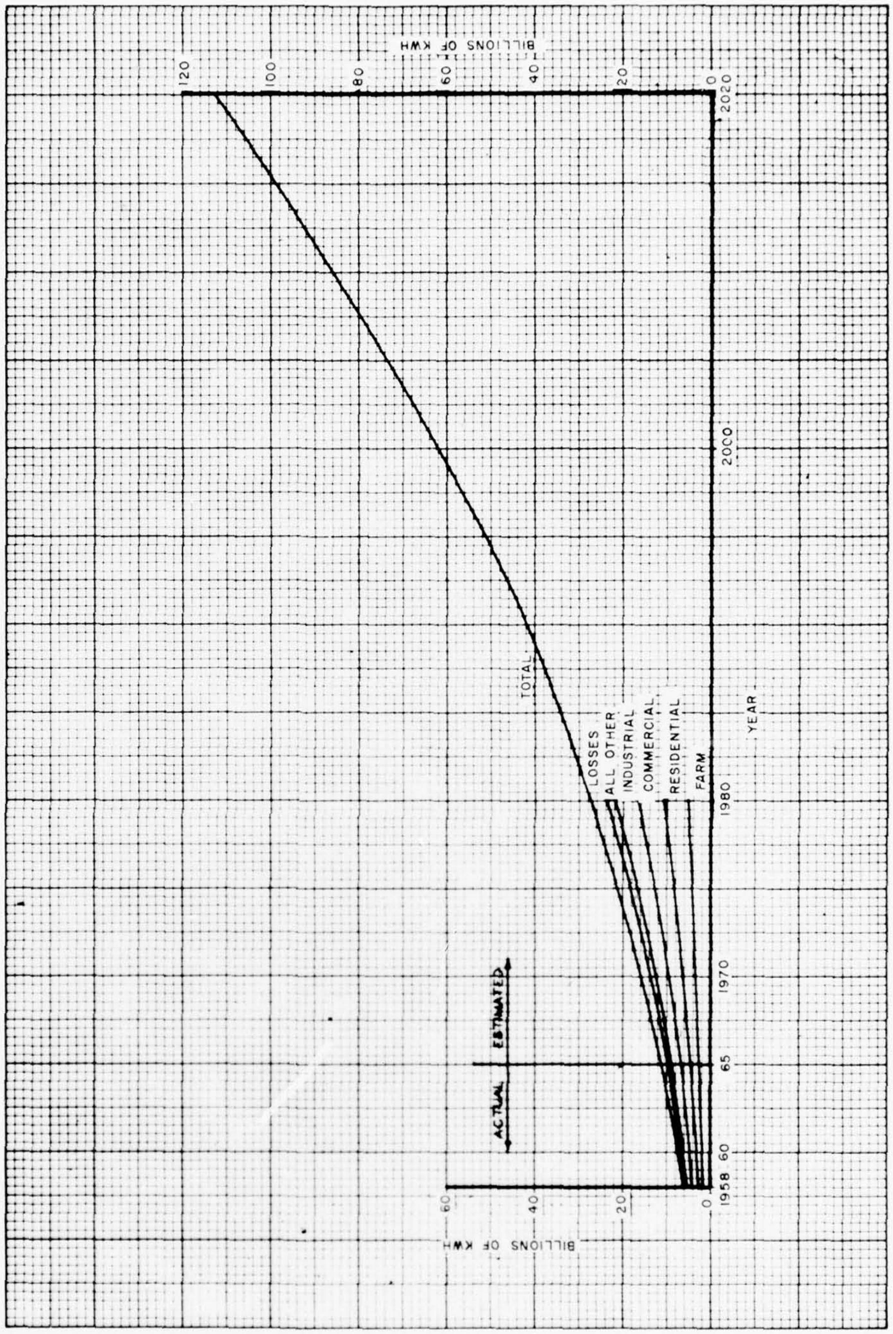


FIGURE 1a

b. Monthly power requirements. The estimated monthly variations in energy requirements, peak demands, and load factors of the preference power user load for 1980 are as follows:

Month	Energy Requirements (million kwh)	Energy Requirements (%)	Peak Demand (mw)	Peak Demand (% annual)	Load Factor (%)
Jan.	2,025	7.5	3,755	67.8	72.5
Feb.	1,915	7.1	3,700	66.8	77.0
Mar.	1,945	7.2	3,705	66.9	70.6
Apr.	1,970	7.3	3,830	69.1	71.4
May	2,075	7.7	4,155	75.0	67.1
June	2,400	8.9	4,890	88.3	68.2
July	2,860	10.6	5,405	97.6	71.1
Aug.	2,830	10.5	5,540	100.0	68.7
Sept.	2,590	9.6	4,915	88.7	73.2
Oct.	2,185	8.1	4,345	78.4	67.6
Nov.	2,050	7.6	4,060	73.3	70.1
Dec.	2,130	7.9	4,035	72.8	71.0
Annual	26,975	100.0	5,540	100.0	55.6

SECTION IV - EXISTING POWER SUPPLY FACILITIES

12. STUDY AREA K POWER FACILITIES

a. Utility systems. In Coordination Study Area K, the designated market for hydroelectric capacity in the Red River Basin below Denison Dam, most of the principal electric utilities are members of the Southwest Regional Group which is one of the four parts of the Interconnected System Group covering the midwest and southeastern United States. The Southwest Regional Group is a voluntary non-contractual organization of some 55 electric utilities from the Nebraska-South Dakota state line to the Gulf of Mexico and from New Mexico to central Mississippi. The Group sets policies, procedures, and operating regulations for the members. Within the Southwest Regional Group, the Southwest Power Pool and associated systems, comprised of 17 investor-owned and 8 non-investor owned systems, has a service area of approximately 350,000 square miles and includes all of the principal electric utilities in Study Area K and two systems in Study Area L, Nebraska. A list of the members in Study Area K is as follows:

Middle South Utilities & Ark-Mo Power Company 1/
- Arkansas Power & Light Company 2/
- Louisiana Power & Light Company 2/
- Mississippi Power & Light Company 2/
- New Orleans Public Service, Inc. 2/
- Arkansas-Missouri Power Company

Gulf States Utilities Company 2/
Central Louisiana Electric Company 2/
Southwestern Power Administration 4/6/

Public Service Company of Oklahoma 2/
Oklahoma Gas & Electric Company 2/
Southwestern Electric Power Company 2/
Grand River Dam Authority
Arkansas Electric Cooperative Corp.
Western Farmers Electric Cooperative

The Empire District Electric Company 2/3/4/
Missouri Public Service Company 3/4/
Kansas Gas & Electric Company 2/3/
The Kansas Power & Light Company 3/
Western Light & Telephone Company
Central Kansas Power Company
Missouri Utilities Company
City Utilities of Springfield, Missouri
Associated Electric Cooperatives, Inc. 4/
- N.W. Electric Power Cooperatives, Inc. 5/
- Central Electric Power Cooperative 5/
- Northeast Missouri Electric Power Cooperative 5/
- M&A Electric Power Cooperative 5/
- Sho-Me Power Corporation 5/
- KAMO Electric Power Cooperative 5/

(Footnotes are on following page)

1/ Generally known as the Middle South Integrated System pool.
2/ Component of the South Central Electric Companies pool.
3/ Component of the Missouri-Kansas Pool, which also includes the Kansas City Power & Light not listed above.
4/ Component of the Missouri Integration Pool, which includes the Kansas City Power & Light not listed above.
5/ Component of the Associated Electric Coop.
6/ The Missouri Integration Pool covered by Footnote 4 has an agreement with SPA covering hydro peaking capacity, etc.

The Southwest Power Pool maintains headquarters in Little Rock, Arkansas. The pool was created in the early part of World War II to provide an adequate and continuous supply of electric power and energy for civil and defense requirements. Within the Southwest Power Pool, the Middle South integrated system, as noted above, coordinates planning, interchanges economy energy, exchanges firm power and energy, provides emergency assistance, and coordinates maintenance schedules. A central dispatcher at Pine Bluff, Arkansas, schedules hourly generation on the integrated system based on incremental cost and losses by the use of an automatic dispatch computer.

The Missouri Integration Agreement has been negotiated, whereby 478,000 kw of hydroelectric peaking capacity from White River hydroelectric projects is marketed by the Southwestern Power Administration under long-term contracts to Associated Electric Cooperative (see six AEC members noted in above list) and three privately owned electric utilities; i.e. Kansas City Power & Light Company, Missouri Public Service Company, and the Empire District Electric Company. The Missouri-Kansas (Mo-Kan) Participation Agreement, as noted in footnote 3 of the above list, is a formal pooling arrangement whereby large new generating units will be constructed on a participation arrangement and 345-kv transmission will be made possible by the resulting savings. The participants' system reserves may be adjusted to a 10 percent fixed minimum base under the contract. Contractual arrangements have been created whereby peaking hydro generation available from SPA will be integrated into the systems to the considerable advantage of all participants.

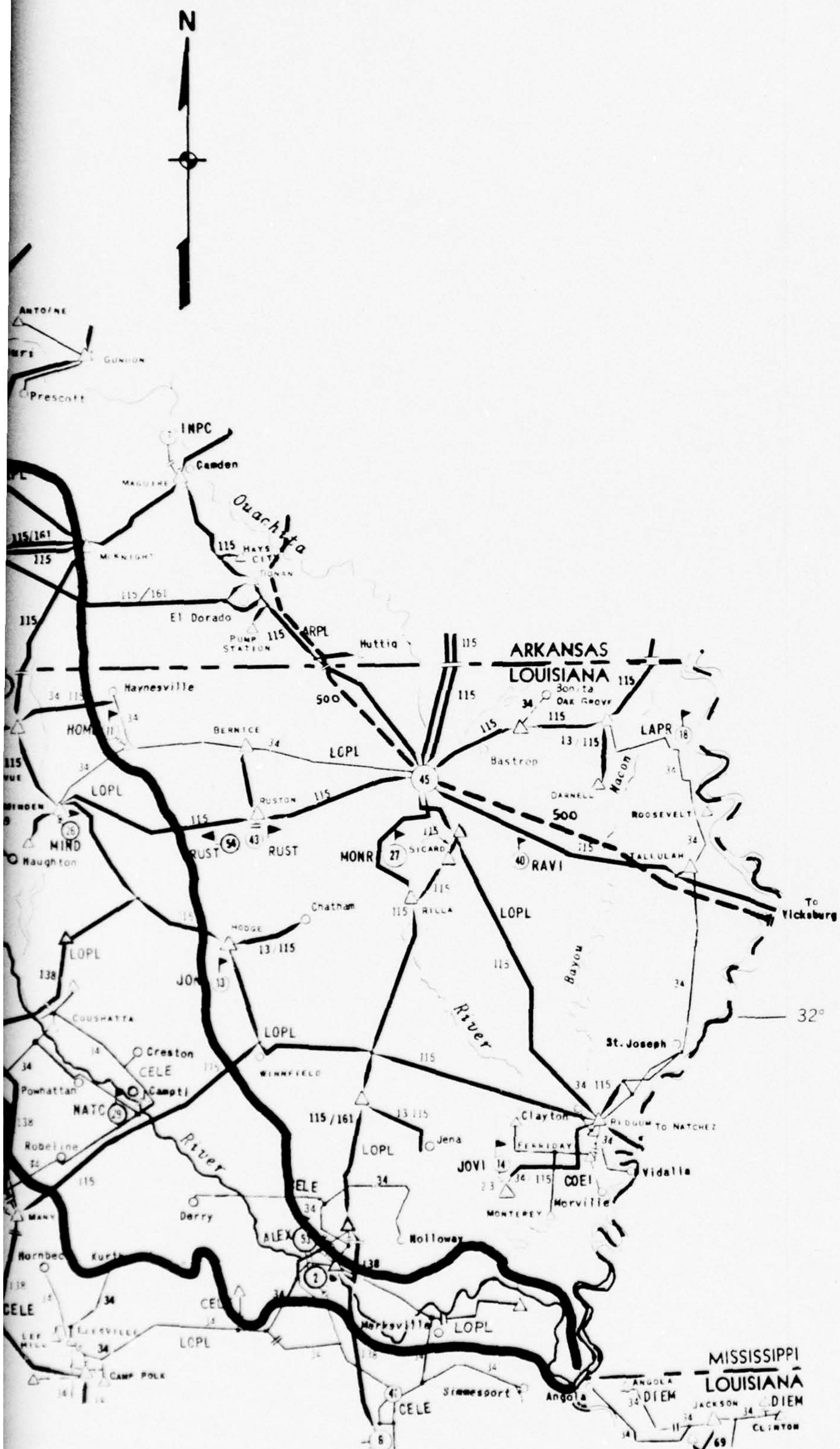
As was noted in footnote 2 of the above list, the 11 members of South Central Electric Companies (SCEC) have negotiated for a seasonal diversity exchange with TVA beginning with 435 mw in 1965 and increasing to 1,500 mw by the winter of 1968-1969. It is the intent of all parties to utilize diversity to the maximum extent and to take full advantage of the Associated EHV transmission for other system operating savings. SCEC has a headquarters in Little Rock, Arkansas, for scheduling of power flows, loss determinations, reserve analyses, and other studies. Public Service Company of Oklahoma and

Southwestern Electric Power Company are members of the Central and Southwest Corporation system but free interchange with the other two members of the system in Texas (West Texas Utilities Company and Central Power & Light Company) is prevented by restrictions imposed to maintain the intrastate status of several Texas companies.

The larger electric utilities operating in the confines of the Red River Below Denison Dam, as shown on the attached transmission map, Plate 2, are the Southwestern Electric Power Company, Louisiana Power and Light Company, Central Louisiana Electric Company, Arkansas Power and Light Company, Public Service Company of Oklahoma, Texas Power and Light Company, Southwestern Power Administration, and the City of Alexandria, Louisiana.

Coordination Study Area K is blanketed by a grid of transmission lines utilizing a mixture of 69-, 115-, 138-, 161-, and 230-kv facilities. In the Red River Basin Below Denison Dam, the Southwestern Electric Power Company, Central Louisiana Electric Company, Gulf States Utilities Company, and Public Service Company of Oklahoma operate a network of 69- and 138-kv facilities as an integral part of the Southwest Power Pool. Louisiana Power & Light Company and Arkansas Power & Light Company, also a part of the Southwest Power Pool, operate 115-kv lines in the Basin. The Southwestern Power Administration operates 138-kv facilities to the north and south from the Denison Project. Texas Power & Light Company operates 69- and 138-kv facilities in Northeast Texas although these facilities are not electrically interconnected with other utilities in the Basin. There is now developing throughout Study Area K a new system of 345- and 500-kv transmission facilities.

OKLAHOMA
ARKANSAS
OKLAHOMA
TEXAS
LOUISIANA
TEXAS
BASIN BOUNDARY
20 0 20 40 60
SCALE IN MILES
OKGE
PSOK
SPA
SOEP
USAR
CHOC
DIFI
TEPL
COPS
CUMM
GRUD
FARM
BOCE
LOSS
UPRE
ARPL
HOPE
INPC
LOPL
MIND
BORE
CELE
NATC
SARA
Red River
Little River
Sulphur River
Ouachita River
Seminole
Wetumka
Holdenville
Wilburton
Stuart
Coalgate
Harden City
Tupelo St.
Clarita
Wapanucka
Atoka
Stringtown
Dougherty
Gene Autry
Madill
Durant
Caney
Rattan
Soper
Valiant
Wright City
Bethel
Thackerville
Denison
Paris
Detroit
Bogata
Honey Grove
Bonham
Wolfe City
Leonard
Farmersville
Commerce
Caddo Mills
Royse City
Talco
Mount Pleasant
Naples
Pittsburg
Linden
Jefferson
Mineola
Big Sandy
Gladewater
Kilgore
Overton
Henderson
Carthage
Center
Logansport
Zwolle
Texarkana
Nashville
De Queen
Foreman
Patterson
Mena
Prescott
Plain Dealing
Shreveport
Haughton
Minden
Bellevue
Coushatta
Powhattan
Robeline
Many
Hornbeck
Kurthwood
Leesville



RED RIVER BELOW DENISON DAM PLANT LIST

Plant No.	Name	Mw Capacity and Type		Utility Abbrevi-ations
	ARKANSAS			
15	Couch, Harvey	188.0	St	ARPL
	LOUISIANA			
2	Alexandria No. 1	21.5	St	ALEX
3	Arsenal Hill	170.0	St	SOEP
19	Lieberman	277.3	St	SOEP
26	Minden	13.8	IC	MIND
29	Natchitoches	10.4	IC	NATC
		5.0	St	NATC
44	Springhill	49.3	St	INPC
53	Alexandria No. 2	97.5	St	ALEX
	OKLAHOMA			
8	Broken Bow	2.3	St	DIFI
57	Wright City	1.5	St	DIFI
67	Broken Bow	85.0	Hy*	USAR 1/
	TEXAS			
22	Clarksville	1.0	IC	TEPL
27	Commerce	4.2	IC	COMM
33	Daingerfield	32.9	St	LOSS
86	Lone Star	50.0	St	SOEP
122	River Crest	112.5	St	TEPL
168	Valley	199.0	St	TEPL
173	Wilkes	180.0	St	SOEP

* Under construction

1/ Power Marketing under Southwestern Power Administration

OWNERSHIP LIST

		ARKANSAS
ARPL	PRI	Arkansas Power & Light
SOEP	PRI	Southwestern Electric Power Co.
		LOUISIANA
ALEX	MUN	Alexandria
BORE	COOP	Bossier Rural Electric Membership Coop.
CELE	PRI	Central Louisiana Electric Co.
INPC	IND.	International Paper Co.
LOPL	PRI	Louisiana Power and Light Co.
MIND	MUN	Minden
NATC	MUN	Natchitoches
SOEP	PRI	Southwestern Electric Power Co.
		OKLAHOMA
CHOC	COOP	Choctaw Electric Cooperative, Inc.
DIFI	IND	Dierks Forests, Inc.
OKGE	PRI	Oklahoma Gas and Electric Co.
PSOK	PRI	Public Service Co. of Oklahoma
SPA	FED	Southwestern Power Administration
USAR	FED	U. S. Army
		TEXAS
BOCE	COOP	Bowie-Cass Electric Coop., Inc.
COMM	MUN	Commerce
COPS	PRI	Community Public Service Co.
LOSS	IND	Lone Star Steel Corp.
SOEP	PRI	Southwestern Electric Power Co.
TEPL	PRI	Texas Power and Light Co.
UPRE	COOP	Upshur Rural Electric Coop. Corp.

COMPREHENSIVE BASIN STUDY
RED RIVER BELOW DENISON DAM
LOUISIANA, ARKANSAS, OKLAHOMA, TEXAS

PRINCIPAL ELECTRIC FACILITIES

SCALE AS SHOWN

PREPARED BY
FEDERAL POWER
COMMISSION

JUNE 1968

PLATE

The installed and dependable capacity of electric utility generating plants in service in Coordination Study Area K as of December 31, 1965, is shown in the following table:

TABLE 3

COORDINATION STUDY AREA K

INSTALLED AND DEPENDABLE CAPACITY OF UTILITY GENERATING PLANTS
December 31, 1965

Power Supply Area	Gas Turbine	Hydro	Steam	Internal Combustion	Total
		Installed Capacity - (kilowatts)			
25	73,700	852,340	4,313,671	223,335	5,463,046
29	1,250	2,910	1,274,674	257,394	1,536,228
33	106,700	415,500	3,440,819	139,453	4,102,472
34	23,750	223,600	1,329,872	96,105	1,673,327
35	0	0	2,839,030	105,376	2,944,406
Area K	205,400	1,494,350 1/2/	13,198,066	821,663	15,719,479
		Dependable Capacity - (kilowatts)			
25	71,950	845,000	4,295,104	208,542	5,420,596
29	1,250	1,500	1,369,662	246,937	1,619,349
33	102,450	397,100	3,543,800	126,587	4,169,937
34	25,750	204,900	1,376,880	91,061	1,698,591
35	0	0	2,728,894	93,574	2,822,468
Area K	201,400	1,448,500 1/2/	13,314,340	766,701	15,730,941

1/ Total capacity includes small hydroelectric plants: i.e., Osceola, Lowell, Niangua, Dams 1 and 3, Bowersock Mills & Power Co., Rocky Ford, Marysville, and Lake Eucha (totals are 11,550 kw installed capacity and 6,500 kw dependable capacity) which are not included in the total dependable capacity used in future monthly load curve analyses because of their small size and are not included in tables 5, 6, 7, and 8.

2/ Taum Sauk pumped-storage plant with rated capacity of 350,000 kw is marketed outside Study Area K and is excluded from this table.

Of the above total, 84.6 percent of the dependable capacity is steam-electric, 9.2 percent is hydroelectric, 4.9 percent is internal combustion, and 1.3 percent is gas turbine driven capacity. The largest generating units in service as of December 31, 1965 (manufacturer's maximum nameplate rating), were Louisiana Power and Light Company's Little Gypsy No. 2 rated at 420,750 kw and Arkansas Power and Light Company's Robert E. Ritchie No. 1 with a rating of 359,040 kw. As a result of the developing EHV grid and growing loads, larger units are under construction and scheduled as discussed later. The James River Plant of Springfield has the largest steam-electric generating units located in the White River Basin and had an installed capacity of 148,000 kw in 1965. Missouri Utilities Company, M&A Electric Coop., and the Cities of Poplar Bluff, Jonesboro, Thayer, and others operate smaller generating stations throughout the basin.

Gas is the principal fuel for steam-electric generation in Study Area K although the use of coal is increasing in Missouri, eastern Kansas, and northeastern Arkansas. There are at the present time no commercial nuclear plants in Study Area K (or the basin) but a commercial nuclear plant of approximately 800 megawatts is scheduled for construction in Study Area K outside the basin. An experimental nuclear reactor project is under construction near Fayetteville, Arkansas. Large conventional outdoor gas-fired steam-electric generating units comprise the principal current and future power supply and thus provide the logical alternative for evaluation of hydroelectric facilities in the basin.

b. Industrial plants. Throughout Coordination Study Area K, a large number of industries own and operate their own generating plants. The installed capacity for industry-owned generation in the area as of December 31, 1965 amounted to 1,796 mw of steam-electric capacity, and 268 mw of diesel-electric capacity for a total of 2,064 mw. Total generation during 1965 was 13,995 million kwh.

By far the largest of the industry-owned generating plants is the Kaiser Aluminum Company primary aluminum reduction plant at Chalmette in Saint Bernard Parish, Louisiana, which had a 1965 installed capacity of 398,000 kw steam and 103,200 kw diesel, and a 1965 generation of 4,094 million kwh. The alumina plants of Alcoa at Bauxite, Arkansas, and of Kaiser at Gramercy and Baton Rouge, Louisiana, had a total installed capacity of 77,750 kw, and a 1965 generation of 537.7 million kwh.

A number of large pulp and paper industrial generating plants are located in the forested portions of the study area. International Paper Company's Pine Bluff plant in Arkansas is the largest with an installed capacity of 97,880 kw and a 1965 generation of 565.9 million kwh. International Paper has other large generating stations at plants located near Camden, Arkansas; Springhill and Bastrop, Louisiana; and Natchez, Mississippi; Gaylord Container Corporation, Olin Mathieson

Chemical Corporation, and Georgia Pacific Corporation have generating plants near Bogalusa and Monroe, Louisiana and Crossett, Arkansas.

A number of large refinery and chemical generating plants are located in the area, particularly along the Gulf Coast and lower reaches of the Mississippi River. The Dow Chemical Company's Plaquemine, Louisiana plant has installed generating capacity of 110,000 kw and generated 1,019.8 million kwh during 1965. The Pittsburgh Plate Glass Company has two plants in the Lake Charles, Louisiana area with installed generating capacity of 90,000 kw and 83,680 kw with 1965 generation of 636 million kwh and 236 million kwh, respectively. The Texas Company and Socony Mobil Oil Company have large refineries at Port Arthur and Beaumont, Texas, respectively, including generating facilities. Other chemical and refining facilities with generation are concentrated in the Beaumont-Port Arthur-Lake Charles and Baton Rouge areas.

Other industrial plants engaged in the manufacturing, processing, or production of sulphur, sugar, lumber, other forest products, salt, cement, and lime, have their own generation at many locations due principally to the advantages of utilizing steam in processing.

In the Red River Below Denison Dam there are a number of industry-owned generating plants. The largest plant is the Lone Star Steel Company's 32,875 kw steam-electric station at their steel mill near Lone Star, Texas. Other plants with their own generation are engaged in the manufacturing or processing of cement, window glass, forest products, sewer pipe and petroleum and gas products.

Industry-owned generation is not a part of the public power supply but is given consideration in projecting future electric utility load levels.

c. Interarea transfers. By far the largest interarea transfer to be considered between Study Area K, the designated market for the Red River Basin below Denison Dam hydroelectric power, and adjoining areas is the seasonal diversity exchange scheduled between the South Central Electric Companies (SCEC) and the Tennessee Valley Authority (TVA). The 11 companies organized as SCEC operate as a part of the Southwest Power Pool and operate in the States of Arkansas, Oklahoma, Louisiana, Mississippi, Missouri, Kansas, and Texas. These utilities all have a decided summer peak, principally resulting from seasonal air conditioning loads. TVA, on the other hand, has a high winter peak load attributable principally to electric heating. By the winter of 1968-1969, the exchange of seasonal diversity will provide the delivery of 1,500 mw of seasonal diversity capacity to TVA from the SCEC companies in winter and the reverse in summer. Two 500-kv lines from the TVA area connecting to an extensive SCEC grid of 500- and 345-kv lines provide the necessary EHV transmission to deliver the scheduled interchange. An interarea transfer of 1,500 mw between Study Area K and Study Area F (TVA) is therefore utilized in the 1970 power requirements and supply analyses. Studies are now in progress toward an expansion of this exchange to 2,500 mw during the early years of the 1970 decade. Indications are that this more extensive exchange will be feasible and the power requirements analyses for 1980 therefore reflect a 2,500 mw interarea transfer between Study Areas K and F.

A 161-kv interconnecting tie line passing through Maryville in northwest Missouri has been placed in service between Southwestern Power Administration operating in the Arkansas-White-Red River Basins and the Bureau of Reclamation Eastern Division, Missouri River Basin Area and is described in the preference user section which follows. Within the limitations of the transmission capacity and generating capability, excess hydroelectric energy available during flood periods and at times of other required releases such as for navigation, excess energy may be transferred between basins having the effect of storing water for later production of usable energy. Similarly, hydraulic benefit may be obtained when adverse hydro conditions occur in either area. With this interconnection, the Southwestern Power Administration system and also the Missouri River Basin system is now considered as having an additional 25 mw of power available for customer service.

In addition to the above seasonal diversity power exchanges, there are a number of contractual firm power commitments affecting utilities operating along the boundary of Study Area K, particularly that portion bordering on Study Area I. These contracts are generally offsetting, subject to rather frequent revision, and are therefore not included in the long-term analyses of power supply and requirements.

d. Retirements. The retirement of generating units involves many operating variables and may be greatly influenced by one principal factor such as space in the plant building. Actual operating experience gives an indication of what to expect. Older machines are usually used for peaking and standby service after having been displaced from base load service by more efficient and larger units. Equipment retired in some cases is not immediately dismantled since the cost of removal may exceed its salvage value. In other cases, sites for station locations have become difficult to find and sometimes unavailable at any reasonable price. Under these circumstances, older units are removed to provide space for newer, more efficient and larger units. Many retirements in the past have been on the basis of aging, physical condition and high operating cost. In the future, it is possible that unit size and obsolescence will be deciding factors as small units become less important with system capacity doubling approximately every ten years. Power pooling by EHV interconnections will tend to promote earlier retirements of units. In general, the retirement age of generating units is assumed to be 35 years in the development of capacity available. Retirements subsequent to 1980 will involve the modern type of high-pressure high-temperature equipment with critical metallurgy and complicated cycle arrangements. This type of equipment may be subject to lower life expectancy - possibly 30 years.

e. Scheduled additions. Extensive and adequate advance planning is essential in order to meet in the most economical manner the rapidly growing future requirements for electric power. Increasing plant size has been a natural step to reap the advantages of economies of scale in capital cost, operation and maintenance. The combination of increasing power demands, decreasing number of excellent sites, and EHV interconnections result in a trend for developing larger units. These larger units have contributed to the increase in temperature and pressure of throttle steam into the supercritical range.

Listed below are known units (300 mw or larger) which are being planned in Study Area K:

Major Scheduled Additions to
Fuel Electric Generating Capacity in Study Area K

PSA	Utility	Plant	Installed Capacity (mw)	Date in Service
25	Mississippi Pwr. & Lt. Co.	Baxter Wilson #1	500*	12/66
25	New Orleans Pub.Svc.Co.,Inc.	Michoud #3	500*	4/67
25	Arkansas Power & Light Co.	Robt.E.Ritchie #2	500*	1/68
25	Louisiana Power & Light Co.	Little Gypsy #3	500*	12/68
25	Arkansas Power & Light Co.	Lake Catherine #4	500	12/69
25	Louisiana Power & Light Co.	Ninemile Pt. #4	550*	12/70
33	Public Ser. Co. of Okla.	Southwestern #3	310	5/67
33	Oklahoma Gas & Elec. Co.	Horseshoe Lake #8	415	5/69
33	Southwestern Public Ser. Co.	Wilkes #2	345	1970
33	Public Ser. Co. of Okla.	Northeastern #2	450*	1970
34	Kansas Gas & Electric Co.	Gordon Evans #2	368	4/67
34	Missouri Public Service Co.	Sibley #3	340*	3/69
35	Gulf States Utilities Co.	Sabine #3	410	11/66
35	Gulf States Utilities Co.	Willow Glen #3	530*	11/68
35	Gulf States Utilities Co.	Nelson #4	530*	11/69

*Super critical steam conditions

A study of the possible critical period operation of hydroelectric plants on the estimated load shape in Study Area K for the year 1970 indicates that hydroelectric capacity appears to saturate the peak portion of the load; however, as the load grows, it will be possible to provide additional peaking capacity to meet this growing segment of the load.

13. PREFERENCE POWER USERS FACILITIES

a. Thermal resources of preference power users. Table 3a presents a summation of the existing generation facilities of the preference power users encompassed in this study. There are 126 generating plants, of which 115 (91 percent) belong to municipalities. Three-fourths of the plants are below 10 mw in size and principally use internal combustion engines.

TABLE 3a

CAPACITY OF GENERATING PLANTS
OF PREFERENCE POWER USERS
December 31, 1965

Power Supply Area	Gas Turbine	Steam	Internal Combustion	Total
	Installed Capacity - (kilowatts)			
15&17	0	386,280	28,905	415,185
25	22,000	207,354	197,229	426,583
29	0	0	5,529	5,529
33	0	209,650	120,320	329,970
34	0	240,250	78,222	318,472
35	0	299,679	90,519	390,198
Total	22,000	1,343,213	520,724	1,885,937
	Dependable Capacity - (kilowatts)			
15&17	0	394,700	27,140	421,840
25	20,000	208,650	184,949	413,599
29	0	0	4,830	4,830
33	0	222,500	108,559	331,059
34	0	238,750	73,326	312,076
35	0	307,550	83,335	390,885
Total	20,000	1,372,150	482,139	1,874,289

Twelve municipalities, using additional internal combustion units to supply their load increase, have developed internal combustion plants larger than 10 mw; noteworthy and unusual in this group is the 30-mw plant of Ponca City, Oklahoma. Eight municipalities have supplemented their internal combustion plants with steam plants, and eleven depend entirely on steam generation.

There are only two gas turbine plants owned by municipalities in the study area. Houma, Louisiana, has supplemented its 20-mw internal combustion plant with a 12-mw gas turbine; and Monroe, Louisiana operates 10-mw gas turbine generation in connection with its 96-mw steam plant.

Although only 21 percent of the plants are steam plants, they contain about 70 percent of the total generating capability.

b. Exchange contracts. There are no major exchange contracts among the preference power user group. However, during short-term periods of excess or need, several power users have made temporary power displacement arrangements to meet temporary shortages with power from distant plants having excess capability.

A major part of the power marketing to preference customers by the Southwestern Power Administration (SPA) is accomplished through contracts with, and facilities of, companies and generating and transmission cooperatives. These contracts include interchange, peaking power sales, energy purchase and/or wheeling arrangements; and require principally, peaking power from the SPA system.

c. Purchase contracts. At the end of 1965 the preference power users owned sufficient generating plants to supply approximately two-thirds of the 2,788-mw total load. The other one-third of the power was obtained by purchases from private utility companies and from State and Federal agencies.

Sufficient plant additions have been scheduled so that the preference power users will have capacity to supply almost 90 percent of their requirements in 1970. However, because of lack of interconnections for full utilization, some of this amount would not be utilized in 1970. The actual supply probably will more closely approximate 75 percent of the load. The other 25 percent will be purchased from companies and from State and Federal agencies.

Plant additions have not been scheduled further than 1971 and cannot readily be forecast at this time. They will be influenced to a large extent by the power that is available for purchase, the transmission interconnections that are available, and the economic feasibility of purchasing power.

d. Interarea transfers. SPA has a 161-kv interconnection with the Missouri River Basin system of the Bureau of Reclamation. Because of the hydraulic and electrical load diversities between the two areas, this line increases the marketable capacity available in both areas. This line has been used for the transfer of more than 60-mw of power.

e. Plant retirements. For the purpose of this study it has been assumed that any retirements of units in the plants of preference power users would necessarily be replaced by an equal amount of new generation. The only plant changes considered in the data tabulations are the plant additions already scheduled.

f. Scheduled additions. The major plant additions (100 mw or more) being planned by the preference power users are shown below.

Major Scheduled Additions to Fuel Electric Generating Capacity of Preference Power Users

PSA	Utility	Plant	Installed Capacity (mw)	Date in Service
15	Associated Elec. Coop	Thomas Hill, Mo.	150	12/66
15	Associated Elec. Coop	Thomas Hill, Mo.	250	6/69
25	Arkansas Elec. Coop	Augusta, Ark.	117	7/66
25	Arkansas Elec. Coop	Camden, Ark.	125	1970
33	Western Farmers Elec. Coop	Mooreland, Okla.	135	1968
34	Springfield, Mo.	Springfield, Mo.	105	1970
35	Alexandria, La.	Plant No. 2	100	1971

14. EXISTING HYDROELECTRIC RESOURCES

a. Projects in the Red River Basin below Denison Dam. In Study Area K there are twenty-nine existing hydroelectric projects with installed capacity of 3,237,400 kilowatts including those projects under construction and those definitely scheduled. Seven of these projects are located in the Red River Basin below Denison Dam (includes those in the Ouachita River Basin). These seven projects have a combined installed capacity of 368.8 mw. Five of the projects are Federal and are operated by the Corps of Engineers. Two projects are privately owned. All of these projects are listed in table 4.

TABLE 4

EXISTING HYDROELECTRIC PROJECTS IN RED RIVER BASIN BELOW DENISON DAM
December 31, 1965 1/

Plant	Installed Capacity - (mw) Existing	Under Construction	Definitely Scheduled	Total	Dependable Capacity (mw)	Average Annual Energy (million kwh)
Denison 2/	35.0 4/	-	-	35.0 4/	27.0 4/	123.5 4/
Broken Bow 2/	-	100.0	-	100.0	86.0	129.0
Blakely Mt. 3/	75.0	-	-	75.0	65.0	155.9
Carpenter 3/	56.0	-	-	56.0	59.0	103.3
Remmel 3/	9.3	-	-	9.3	10.0	49.0
De Gray 3/	-	68.0	-	68.0	62.0	91.1
Narrows 3/	17.0	8.5	-	25.5	21.0	29.1
Total	192.3	176.5	-	368.8	330.0	680.9

1/ Includes projects under construction.
2/ Located in Lower Red River Basin.
3/ Located in Ouachita River Basin portion of Red River Basin.
4/ One-half of totals are tabulated since one-half of output is considered to be available for Texas (Study Area J).

Five of these are Federal projects, constructed and operated by the Corps of Engineers, with operation of the power plants subject to instructions as listed subsequently, by plants. These five projects are:

(1) Denison, with installed capacity of 70.0 mw in two 35.0 mw units which were placed in operation in 1945 and 1949. There are provisions for an ultimate installation of five units with a total capacity of 175.0 mw. One unit is scheduled by the Southwestern Power Administration (SPA) into its system and the other unit is scheduled by Texas Power and Light Company under contract with the SPA.

(2) Broken Bow, under construction, with tentative in-service date of 1969. The power plant, with installed capacity of 100.0 mw in two 50.0-mw units, will be operated in accordance with loading instructions from the SPA.

(3) Blakely Mountain, with installed capacity of 75.0 mw in two 37.5-mw units, began commercial production of power in 1955. The power plant is operated according to loading instructions from the Arkansas Power and Light Company. By

contract with the SPA, the company schedules generation from the plant as needed for its system and in return the SPA withdraws a contractually specified amount of power from the company's system at other points.

(4) DeGray, under construction with scheduled completion during 1971, will include a power plant of one 40.0-mw conventional unit and one 28.0-mw reversible unit. There are provisions for an additional conventional unit. It is contemplated that the power plant will be operated in the same manner as the Blakely Mountain plant.

(5) Narrows, placed in operation during 1950. The initial installation is 17.0 mw, two 8.5-mw units, with space for a third 8.5-mw unit which is scheduled to be placed in-service during 1968. The power plant is operated in accordance with loading instructions from the Southwestern Electric Power Company arranged contractually by the SPA.

The Carpenter and Remmel projects are tandem power projects owned and operated by the Arkansas Power and Light Company under Federal Power Commission license No. 271. The Remmel plant was completed in 1924 with three units and total capacity of 9.3 mw. There are provisions for two additional units. The Carpenter plant was completed in 1932 with installed capacity of 56.0 mw in two 28.0-mw units. There is space for one additional unit. The plants are operated by the Arkansas Power and Light Company for peaking purposes on the interconnected system of the Middle South Utilities.

There are no definitely scheduled hydro projects in the Red River Basin below Denison Dam at this time.

b. Projects in other basins in Study Area K. The remaining 22 hydroelectric projects outside of the Red River Basin and within Study Area K are listed with some of their pertinent data in tables 5, 6, and 7.

TABLE 5

EXISTING HYDROELECTRIC PROJECTS IN WHITE RIVER BASIN
December 31, 1965

Plant	Installed Capacity (mw)	Dependable Capacity (mw)	Average Annual Energy (million kwh)
Beaver	112.0	112.0	172.0
Table Rock	200.0	200.0	495.0
Ozark Beach	16.0	- 1/	94.4
Bull Shoals	340.0	340.0	785.0
Norfork	70.0	70.0	196.0
Taum Sauk 2/	350.0	- 2/	- 2/
Greers Ferry	96.0	96.0	189.0
Total	1,184.0	818.0	1,931.4

1/ Dependable capacity limited by high tailwater during, and following, flood periods.

2/ Project is physically located within Area K, but generation is marketed on system of Union Electric Company outside of Area K. Rated capacity is 350 mw. Name plate is 408 mw at unity power factor.

TABLE 6

EXISTING HYDROELECTRIC PROJECTS IN ARKANSAS RIVER BASIN
December 31, 1965 1/

Plant	Installed Capacity - (mw) Existing	Under Construction	Definitely Scheduled	Total	Dependable Capacity (mw)	Average Annual Energy (million kwh)
Keystone	-	70.0	-	70.0	70.0	228.0
Pensacola	86.4	-	-	86.4	85.0	330.0
Salina	-	130.0	390.0	520.0	520.0 2/	520.0 3/
Markham Ferry	108.0	-	-	108.0	110.0	190.0
Fort Gibson	45.0	-	-	45.0	45.0	190.5
Webbers Falls	-	60.0	-	60.0	66.0	213.3
Tenkiller Ferry	34.0	-	-	34.0	28.0	114.5
Eufaula	90.0	-	-	90.0	88.0	317.0
Robert S. Kerr	-	110.0	-	110.0	110.0	459.0
Ozark	-	100.0	-	100.0	100.0	429.0
Dardanelle	93.0	31.0	-	124.0	124.0	613.0
Total	456.4	501.0	390.0	1,347.4	1,346.0	3,604.3

1/ Includes projects under construction and definitely scheduled.
2/ This installation will be accomplished in four stages, 130-mw each; 130-mw definitely scheduled for 1968 and the three remaining stages planned for 1971, 1974, and 1977.
3/ Based on 1,000 hr./yr. operation. Pumping and generating cycle efficiency will be 76.2 percent.

TABLE 7

EXISTING HYDROELECTRIC PROJECTS WITHIN STUDY AREA K
OTHER THAN IN WHITE, RED, OR ARKANSAS RIVER BASINS
December 31, 1965 1/

Plant	Installed Capacity - (mw) Existing	Under Construction	Definitely Scheduled	Total	Dependable Capacity (mw)	Average Annual Energy (million kwh)
Neches River Basin						
Sam Rayburn	52.0	-	-	52.0	49.0	116.8
Missouri River Basin						
Stockton	-	45.2	-	45.2	44.0	55.0
Kaysinger Bluff	-	160.0	-	160.0	160.0	282.0
Total	-	205.2	-	205.2	204.0	337.0
Sabine River Basin						
Toledo Bend	-	80.0	-	80.0	80.0	205.2
Total other basins	52.0	285.2		337.2	333.0	659.0

1/ Includes projects under construction.

TABLE 8

DEPENDABLE HYDROELECTRIC CAPACITY, EXISTING, UNDER CONSTRUCTION, AND SCHEDULED IN STUDY AREA K

Plant	Dependable Capacity (mw) Existing 12-31-65	Scheduled 1966-1970	Scheduled 1971-1980	Total 1980
Red River Basin				
Denison	27.0 1/	-	-	27.0 1/
Broken Bow	-	86.0	-	86.0
Blakely Mountain	65.0	-	-	65.0
Carpenter	59.0	-	-	59.0
Remmel	10.0	-	-	10.0
De Gray	-	-	62.0	62.0
Narrows	14.0	7.0	-	21.0
White River Basin				
Beaver	112.0	-	-	112.0
Table Rock	200.0	-	-	200.0
Bull Shoals	340.0	-	-	340.0
Norfork	70.0	-	-	70.0
Greers Ferry	96.0	-	-	96.0
Arkansas River Basin				
Keystone	-	70.0	-	70.0
Pensacola	85.0	-	-	85.0
Salina	-	130.0	390.0	520.0
Markham Ferry	110.0	-	-	110.0
Fort Gibson	45.0	-	-	45.0
Webbers Falls	-	-	66.0	66.0
Tenkiller Ferry	28.0	-	-	28.0
Eufaula	88.0	-	-	88.0
Robert S. Kerr	-	55.0	55.0	110.0
Ozark	-	-	100.0	100.0
Dardanelle	93.0	31.0	-	124.0
Missouri River Basin				
Stockton	-	-	44.0	44.0
Kaysinger Bluff	-	-	160.0	160.0
Neches-Sabine Basin				
Sam Rayburn	-	49.0	-	49.0
Toledo Bend	-	80.0	-	80.0
Total	1,442.0	508.0	877.0	2,827.0

1/ One-half of capacity is tabulated since one-half of output is considered to be available for Texas (Study Area J).

c. <u>Summary of hydroelectric projects in Study Area K</u>. The total dependable capacity of existing, under construction, and definitely scheduled hydroelectric projects in Study Area K is 2,827,000 kw and the total average energy is 6,875.6 million kwh. The analyses of future monthly load curves in this report do not include the Salina and Webbers Falls projects.

With the above noted exceptions, the load curves reflect the dependable capacity of existing and under-construction projects to be marketed in Area K.

15. STUDY AREA K

The following table 9 shows power requirements, power supply, and additional capacity needed in Study Area K for 1965, 1970, and 1980.

TABLE 9

ADDITIONAL DEPENDABLE CAPACITY TO SUPPLY ESTIMATED ELECTRIC UTILITY LOADS IN STUDY AREA K (megawatts)

	1965	1970	1980
Capacity Requirements			
Peak Demand	13,070	19,300	35,900
Reserve Requirement (12%)	1,568	2,316	4,310
Total Capacity Required	14,638	21,616	40,210
Capacity Available			
Existing Fuel-Electric 12-31-65	14,282	14,282	14,282
Less Estimated Retirements	0	934	1,460
Net Fuel-Electric	14,282	13,348	12,822
Existing Hydroelectric 12-31-65	1,442 1/	1,442 1/	1,442 1/
Scheduled Additions to Fuel-Elec.	-	9,273	9,273
Scheduled Additions to Hydro	-	508 1/	1,385 1/
Imports of Firm Power	448	1,525 2/	2,525 3/
Total Capacity Available	16,172	26,096	27,447
Additional Capacity Required	(1,534)	(4,480)	12,763

1/ See table 8.
2/ SCEC-TVA Seasonal Capacity Agreement. Hydroelectric capacity diversity from NPS Study Areas I and L estimated to be 25 mw.
3/ SCEC-TVA capacity diversity estimated to increase to 2,500 mw by 1980. Hydroelectric capacity diversity from NPS Study Areas I and L estimated to be 25 mw.

The preceding table, which allows a reserve requirement of 12 percent, shows a surplus of capacity of 1,534 mw in 1965 and 4,480 mw in 1970 and a deficiency of 12,763 mw in 1980. A major part of this deficiency in 1980 will be met by future steam-electric generating capacity. The tabulation demonstrates the large and growing need for additional generating capacity in the future, some of which may be met by conventional and pumped-storage hydroelectric capacity. The Federal Power Commission's National Power Survey of 1964 was not extended beyond 1980 and adequate details are not available for extending the above table beyond that date for this report.

16. PREFERENCE POWER USERS

Part 11 of Section III described the power needs of the preference power users (tabulated in table 1a). Part 13 of Section IV discussed the existing thermal-electric power supply of the preference users (tabulated in table 3a), power exchange arrangements, and major planned plant expansions. The Federal hydroelectric projects data included in table 8 (including that part of the capacity in the State hydro projects committed to the service of preference users), is combined with the above information to develop the estimated additional capacity that will be required by preference power users in 1980: shown in table 9a.

The capacity retained by the companies, listed in table 9a under "Less Hydroelectric to Companies", is considered essential use of hydroelectric power in supplying total electric service to preference power users.

TABLE 9a

ADDITIONAL DEPENDABLE CAPACITY REQUIRED
TO SUPPLY ESTIMATED PREFERENCE POWER USER LOAD
(megawatts)

	1965 1/	1980
Capacity Requirements		
Peak Demand	2,788	5,540
Reserve Requirements (12%)	335	665
Total	3,123	6,205
Capacity Available		
Existing Fuel Electric (Dependable 12/65)	1,874	1,874
Less Retirements	-	-
Scheduled Additions to Fuel (Electric)	-	1,151
Existing Hydroelectric (Dependable 12/65)	1,373	1,373
Scheduled Additions to Hydroelectric	-	785
Less Hydroelectric to Companies 2/	-286	-576
Total	2,961	4,607
Additional Capacity Required	162	1,598

1/ 1965 data is used in the first column in this tabulation inasmuch as the 1965 load data is the latest actual data used in the base for projecting the power requirements for preference power users to 1980, 2000, and 2020.

2/ Hydroelectric capacity retained by companies under arrangements whereby transmission and off-peak energy is supplied by companies.

17. PORTION OF FUTURE LOAD WHICH COULD BE SUPPLIED BY POTENTIAL HYDROELECTRIC PROJECTS

a. Advantages in hydroelectric projects in supplying future load.

(1) General. Hydroelectric plants have several important advantages over thermal plants. They neither consume water, nor do they heat the waters of rivers and streams as thermal plants do with the possibility of causing thermal pollution; and they do not contribute to air pollution. The maintenance costs of hydroelectric plants are relatively low, and in many cases the plants can be designed for automatic or remote control operation. The ability to start quickly and change power output rapidly makes hydroelectric plants particularly suitable for carrying peak loads.

When hydro peaking capacity is added to meet load growth, system energy costs are greater, as a rule, than they would be if base-load thermal units were added instead. However, this differential becomes negligible over the life of the project due to the displacement of the alternate thermal plant from a base-load position when the thermal plant is new to a peaking position during the later years of its useful life.

(2) Multiple purpose projects. Sites for the economical development of single purpose hydro plants in Study Area K are virtually non-existent. There are a number of factors which contribute to this situation. Technological advancement is producing a continuing decrease in unit cost of steam-electric developments, the competing alternative source of electric power. Thus, hydroelectric development is being subjected to increasingly heavy challenge in regard to economics. Another deterrent is the awareness in recent years of the shortage of water in long range plans for resource development. This has resulted in a low priority for hydroelectric power in the planned use of water storage. Therefore, the future development of most hydroelectric power is dependent on the addition of this function to a project which might be constructed for other primary purposes.

In many cases the development of hydroelectric power provides such other associated benefits as recreation, fish and wildlife enhancement, flood control, and cooling water for thermal-electric plants and industrial plants. Many multiple-purpose projects would not be economically justified without the inclusion of power as one of the project purposes. The favorable characteristics of hydroelectric power and the frequent multiple use benefits associated with its development provide strong incentives for utilizing the remaining potential of our water power resources wherever they can be developed on an economical basis. Peak loads usually occur in months coincident with peak water supply needs in this area and where water supply withdrawals are made downstream from the powerhouse make the inclusion of hydroelectric power more adaptable to projects in which water supply is of paramount importance.

(3) Peaking operations. Peaking capacity is generally understood to mean that part of a system's generating equipment which is operated intermittently for short periods during the hours of highest daily, weekly, or seasonal demand. Variations in power demands are caused by many factors, but usually the maximum loads result from weather extremes superimposed on the more normal peaks associated with the living habits and work schedules of the population served and characteristics of the industries included in the load.

Hydroelectric developments in Study Area K are designed to operate largely during the hours of peak power loads. The annual cost of providing peaking capacity by installing additional units in hydroelectric plants is less, in most cases, than the cost of additional capacity at alternative sources. Also the ability to start quickly and change power output rapidly makes hydroelectric plants particularly suitable for carrying peak loads and for assistance in the supply of spinning reserve. Hydroelectric plants having seasonal or annual storage frequently have their operations scheduled to serve loads during only the months of highest peak demands on the system. Plants having only sufficient storage for daily operations are used daily during the hours of peak load.

The growing need for peaking capacity is resulting in planning for lower plant factor operations. However, the effects of such operations, with the accompanying high discharges of water for short periods of time, must be carefully studied to be certain that they are consistent with the over-all basin development. One hydroelectric plant in Study Area K has been planned and constructed to operate at an annual plant factor of about five percent to meet particular system needs. Operated primarily for peaking power at low plant factor, project sites previously considered infeasible of development may be found to be economical as the need for additional peaking capacity develops.

b. Potential hydroelectric resources.

From past studies made at various times under varying conditions of cost, a backlog of potential sites for hydroelectric power development in Study Area K has been catalogued. The total, for conventional and pumped-storage installations, is 14,087,400 kw, of which 7,958,000 kw are in the Red River Basin as listed in table 10.

TABLE 10

HYDROELECTRIC POTENTIALS IN RED RIVER BASIN

	Project	State	PSA	Installed Capacity (mw)	Remarks
	Gainesville	Tex.-Okla.	33	50.0 2/	
	Dougherty	Okla.	33	25.0	
	Durwood	Okla.	33	20.0	
	Denison	Tex.-Okla.	33	52.5 2/	Additional capacity at existing project.
1/	Durant	Okla.	33	7.5	
1/	Boswell	Okla.	33	7.6	Authorized without power.
1/	Tuskahoma	Okla.	33	1,000.0	Pumped storage.
1/	Choctaw	Okla.	33	450.0	Pumped storage.
1/	Jack Fork	Okla.	33	1,300.0 3/	Pumped storage.
1/	Clayton	Okla.	33	1,000.0 3/	Pumped storage.
1/	Buck Creek	Okla.	33	12.0	
1/	Upper Antlers	Okla.	33	100.0	
1/	Hugo	Okla.	33	900.0	Authorized without power. Potential includes 850-mw pumped storage.
1/	Caney Mountain	Okla.	33	18.0	
1/	Pine Creek	Okla.	33	86.0	Authorized without power.
1/	Lukfata	Okla.	33	32.0	Authorized without power.
1/	Sherwood	Okla.	33	1,600.0 4/	100-mw conventional, 500-mw reversible units, 1,000-mw adjoining pumped storage.
1/	Broken Bow	Okla.	33	700.0	Pumped storage. Additions to under construction conventional power plant.
1/	DeQueen	Okla.	33	14.0	Under construction without power.
1/	Gillham	Ark.	33	430.0	Under construction without power. Potential includes 380-mw pumped storage.
1/	Dierks	Ark.	33	13.5	Under construction without power.
	Fiddler's Creek	Ark.	25	20.0	
	Carpenter	Ark.	25	28.0	Additional capacity at licensed project.
	Remmel	Ark.	25	6.6	Additional capacity at licensed project.
	Rockport	Ark.	25	8.0	
	Caddo Gap	Ark.	25	2.3	
	De Gray	Ark.	25	40.0	Additional capacity at existing project.
	Riggs Bluff	Ark.	25	6.0	
	Kirkland	Ark.	25	4.0	
	Benton	Ark.	25	25.0	
	Total			7,958.0	

1/ Located in Red River Basin Below Denison Dam.
2/ One-half of potential capacity is tabulated since one-half of output is considered to be available for Texas (Study Area J).
3/ Based on preliminary studies and field reconnaissance.
4/ 10- to 15-year plan includes 600-mw combination of conventional and reversible units. Potential pure pumped storage of 1,000-mw remains.

It is to be recognized that further study as to the usability of potential Red River Basin below Denison Dam hydro on the Study Area K load will be necessary since there are other potentials located within Study Area K outside the basin boundaries. Also, the marketing agency for power generated at federally constructed projects must give preference in marketing such power to certain customers. Accordingly, each hydroelectric installation definitely proposed by a Federal construction agency must be individually examined as to both economic and financial feasibility prior to authorization and also prior to construction to determine whether or not suitable marketing arrangements under the preference clause can be negotiated.

Other potentials in other basins within Study Area K are shown in tables 11 and 12. These potentials include future additional capacity at existing plants, authorized inactive projects, and sites that have been screened and found to warrant further consideration under appropriate conditions of economics and site development for other purposes. It is emphasized that this list of potential projects is not to be considered as firm since much additional study would be required based on modern day procedures, conditions, and costs to develop a reasonably accurate listing.

TABLE 11

HYDROELECTRIC POTENTIALS IN WHITE RIVER BASIN

Project	State	PSA	Installed Capacity (mw)	Remarks
Grandview	Ark.	25	18.0	
Galena	Mo.	34	43.0	
Ozark Beach	Mo.	34	24.0	Additional capacity at licensed project.
Cotter	Ark.	25	33.0	
Buffalo City	Ark.	25	30.0	
Compton	Ark.	25	1,000.0 1/	Pumped storage. On proposed Buffalo National Scenic River.
Point Peter	Ark.	25	700.0 1/	Pumped storage. On proposed Buffalo National Scenic River.
Gilbert	Ark.	25	87.0	Includes 31.0-mw reversible unit. On proposed Buffalo National Scenic River.
Lone Rock	Ark.	25	90.0 2/	Authorized for flood control. On proposed Buffalo National Scenic River.
Norfork	Ark.	25	70.0 3/	Additional capacity at existing project.
Optimus	Ark.	25	500.0 1/	Pumped storage.
Marcella	Ark.	25	1,000.0 1/	Pumped storage.
Wolf Bayou	Ark.	25	180.0	
Clearwater	Mo.	34	28.0	Existing project for flood control and water supply.
Blair Creek	Mo.	34	120.0	On Ozark National Scenic Riverways.
Doniphan	Mo.	34	60.0	On Ozark National Scenic Riverways.
Wildhorse	Ark.	25	13.0	
Hardy	Ark.	25	52.0	
Water Valley	Ark.	25	25.0	Authorized without power. On proposed National Scenic Riverway.
Bell Foley	Ark.	25	24.0	Authorized without power.
Millers Point	Ark.	25	600.0 1/	Pumped storage.
Judsonia	Ark.	25	18.0	
Total			4,715.0	

1/ Based on preliminary studies and field reconnaissance.
2/ Alternate plan provides for run-of-river power plant with 22-mw capacity.
3/ 10- to 15-year plan includes 85-mw addition.

TABLE 12

HYDROELECTRIC POTENTIALS IN STUDY AREA K
OTHER THAN WHITE OR RED RIVER BASINS

Project	State	PSA	Installed Capacity (mw)	Remarks
Arkansas River Basin				
Kaw	Okla.	33	25.0	Project authorized without power.
Oologah	Okla.	33	12.0	Project constructed with power deferred.
Chewey	Okla.	33	42.0	
White Oak	Ark.	33	500.0	Pumped storage.
Nimrod	Ark.	25	14.0	Existing project for flood control and water supply.
Petit Jean	Ark.	25	500.0	Pumped storage
Total			1,093.0	
St. Francis River Basin				
Rowland Church	Mo.	25	35.0	
Wappapello	Mo.	25	7.5	Existing flood control and water supply project.
Total			42.5	
Yazoo River Basin				
Arkabutla	Miss.	25	12.0	Existing flood control and water supply project.
Sardis	Miss.	25	15.0	Existing flood control and water supply project.
Grenada	Miss.	25	5.0	Existing flood control and water supply project.
Total			32.0	
Missouri River Basin				
Pomme de Terre	Mo.	34	16.8	Existing flood control and water supply project.
Richland	Mo.	34	25.0	
Arlington	Mo.	34	30.0	
Total			71.8	
Big Black River Basin				
Youngton (Edwards)	Miss.	25	28.0	
Kansas River Basin				
Milford	Kan.	29	13.0	
Tuttle Creek	Kan.	29	20.0	
Topeka	Kan.	29	20.0	
Tecumseh	Kan.	29	15.0	
Lecomptan	Kan.	29	15.0	
Eudora	Kan.	29	25.0	
Total			108.0	
Neches River Basin				
Rockland	Tex.	35	13.5	Authorized - inactive.
Dam "A"	Tex.	35	2.7	Authorized - inactive.
Dam "B"	Tex.	35	2.9	Existing flood control and water supply project.
Total			19.1	
Sabine River Basin				
Bon Wier	Tex.	35	20.0	Project located below Toledo Bend Dam
Total Other Basins			1,414.4	

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c. Estimated load shapes for 1980, 2000, and 2020.

(1) Study Area K. Figures 2, 3, and 4 show - for the peak month of August - the possible critical period operation of hydroelectric plants on the estimated load shapes in Study Area K for the years 1980, 2000, and 2020. These load shapes are projected from the National Power Survey estimates to 1980. The estimated load shape for the peak week in 1980 is shown later in this section of the report under the discussion of pumped-storage hydroelectric plants, Study Area K load.

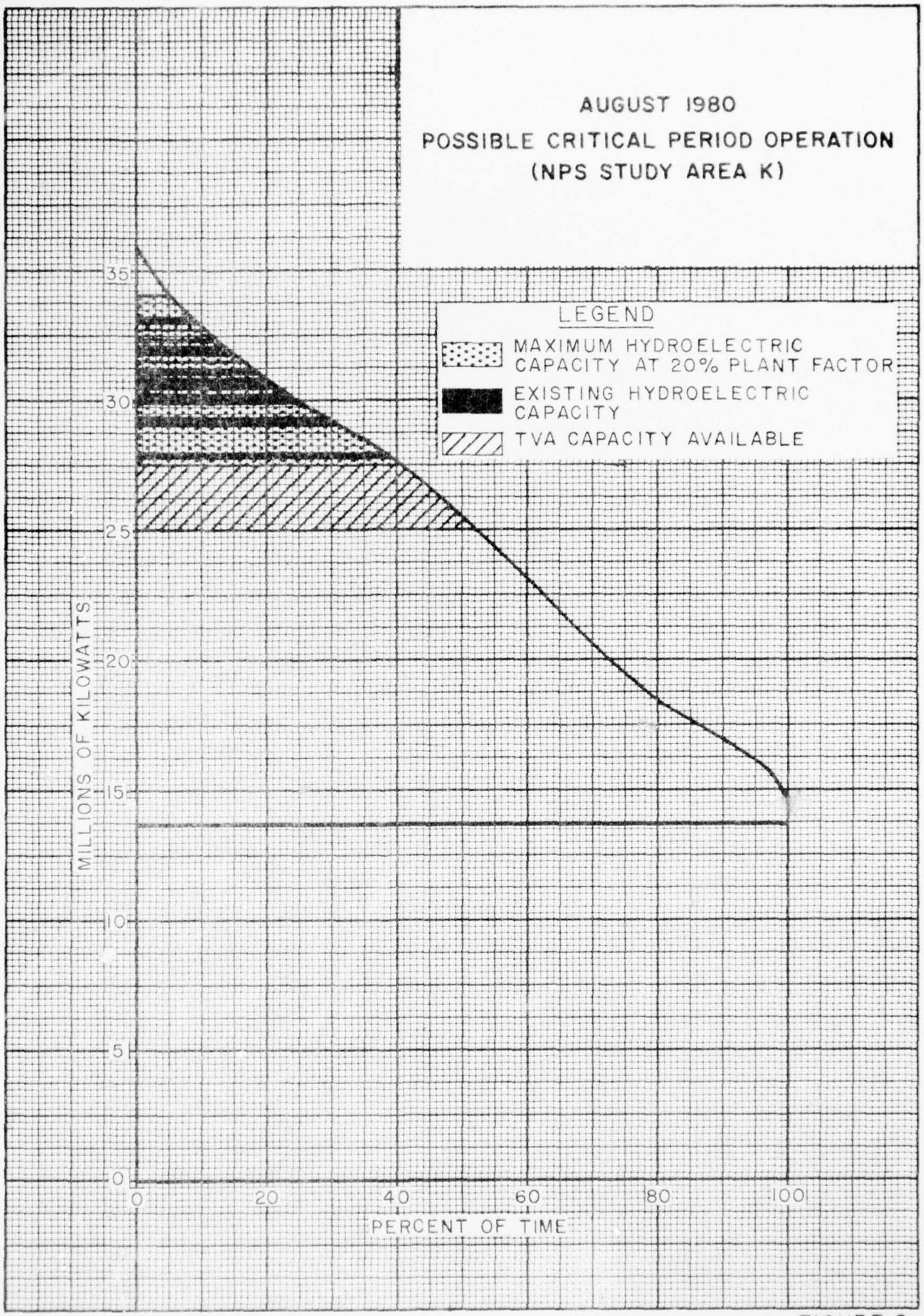

AUGUST 1980
POSSIBLE CRITICAL PERIOD OPERATION
(NPS STUDY AREA K)
LEGEND
MAXIMUM HYDROELECTRIC CAPACITY AT 20% PLANT FACTOR
EXISTING HYDROELECTRIC CAPACITY
TVA CAPACITY AVAILABLE
MILLIONS OF KILOWATTS
35
30
25
20
15
10
5
0
0
20
40
60
80
100
PERCENT OF TIME

FIGURE 2

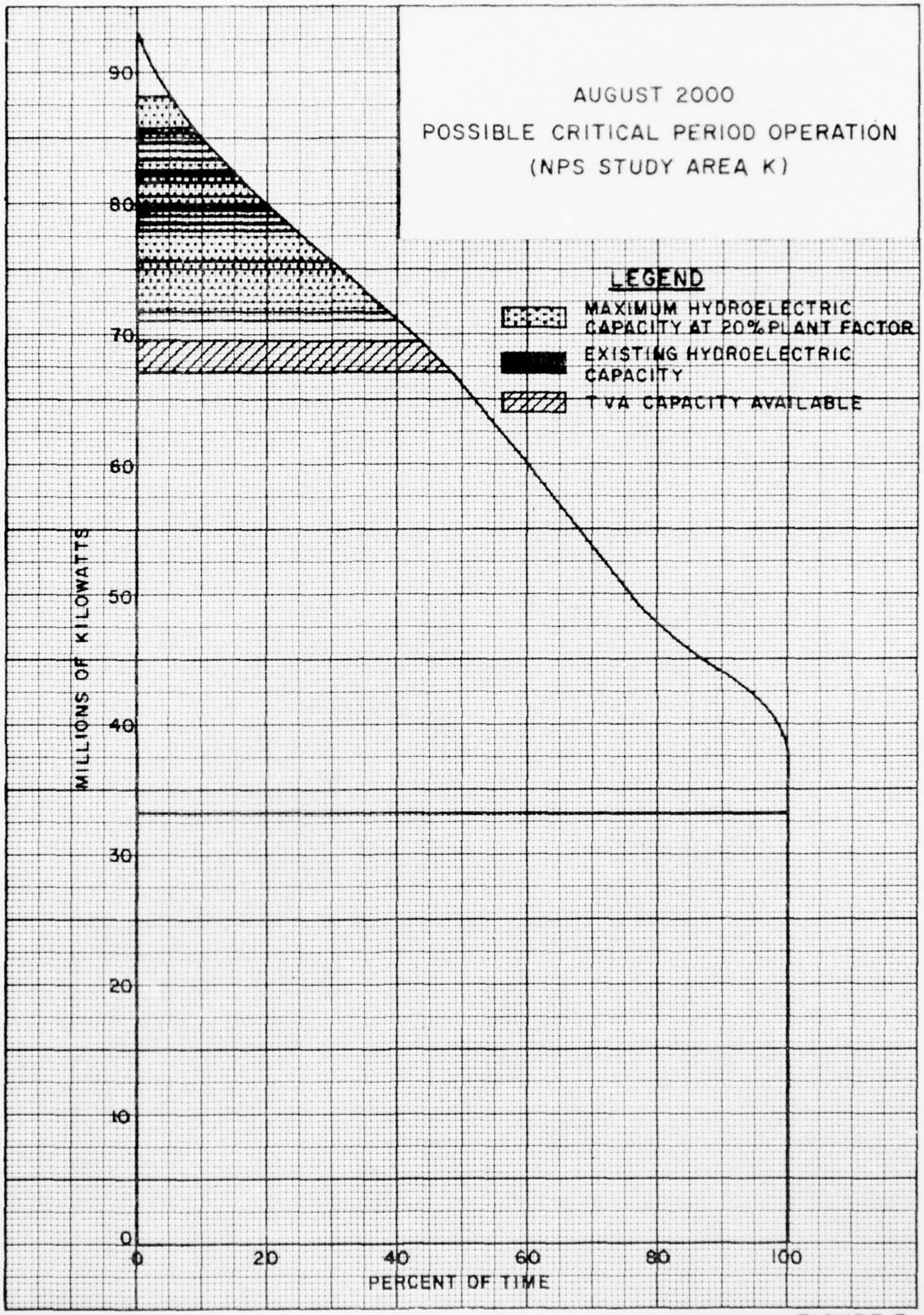

AUGUST 2000
POSSIBLE CRITICAL PERIOD OPERATION
(NPS STUDY AREA K)
LEGEND
MAXIMUM HYDROELECTRIC CAPACITY AT 20% PLANT FACTOR
EXISTING HYDROELECTRIC CAPACITY
TVA CAPACITY AVAILABLE
MILLIONS OF KILOWATTS
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
PERCENT OF TIME

FIGURE 3

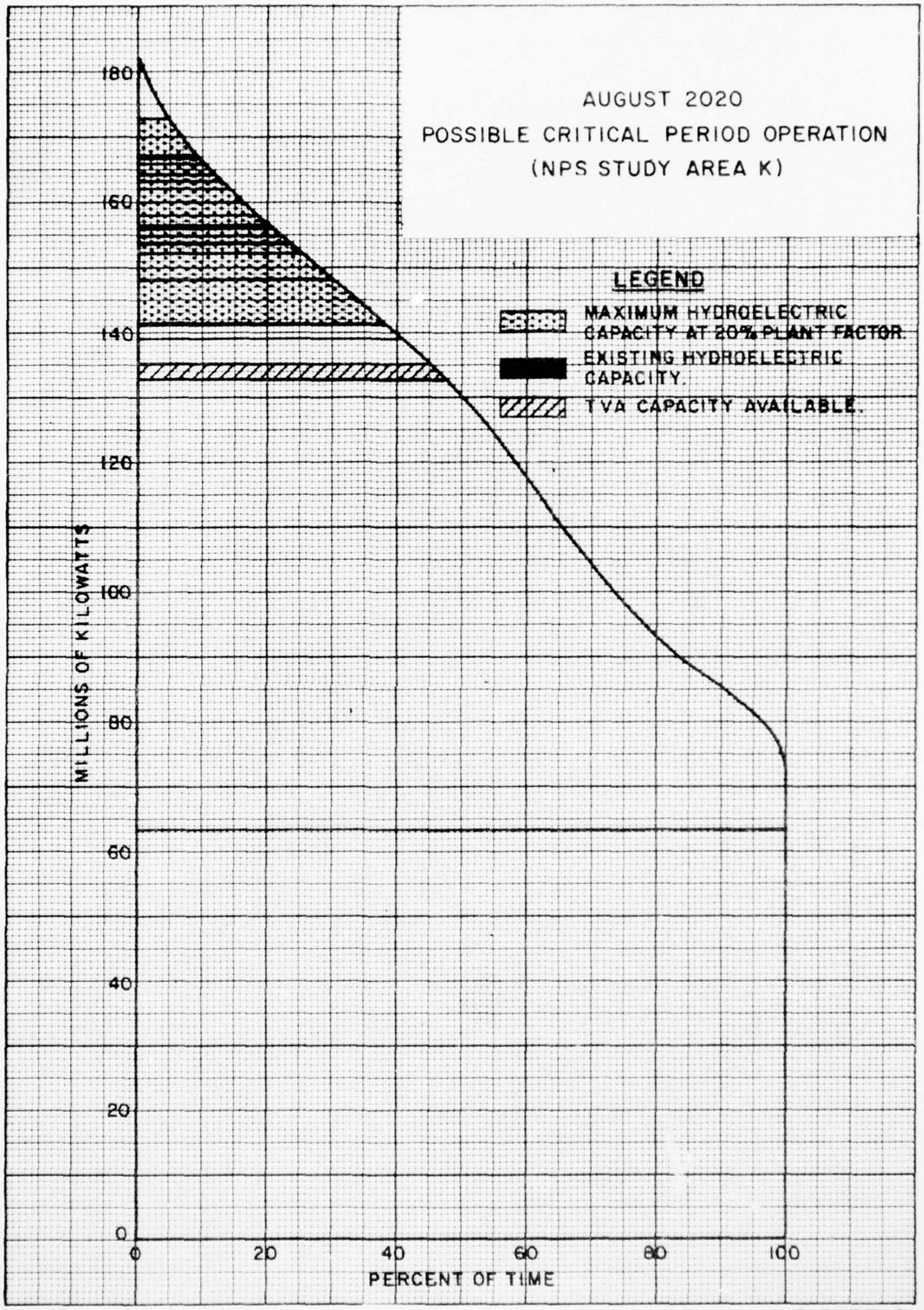

AUGUST 2020
POSSIBLE CRITICAL PERIOD OPERATION
(NPS STUDY AREA K)
LEGEND
MAXIMUM HYDROELECTRIC CAPACITY AT 20% PLANT FACTOR.
EXISTING HYDROELECTRIC CAPACITY.
TVA CAPACITY AVAILABLE.
MILLIONS OF KILOWATTS
180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
PERCENT OF TIME

FIGURE 4

(2) Preference power users. The estimated Load-Duration Curves for the total loads of the preference power users for 1980, 2000, and 2020 are shown as figures 2a, 3a, and 4a. The estimated load shape for the peak week in August 1980 is shown later in this section of the report under the discussion of pumped-storage hydroelectric plants, preference power users load.

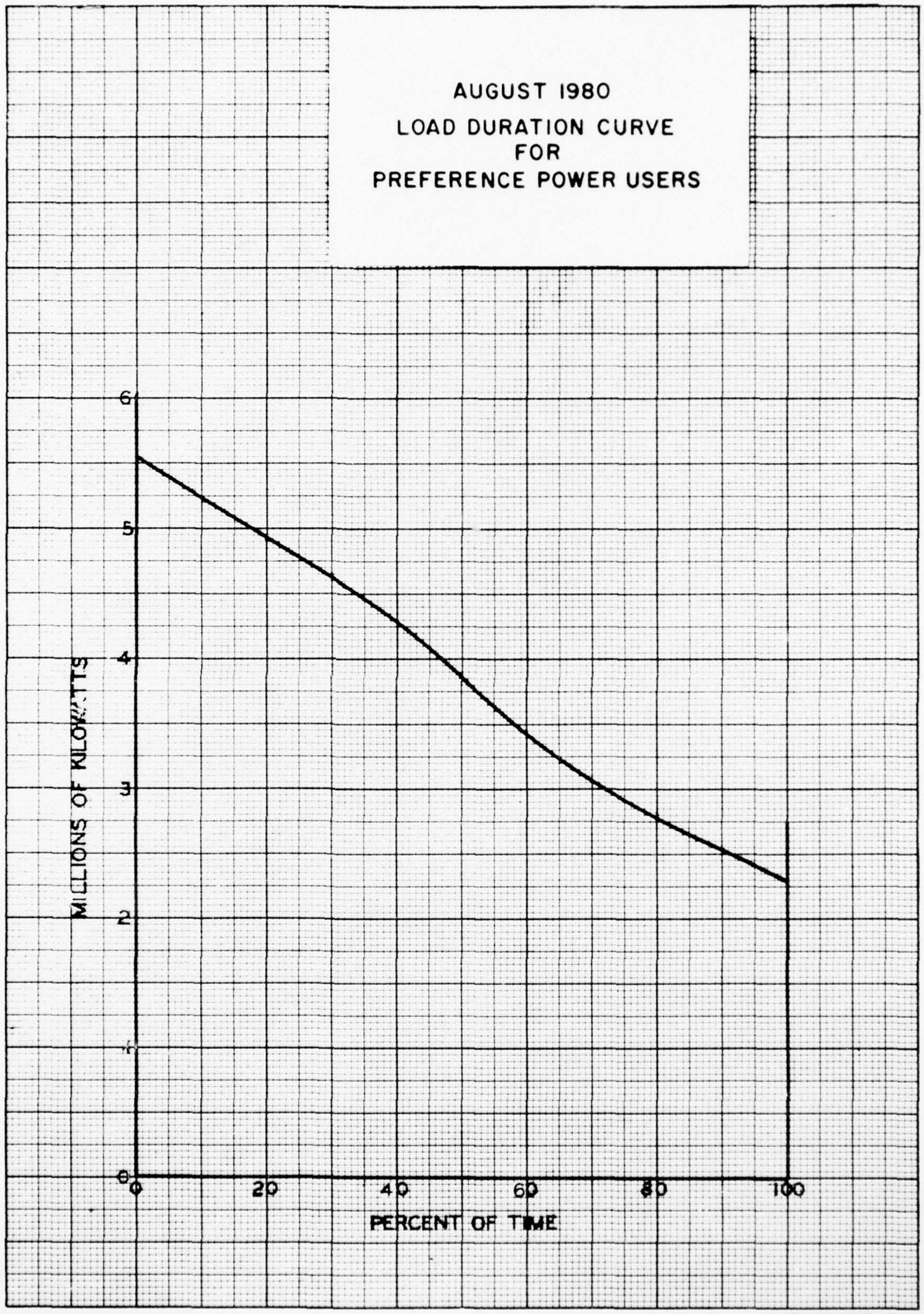

AUGUST 1980
LOAD DURATION CURVE
FOR
PREFERENCE POWER USERS
6
5
4
3
2
0
MILLIONS OF KILO
0
20
40
60
80
100
PERCENT OF TIME

FIGURE 2a

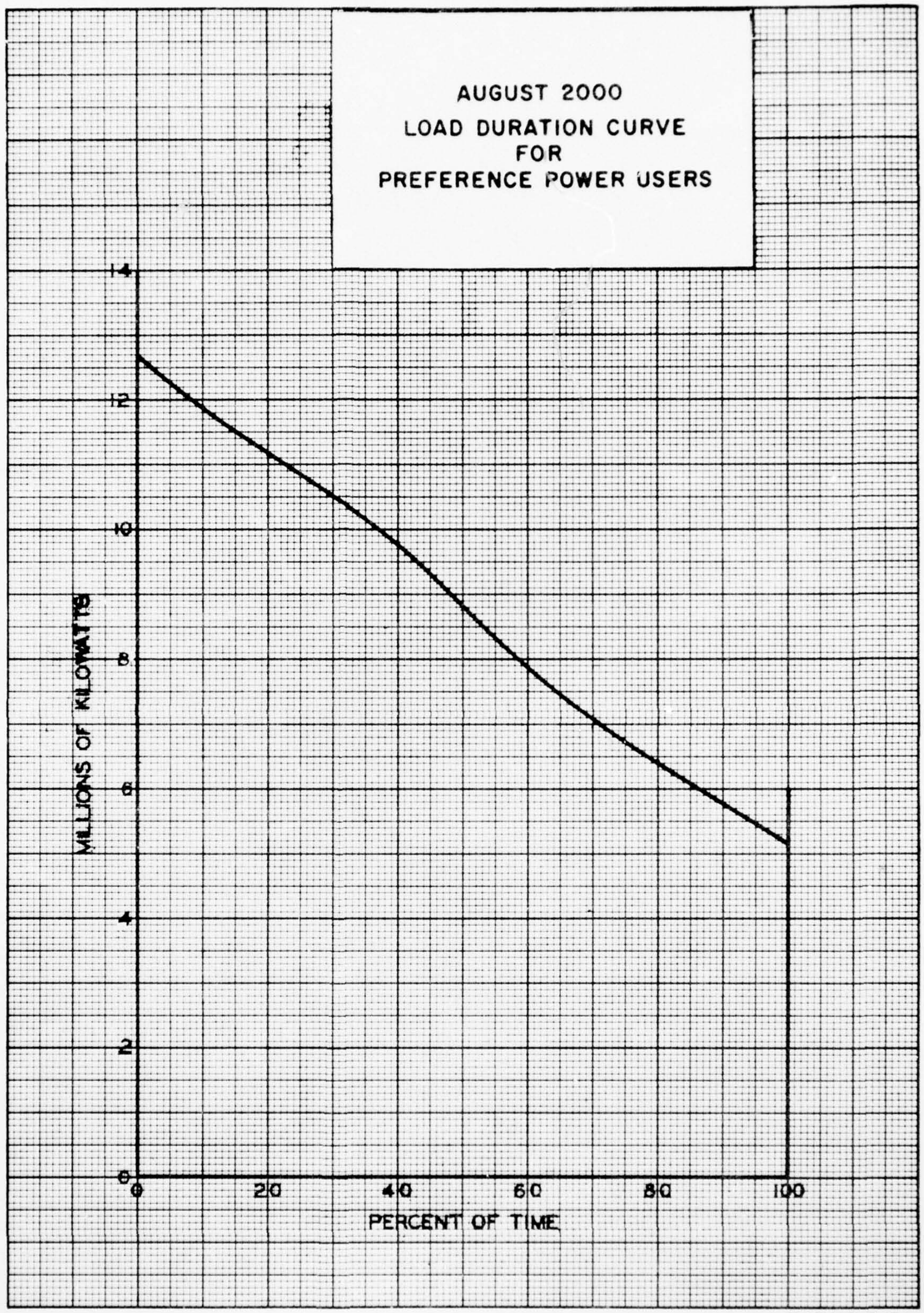
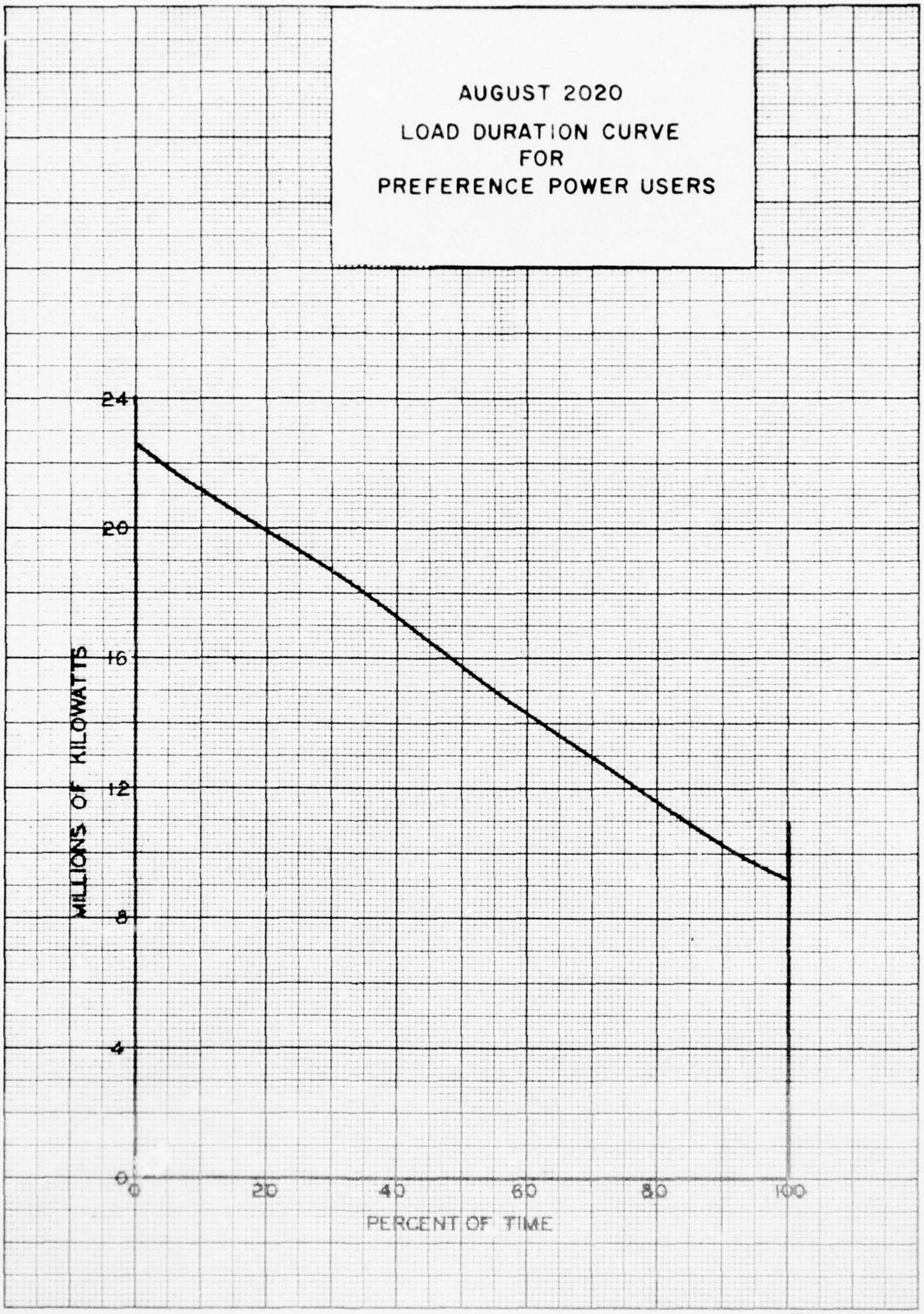

AUGUST 2000
LOAD DURATION CURVE
FOR
PREFERENCE POWER USERS
MILLIONS OF KILOWATTS
0
2
4
6
8
10
12
14
PERCENT OF TIME
0
20
40
60
80
100

FIGURE 3a



AUGUST 2020
LOAD DURATION CURVE
FOR
PREFERENCE POWER USERS
MILLIONS OF KILOWATTS
24
20
16
12
8
4
0
0
20
40
60
80
100
PERCENT OF TIME

FIGURE 4a

d. Hydroelectric capacity utilization.

(1) Conventional hydroelectric plants.

(a) Study Area K. Hydroelectric generating capacity, either existing or under construction, as shown in table 8, is represented on figures 2, 3, and 4 as solid areas, except as noted elsewhere. The dotted areas on these curves represent the maximum amount of hydroelectric capacity that could be utilized at 20 percent plant factor during August. Also shown are curves (figure 5) indicating the maximum hydroelectric capacity utilization at various August plant factors ranging from five to 30 percent in Study Area K for the years 1980, 2000, and 2020. These curves are based on the load duration curves illustrated in figures 2, 3, and 4. These estimates of the maximum amount of hydroelectric capacity which could be applied to future loads are conservative in that no hydroelectric capacity is shown in the peak five percent of the load. Even so, the amount which can be applied to the load is much larger than the potential capacity which has been listed in tables 10, 11, and 12.

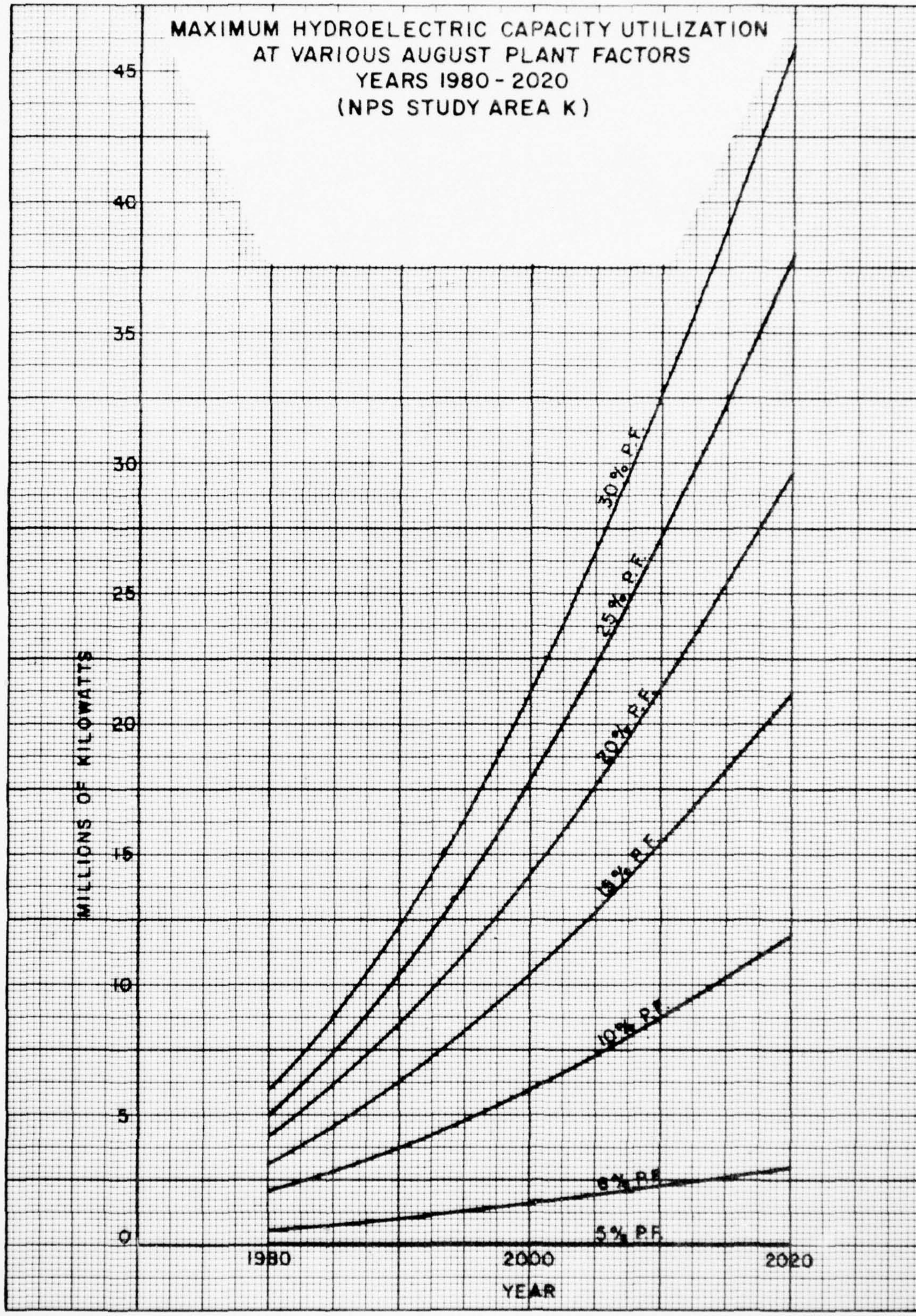

MAXIMUM HYDROELECTRIC CAPACITY UTILIZATION
AT VARIOUS AUGUST PLANT FACTORS
YEARS 1980 - 2020
(NPS STUDY AREA K)
MILLIONS OF KILOWATTS
0
5
10
15
20
25
30
35
40
45
1980
2000
2020
YEAR
30% P.F.
25% P.F.
20% P.F.
15% P.F.
10% P.F.
6% P.F.
5% P.F.

FIGURE 5

(b) Preference power users. SPA as the principal marketing agency for Federal hydroelectric power in this area, has a marketing program which is designed to require principally peaking power from the hydroelectric projects. The hydroelectric energy is supplemented by off-peak thermal energy either supplied into the SPA system or generated in the system of the customer. Thus the over-all load shape on the SPA system does not parallel that of the preference customers, but is more of a peaking curve. Under this marketing program SPA is able to use hydroelectric capacity to supply loads of preference customers at approximately 30 percent load factor.

Applying SPA's marketing criteria to the preference power user load curves in figures 2a, 3a, and 4a, the amounts of hydroelectric capacity that can be used in the various years of the study to supply preference power user loads has been determined as shown in table 13.

TABLE 13

HYDROELECTRIC CAPACITY THAT CAN BE USED IN SUPPLYING PREFERENCE USER LOAD (megawatts)

Year	Total Preference Load	Hydro for Preference Users	Hydro for Area Use 1/	Total Hydro Usable	Existing Hydro 2/	Load for Potential Hydro	Fuel Electric
1980	5,540	2,040 3/	580	2,620	2,160	460	3,500
2000	12,620	3,620 4/	970	4,590	2,160	2,430	9,000
2020	22,610	6,410 4/	1,740	8,150	2,160	5,990	16,200

1/ Hydroelectric power to companies under existing wheeling and energy purchase arrangements in exchange for service to preference users, and under an existing pooling arrangement with a company for service of one defense industry.

2/ Federal projects, including capacity under construction, and State project capacity serving preference power users.

3/ Hydro projects assumed usable by marketing agency in supplying loads of preference customers at 30 percent load factor in summer peak month. Hydro energy, for service to preference customers, is supplemented by private and public thermal energy where necessary to meet the total energy requirements.

4/ Hydro projects assumed usable by marketing agency in supplying loads of preference customers at 25 percent load factor in summer peak month.

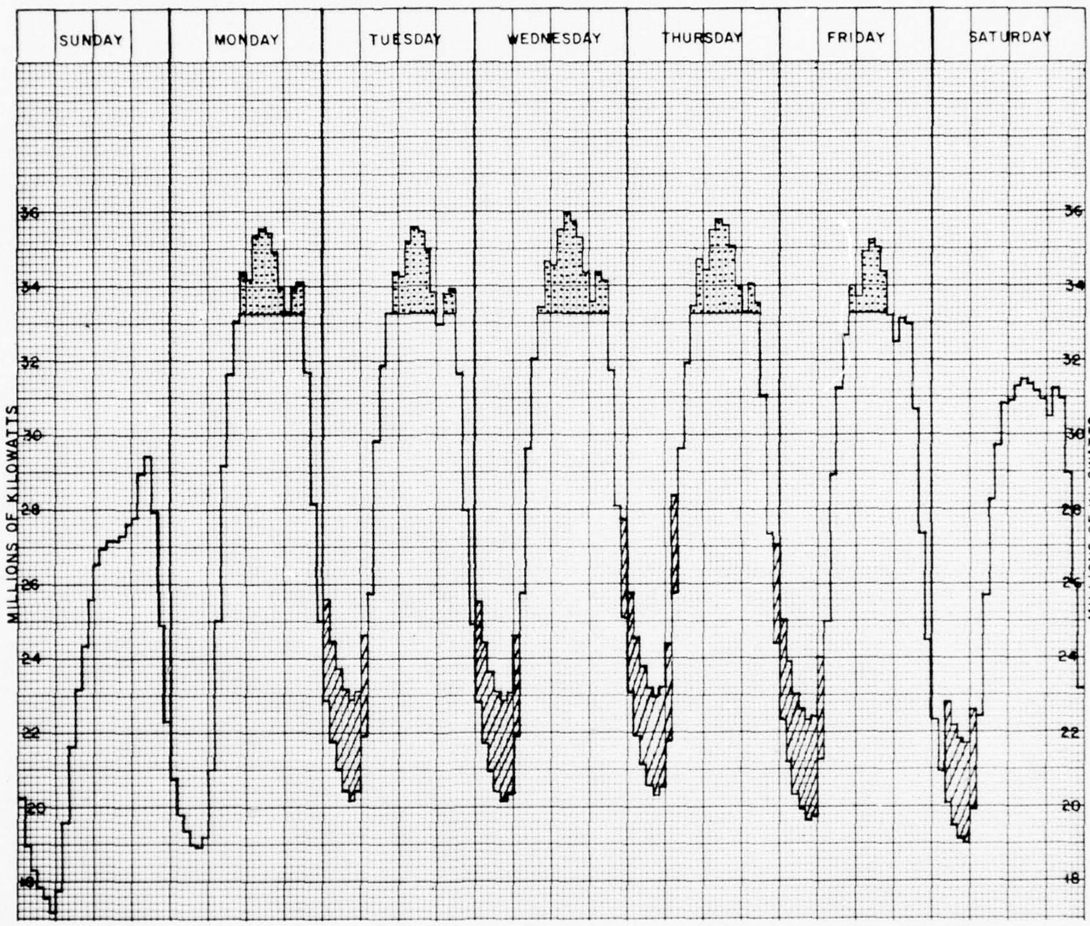
For 1980, this amount is 2,620 mw. Of the total hydroelectric plant capacity expected to be available in this area in 1980 (table 8), only 1,963 mw are in multiple-purpose Federal hydroelectric projects. Therefore it is concluded that all multiple-purpose Federal hydroelectric projects that have been found economically and financially feasible in the basins in this area could be utilized by 1980 by the marketing agency on preference user load, and/or to serve to companies or cooperatives under existing wheeling and energy purchase arrangements in exchange for service to preference customers.

(2) Pumped-storage hydroelectric plants.

(a) Study Area K. There are a number of possible sites for adjoining pumped-storage hydroelectric development but there are limitations on the amount of such capacity which could be applied to future loads. Figure 6 illustrates operation of pumped-storage hydroelectric capacity in the peak week of 1980 using a minimum of generation. This would be normal operation since, for economy, no more pumping would be done than necessary to supply loads and to keep the upper pond full for reserve. The energy generation indicated for the peak day is equivalent to six hours generation at maximum capacity. Some plants have been constructed at sites to provide only enough storage for six hours generation and nine hours pumping (assuming the commonly accepted ratio of 3 kwh pumping to 2 kwh generation). However, in areas of the Southwest affected by prolonged drouths and heat waves sufficient usable storage in the forebay should be available to provide operating flexibility, additional reserve, and application on lengthening daily peak loads. Therefore the expected normal requirements of 6-hour daily generation should be supplemented with an additional 2 hours of full load generation to develop an 8-hour generation day for a five-day week, thus providing a 2-hour daily reserve. These considerations would dictate the installation of 16 hours of forebay storage capacity in a weekly cycle of generation. The operation of the conventional hydroelectric plants in the peak week is not illustrated, but the August load duration curve for 1980 (figure 2) shows all loads above 27,500 mw being carried by some combination of hydroelectric and fuel-electric capacity, and on this basis the weekly curve shows that some week-end hydroelectric generation would be required. If necessary to conserve water at conventional hydroelectric plants, some of this generation could be supplied by the pumped-storage plants and these plants could operate at 20 percent monthly plant factor, the same as assumed for the future potential conventional hydroelectric plants.

It is highly advantageous in the development of pumped-storage hydroelectric capacity that this capacity be physically located near a major load center and related in size to the electric load in that particular area. Concentrations of load are usually surrounded by the supporting steam-electric generation which represents a source of pumping energy for area pumped-storage facilities.

1980
ESTIMATED PEAK WEEK
SHOWING
MAXIMUM PUMPED STORAGE CAPACITY
(NPS STUDY AREA K)



LEGEND

PUMPED-STORAGE HYDRO

PUMPING LOAD

FIGURE 6

(b) Preference power users. Based on the summary data shown in table 13, and on application of pumped-storage on the peak week load-distribution curve (figure 6a) and the peak month load-duration curve, it is concluded that the 1980 loads of the preference power users in the area will be sufficient to utilize approximately 500 mw pumped-storage capacity, in addition to the capacity of the multiple-purpose Federal hydroelectric projects now existing or under construction (included in table 8).

e. Summary of future loads which can be supplied by hydroelectric power generation.

(1) Study Area K. A summary of the portion of the future load which could be supplied by potential hydroelectric projects at 20 percent August load factor is as follows:

	(millions of kilowatts)				
Year	Total Load	Fuel-Electric	Total Hydro	Existing Hydro 1/	Potential for Added Hydro 2/
1980	35.90	29.42	6.48	2.24	4.24
2000	93.00	76.52	16.48	2.24	14.24
2020	182.00	150.12	31.88	2.24	29.64

1/ Including capacity under construction or scheduled, except Salina (0.52 million kw) and Webbers Falls (0.066 million kw).

2/ Of these amounts the following could be in adjoining pumped-storage hydroelectric capacity:

Year	Millions of Kilowatts
1980	2.67
2000	6.92
2020	13.54

Summarizing, by 1980 the load shape is expected to be able to accommodate potential new hydroelectric capacity amounting to 4,240 mw of which 2,670 mw could be pumped-storage hydroelectric capacity as illustrated by the curve of the peak demand during the estimated peak week. This 2,670 mw includes a total of 520 mw for the Salina project now under construction and leaves 2,150 mw of new pumped-storage capacity for development by 1980. Similarly, for the year 2000, the load would accommodate new hydroelectric capacity totaling 14,240 mw of which 6,920 mw (including the 520 mw now under construction) could be new pumped storage capacity. For the year 2020, corresponding figures would be 29,640 mw and 13,540 mw (including the 520 mw now under construction). The future need for conventional hydroelectric capacity is greater than the amount available from the total of all the potential sites.

1980
ESTIMATED PEAK WEEK (AUGUST)
PREFERENCE POWER USER LOAD

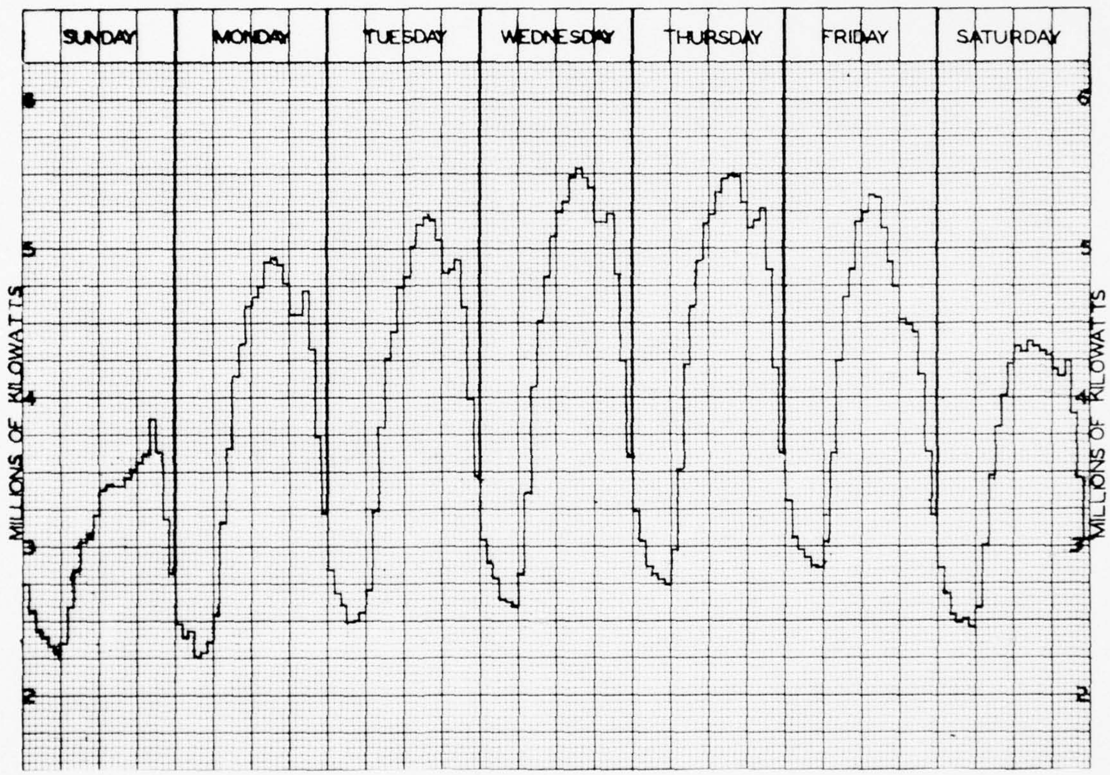


FIGURE 6a

AD-A036 752 RED RIVER BASIN COORDINATING COMMITTEE NEW ORLEANS LA F/G 8/6
COMPREHENSIVE BASIN STUDY. RED RIVER BELOW DENSION DAM, ARKANSA--ETC(U)
JUN 68

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(2) Preference power users load. The amounts of hydroelectric power that can be used in supplying loads of preference power users in the study area in the years 1980, 2000, and 2020 are summarized in table 13.

Table 13 has been developed by application of hydroelectric power on the preference power user load curves, using certain limiting criteria. As explained earlier under the discussion of hydroelectric capacity utilization, conventional plants, the marketing arrangements of SPA make it possible to use hydroelectric capacity to supply preference user load at approximately 30 percent plant factor. Inasmuch as the marketing agency has basically a hydroelectric system, hydroelectric power has been applied at the peak of the load curves. In determining the total hydroelectric capacity that can be utilized, the power that is delivered to the companies for Area use, in return for service to preference users, has been included and considered as an essential use of hydroelectric power for service of preference users load.

The amount of hydroelectric capacity determined as usable by such criteria is conservative, since provision for supplying reserve from hydroelectric resources has not been included.

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SECTION VI - CRITERIA AND INVESTIGATIONS

18. CRITERIA FOR SCREENING AND HYDROELECTRIC PROJECT DEVELOPMENT

a. Conventional hydroelectric projects.

(1) General criteria. The project formulation studies gave consideration to the hydroelectric power potential at all reservoir sites. Preliminary factors that had a direct bearing on the scope of consideration were: the head that could be developed at each site; the flow available; the volume of storage available and any restrictive operating rules. The head that could be developed and the storage available at each site were determined from topographic maps. The water available for conventional hydroelectric power production was determined from stream flow records. These records were adjusted to reflect existing and authorized reservoir storage as well as existing and potential diversions. From the data gathered, mass inflow curves and flow-duration curves were developed at each site that gave preliminary indications of potential power production. These curves were used to determine the gross minimum yield that would be available at each potential hydroelectric power site from the contributing drainage area. The flow values thus determined were used in the preliminary appraisal to determine plant capacity for all peak power installations. Average flows for determining average annual energy values were obtained from analysis of flow duration curves.

(2) Specific criteria.

(a) Firm capacity and energy. The most critical period of record for the storage in question was used to determine the prime power available. Prime power is that amount available over the critical period, from that portion of the yield allocated to power generation, with proper adjustment for reduced head due to peaking operation.

(b) Average annual potential energy. The streamflow period of record, adjusted to at-site conditions and for upstream development as necessary, was used in the determination of average annual hydroelectric energy potentially available at reservoirs under study.

(c) Power drawdown storage. The power drawdown or storage was based on the conservation storage provided for other reservoir purposes. In general and when possible the maximum economic ratio for power was produced where the minimum head (during the peak load season) was at or near critical head, i.e. where the capability at minimum head was equal to installed capacity.

(d) Rated head for hydraulic turbines. For design of hydraulic turbines, the rated head was based upon the average head during the critical hydro period. The rated head is considered to be the head at which the turbine output at point of best efficiency equals the rated generator capacity in kilowatts.

(e) Plant factors. For screening type studies as made for this report, the plant factor during a critical year was generally assumed to be 10 percent based upon the assumed dependable capacity (minimum during peak load season). This determines the installed capacity to be considered and can later be confirmed or revised as a result of more detailed studies.

(f) Installed and dependable capacity. The minimum peaking capability, based on the minimum head available during July and August of the critical period, was considered to be dependable capacity, based on the firm energy available for the specified monthly plant factors.

On the basis that the hydroelectric power plants would operate in a large, interconnected system, unit size was not restricted by marketing conditions or replacement requirements.

(g) Power values. For screening purposes, at-market values of $15.50 per kilowatt and 2.2 mills per kilowatt-hour were used for capacity and energy, respectively. These at-market alternative steam-electric capacity and energy costs are composite figures and represent an average of alternative at-market costs in Power Supply Areas 25, 29, 33, 34, and 35 (Kansas, Oklahoma, southern Missouri, Arkansas, Louisiana, western Mississippi, and eastern Texas).

(h) Economics for screening. Preliminary designs and cost estimates were prepared for the power facilities selected for each site. Estimates of costs for each of the power plants, including their hydraulic and electrical equipment, were determined from generalized cost curves showing average costs for existing hydroelectric installations. Cost estimates for the intakes, waterways and outlet facilities were prepared in the office of the U. S. Corps of Engineers, Tulsa District. For comparative purposes, the construction period was assumed as 3 years for each site and interest on the amount of the increasing investments in each year was assumed to be the prevailing rate for 1-1/2 years. For determination of annual charges in the preliminary investigations, interest, amortization and interim replacement charges were taken as 5 percent of the investment for power facilities. This figure was based on a low-risk interest rate and was considered sufficiently conservative for use in the preliminary investigations. Operation and maintenance charges for the power facilities were taken as $0.34 per kw. Only those screened projects with a benefit-to-cost ratio of 0.80 or better (based on a 100-year amortization period) were given consideration for further study.

b. Pumped-storage hydroelectric projects.

(1) General criteria. Pumped hydro-storage is unique among methods of hydroelectric generation in being dependent upon other power sources for energy supply. It functions as an energy accumulator which stores low-cost off-peak energy by using it to pump water from a lower to a higher reservoir from which it may be returned through its turbine to generate power during peak periods when it has capacity as well as energy value. Thus, a prerequisite for such development is the availability of low incremental cost off-peak energy for the pumping or charging cycle.

Reduced equipment cost brought about by the development in recent years of the reversible pump-turbine unit, permitting the pumping and generating operations to be combined in a single machine, has contributed significantly to the economics of pumped storage installations.

(2) Specific criteria.

(a) Head limitation. The investigations for pumped storage hydroelectric sites were limited to the sites with not less than 150-foot head between the upper and lower reservoirs.

(b) Daily and annual plant factors. For screening purposes, a ten percent annual plant factor was assumed. It was further assumed that the normal operation would consist of 6-hour daily generation, 5 days per week, with provisions for an added 2 hours per day reserve. (See Section V-17-d-(2).)

(c) Station efficiency. Over-all plant efficiency was assumed to be 75 percent.

(d) Useable forebay storage. The weekly cycle of 6-hours normal daily generation plus a 2-hour daily reserve requires forebay storage sufficient for 15 hours of generation.

(e) Power values and pumping rates. Power values used for screening the potential pumped-storage sites were those noted in Section VI-18-a-(2)-(g), preceding. These values were considered to be adequate for screening purposes.

(f) Economics for screening. Estimates of costs for use in screening were made in a manner similar to the criteria outlined in Section VI-18-a-(2)-(h). It should be noted that at the time of screening studies the prevailing interest rate was 3-1/8 percent. Substitution of the current rate of 3-1/4 percent would not alter the results of the screening studies.

19. INVESTIGATIONS COMMON TO ALL PLANS OF DEVELOPMENT

a. General. All hydro-power projects fall into one of two classes; either run-of-river or storage. The run-of-river power development uses the flow of the stream as it occurs and utilizes minor storage capacity. Power development at navigation dams is considered run-of-river even though the flow required for lock filling is released intermittently. Hydro-power development from storage may be classified as either conventional storage or pumped storage. Conventional storage power development requires a reservoir of considerable capacity so that surplus stream flows may be conserved for use during periods of low flows for power generation. Pumped storage power development requires two reservoirs, one at a higher elevation than the other for use as a forebay while the reservoir at the lower elevation is used as an afterbay. Power is generated during periods of demand by the transfer of water from the higher reservoir to the lower but low incremental cost off-peak energy must be available to pump the water back to the higher reservoir.

The basic data required to determine the hydro-power capability at a site are the observed or computed stream flow, an estimate of water losses, a tail water rating curve, reservoir area and capacity curves and a profile of the stream.

b. Stream flow and critical hydro-period. Observed stream flow data are obtained from publications of the U. S. Geological Survey or other sources. The flow record for the stream at the nearest gaging station is corrected to give the flow at the proposed site. It may be necessary to prepare a synthetic flow record for streams that do not have an adequate period of record. The period of record must include the most probable dry period that can be expected for the area. A tabulation of monthly and annual stream flows is prepared so that the dependable storage available may be evaluated.

The tabulation of stream flows will reveal the minimum amount of water available for power generation over an extended period of time. The minimum water available will occur near the end of a dry period of several years' duration.

c. Water losses. The major losses of water from power storage includes seepage through the foundation and abutments of the dam, leakage through the power plant, and evaporation loss from the reservoir.

For concrete dams, founded on rock, seepage may be considered negligible. For earth dams, an allowance of from 1 up to as much as 10 c.f.s. is recommended, unless the foundations are unusually permeable, in which case the figure to be taken for seepage loss should be obtained from the soils branch of the field office. Leakage losses through the power plant vary, depending on the number and size of turbine units, the load factor, and the head. For estimating purposes, an average loss of about 5 c.f.s. per unit can be assumed. Gross evaporation for the reservoir area may be obtained from pan records in the locality or may be computed by using a formula with the needed basic data obtained from Weather Bureau stations in the vicinity. The formulas for computing evaporation from water surfaces are based on the vapor pressure gradient between the water surface and the air above the water, and the wind velocity. The gross evaporation from the reservoir area as determined from computations or observations should be corrected to include the effect of precipitation on the reservoir area.

These water losses should be applied to the observed stream flow data or computed regulated flow to obtain the net yield of the stream available for power generation.

d. Head relationships. One of the basic elements in the development of a hydroelectric project is the head that can be developed. The higher the head, the lower the cost per kilowatt for the power plant and hydraulic and electrical equipment. The topography at the damsite, the extent of relocations of highways, railroads and utilities that would be required, and the effect on the community life in the area, all have a bearing on the height to which a dam could feasibly be constructed. The gross head is the difference in elevation between the still water surface in the reservoir and the elevation of the tailrace. The net or effective head is defined as the gross head minus the friction losses in the conveyance of the water from the reservoir to the entrance of the spiral case.

The effective head on run-of-river plants is usually small and may approach zero during periods of high flow that inundate the control weir. Conventional storage power plants, properly sized for stream flow, can always maintain an operating head. Where the stream flow is not sufficient to maintain the storage pool, pumped storage hydroelectric plants may be used, terrain permitting. Consideration must be given, however, to the recharging or pumping cycle of the pumped storage plant.

e. Tailwater conditions. The discharges associated with full-load operation for peaking purposes creates a higher elevation in the tailrace than do part-load discharges of continuous operation. Thus, with a relatively stable headwater elevation, the available head for peaking will be less than that for continuous power generation.

At any dam where clear water from the reservoir is discharged into a river channel which is composed of soft material, the material is picked up and conveyed downstream resulting in the stream gradient below the dam being progressively altered. This effect may be accelerated by the fluctuations of flow inherent to power production. Over a period of time this degradation of tailwater may amount to several feet with a resulting increase in effective head.

f. Area-capacity tables. Reservoir area and capacity curves were prepared for each site that was given preliminary investigation.

g. Power generation schedules and energy distribution. Hydro power is used essentially for peaking purposes with the majority of the hydro energy available on an annual basis used during the summer heavy load months. Pumped-storage plants will operate only when there is a need for peaking power which will normally be in the peak load months. When not generating for load the pumped-storage projects will be vital for reserve and reactive power.

h. Plant factor and annual generation. Plant factor may be defined as the percent of time the plant operates. For screening type studies, the plant factor may be assumed to be 10 percent based upon the assumed dependable capacity. This will determine the installed capacity to be considered and this will later be confirmed or revised as a result of more detailed studies. The plant factor multiplied by the installed capacity times the number of hours in a year gives the annual firm generation.

i. Economics assumed in screening of site development. In the formulation of a hydro-power project, it is required that the average annual power benefits exceed the average annual costs of the hydroelectric power project. The following criteria are used for determining benefits and costs.

(1) Benefits. Average annual hydro-power benefits are based on the alternative costs of producing steam-electric power by means of an investor-owned and -financed, large, efficient thermal plant.

(2) Costs. The total allocated annual costs for hydroelectric power are the separable power costs plus the part of joint costs allocated to power. These costs include interest and amortization on the project investment costs over a period of 100 years at 3-1/4 percent interest; operation, maintenance, and replacement cost; and annual costs of pumping energy when applicable. These allocated costs are generally determined by the Separable Costs-Remaining Benefits method of allocation. In determining the cost allocated to power by this method, it is necessary to estimate the alternative cost of power and the separable cost to power.

Annual separable power cost is equal to the annual cost of the multiple-purpose project that includes power minus the annual cost of a similar project with power omitted. The cost of both projects must be based on comparable financing and at-site hydroelectric power.

Annual alternative power costs are used as a limit on benefits in connection with cost allocation. Under the present policy, these costs are generally the unit power values furnished by the Federal Power Commission and are based on alternative thermal power computed on the same basis as for benefits except Federal financing is used and taxes and insurance are excluded.

(3) Comparability test. Another test in determining whether hydroelectric power should be included as a function in a multiple-purpose project is set forth in letter ENGCW-PD to SWD dated 15 June 1962, which states that where hydroelectric power is a proposed function of a Federal project the limit on the separable cost of its inclusion would be based on the cost of alternative measures serving the same need computed on the exact basis used in computing the cost of the project hydroelectric power function. The separable costs of hydroelectric power must be no more than the cost of alternative steam-electric measures to serve the same need and financed on a comparable basis. Cost computations are to be on the same basis as those used in determining alternative costs for cost allocation.

(4) Financial Feasibility. Another requirement in making decisions whether hydroelectric power should be included as a project function is that the marketing agency can recover the annual cost allocated to hydroelectric power from the sale of power from the project. Current criteria require that costs allocated to power (using a 100-year economic life) be amortized during a 50-year period for repayment purposes. As previously indicated, the alternative cost used in cost allocation as a limit to benefits is based on a hypothetical large, efficient, steam-electric plant with financing comparable to that for a Federal hydroelectric plant; that is, an interest rate of 3-1/4 percent and with taxes and insurance excluded. In most cases this procedure results in a lower allocation of joint costs to the power features of multiple-purpose projects than would have been allocated under earlier criteria.

SECTION VII - PROJECT SCREENING

20. INDIVIDUAL SITE PLANS SCREENED

a. General. Hydropower was considered in the preliminary investigations of all dam sites. This investigation included authorized projects, projects under construction, all projects in the framework plan, and a review of existing reservoirs. Where preliminary investigations gave evidence of the possibility of inclusion of hydropower, either conventional, pumped storage, or both, the costs and benefits incurred at each site were computed. At those sites adaptable to either mode of development, costs and benefits were computed for each development. It readily became apparent that many of the sites did not lend themselves to the development of hydropower due to low heads or lack of adequate storage. In addition, an analysis of the basin as a whole showed that either present or future water supply needs, both in-basin and trans-basin, may require the entire dependable yield of some of the streams.

b. Conventional hydroelectric power. Eleven reservoir sites met the preliminary investigation criteria of adequate flow, adequate storage available and adequate head for conventional hydroelectric power development. These sites were then screened for benefit-cost ratio and comparability with steam-electric costs. These sites are listed and the data is summarized in table 14. Although Hugo Reservoir on Kiamichi River is included in the table, hydroelectric power development is not recommended at this site because of the comparability ratio, and provision for future power is not recommended because of future water supply requirements. Due to the low benefit-cost ratios, only Sherwood Reservoir is recommended for conventional hydroelectric power development.

c. Pumped-storage hydroelectric power. Eight sites met the criteria for pumped-storage hydroelectric power development. This criteria specified that: (1) a head of at least 150 feet be available between the upper and lower reservoirs; and (2) sufficient usable storage could be developed in the upper reservoir to allow at least a daily cycle of generating and pumping. The sites and the screening data are summarized in table 15. All sites were screened for the capability to deliver 6 hours machine capacity generation at the rated head. All sites screened had preliminary benefit-cost and comparability ratios that would indicate detailed studies were warranted; however, significantly higher heads could be developed at the Clayton Reservoir and the Tuskahoma Reservoir sites. Since forebay storage equivalent to 16 hours of generation was desirable in a weekly cycle operation, studies were made considering this requirement for both the Clayton and Tuskahoma sites.

TABLE 14

SUMMARY OF CONVENTIONAL HYDRO-POWER SCREENING STUDIES

Project	Stream	Drainage Area (sq.mi.)	Power Storage Available (ac.ft.)	Head Available (feet) max.	Head Available (feet) min.	Total Installed Capacity (kw)	B/C	Comparability Ratio
Upper Antlers	Kiamichi River	1,119	1,090,000	152	124	90,000	0.55	0.28
Caney Mountain	Little River	315	352,100	98	65	18,000	0.42	0.22
Finley	Cedar Creek	172	210,020	74	50	7,400	0.21	0.10
Durant	Blue River	649	172,000	69	47	7,500	0.24	0.13
Boswell	Boggy Creek	2,273	2,680,000	99	69	73,000	0.21	0.11
Tuskahoma	Kiamichi River	347	707,800	92	61	18,800	0.25	0.13
Clayton	Jackfork Creek	275	331,700	75	50	12,900	0.17	0.09
Buck Creek	Buck Creek	97	122,140	195	141	12,000	0.70	0.37
Hartley	Cossatot River	93	195,700	189	126	14,200	0.34	0.17
Hugo	Kiamichi River	1,709	1,352,200	85.5	57	50,000	1/	0.8
Sherwood	Mountain Fork River	601	843,800	181	147	600,00 2/	1.6	1.1

1/ Not available.
2/ Integral project with 100,000 kw conventional, 500,000 kw reversible.

TABLE 15

SUMMARY OF PUMPED STORAGE HYDRO-POWER SCREENING STUDIES

Reservoir	Stream	Installed Capacity (mw)	Rated Generating Head (ft.)	Length of Conduit (ft.)	Investment (mill. $)	B/C	Comparability Ratio
Clayton	Jackfork Creek	1,000	915	2,430	173.6	1.6	0.9
Broken Bow	Mountain Fork River	700	465	2,300	88.4	1.6	0.9
Sherwood	Mountain Fork River	1,000	718	6,180	107.4	1.6	0.9
Gillham	Cossatot River	380	327	1,100	53.5	1.5	0.9
Hugo	Kiamichi River	850	368	5,500	195.5	1.2	0.7
Tuskahoma 1/	Kiamichi River	1,500	1,030	9,000	183.4	1.6	0.9
Tuskahoma 2/	Kiamichi River	1,000	1,049	5,820	115.8	2.2	1.3
Sherwood	Mountain Fork River	1,000	718	6,180	107.1	1.6	0.9

1/ Forebay located in Sec 33, T2N, R21E, on tributary of Black Fork; 10,000 acre-feet.
2/ Forebay is located in Sec 19, T2N, R23E, on tributary of Kiamichi River; 19,000 acre-feet available in forebay.

SECTION VIII - EXISTING PROJECTS AND PROJECTS STUDIED FOR BASIN PLAN

21. EXISTING HYDROELECTRIC STATIONS IN RED RIVER BASIN BELOW DENISON DAM

There are 29 existing hydroelectric projects in Study Area K with an installed capacity of 3,237.4 mw including those projects under construction and scheduled for construction. Seven of the hydroelectric projects are located in the Red River Basin below Denison Dam - two in the Lower Red River Basin and five in the Ouachita River Basin. These seven projects have a combined installed capacity of 368.8 mw - 135.0 mw in the Lower Red River Basin and 233.8 mw in the Ouachita River Basin. Five of the projects are Federal and are operated by the Corps of Engineers. Two projects are privately owned. All of these existing projects are described in Section IV-14 and listed in table 4 of this appendix.

22. MODIFICATION OF AUTHORIZED FLOOD CONTROL PLAN TO INCLUDE HYDRO-POWER

Preconstruction planning studies of the authorized projects in the Red River Basin below Denison Dam were made regarding feasibility of including hydroelectric power facilities. These studies were made under authority of a resolution adopted 6 January 1961 by the Senate Public Works Committee which authorized a study to determine the advisability of modifying the general plan for flood control on the Red River for the purpose of providing additional facilities for the production of hydroelectric power. The results of these studies indicated that inclusion of hydro-power facilities in Pine Creek and Gillham Reservoirs would not be warranted in that the incremental non-power cost of an enlarged project would not be justified by the incremental non-power benefits. The remaining projects studied did not meet economic justification based on the comparability ratio. The comparability ratio was computed by comparing the separable cost for hydroelectric power with an alternate cost based on a Federally financed steam-electric station with Federal transmission and interest rates.

23. TIMING OF PROJECT DEVELOPMENT

The actual peak demand of 13,070 mw in 1965 in Study Area K is expected to grow to 35,900 mw in 1980 as estimated in the National Power Survey of 1964. This estimate has been extended to the year 2020 for this study at which time the peak is expected to reach 182,000 mw. In 1980 the August energy requirements for the area load are expected to be 10.4 percent of the annual requirements. The annual peak demand is expected to occur in August with the maximum monthly demand in March representing 64.7 percent of the annual peak demand.

An analysis of the existing and expected future power supply in Study Area K, indicates that there was a surplus above reserves of 1,534 mw in 1965, and 4,480 mw in 1970 and an indicated need for 12,763 mw of additional capacity by 1980. A major part of this deficiency in 1980 will be met by future steam-electric generating capacity, but the growing loads will create a demand for large amounts of peaking capacity which hydroelectric plants are best suited to supply.

SECTION IX - PROPOSED PLAN OF DEVELOPMENT

24. FOR CONSTRUCTION WITHIN 10-15 YEARS

a. Tuskahoma Pumped Storage Project. The Tuskahoma pumped storage project consists of four 250 mw pump-turbine units operating under a rated net head of 1,049 feet. The project was developed on the basis that the plant would be operated on a 12 percent annual plant factor with a 75 percent over-all efficiency. Normally the plant would operate on a weekly generation of 30 hours. The proposed project is an adjoining type development which uses the authorized Tuskahoma project as an afterbay reservoir.

The forebay reservoir, backed up by a 247-foot high dam, would have a usable capacity of 19,000 acre-feet between elevations 1710 and 1750. This storage would provide the equivalent of 16 hours of continuous generation, including seepage and evaporation losses and would produce 50 feet of drawdown. The drainage area above the dam site would be about 800 acres while the area at the top of the operating pool would be about 590 acres. Five feet of freeboard, adequate to store the entire 24-hour rainfall during the spillway design flood, would be provided above the top of the power pool. With the turbines operating at the rated head, the discharge would be about 13,100 cfs which would be in excess of the peak inflow of the spillway design flood. Pertinent data are included in table 16. The top of the dike at the upper end of the forebay would be set three feet below the top of the dam to act as an emergency spillway if the outlet works would be inoperative when a spillway design flood occurs. The spilled water would pass into the Tuskahoma Reservoir.

Either a penstock or pressure shaft could be used between the upper and lower reservoirs. Preliminary investigations indicate a vertical shaft connected to a 27-foot diameter steel-lined tunnel would be more economical.

A powerhouse located at the foot of the mountain in the periphery of the authorized Tuskahoma project would house the four 250 mw pump-turbine units.

The authorized but not constructed Tuskahoma Dam and Reservoir would be enlarged and used as an afterbay for the proposed pumped storage project. Daily fluctuations in water surface in Tuskahoma Reservoir during operations would be less than two feet. Pertinent data on the authorized and the proposed modification of Tuskahoma Reservoir are included in table 17.

Operating five days a week for maximum weekly generation of 30 hours would require six hours daily generation. The average annual plant factor would be 12 percent. A 75 percent over-all efficiency would require about 8 hours of pumping to replenish storage in the upper reservoir. The forebay storage has capacity for 16 hours generation should loads require greater than 6 hours daily generation. Deficits in daily pumping, up to a total of 57 hours, could be replenished over the weekend.

The proposed forebay reservoir and power facilities would not require relocation of any existing roads or structures. The necessary modification of the authorized Tuskahoma Dam would require the additional purchase of 1,800 acres of land. The overall relocation plan for the authorized reservoir area would be essentially the same as the authorized plan with the exception that the south bank access road would be realigned to provide access to the powerhouse and canal.

The average annual generation would be 1,051 million kilowatt-hours. The separable first cost of construction is estimated at $108,700,000. Annual costs, including interest and amortization, separable operation and maintenance, separable major replacements, engineering studies, and pumping cost are estimated at $8,174,400. Average annual benefits, credited to hydroelectric power, total $17,996,900. The total annual benefits of $17,996,900 compared with the total annual charges of $8,174,400 based on a 50-year period of analysis show a benefit-cost ratio of 2.2. With the limit on the separable costs based on the cost of alternative measures serving the same need the comparability ratio would be 1.16. The economic analysis is summarized in table 18.

A study by the marketing agency, Southwestern Power Administration, of the Tuskahoma Pumped Storage Project resulted in a proposal that the first two units be installed by 1980-81 and the last two units by 1982-83.

TABLE 16

PERTINENT DATA
TUSKAHOMA PUMPED STORAGE PROJECT

Forebay Reservoir - Hilltop	
Maximum W.S. Elevation	1750.0
Minimum W.S. Elevation	1710.0
Capacity (1710-1750) acre-feet	19,000
Afterbay Reservoir - Tuskahoma Reservoir	
Top Flood Control Pool, elevation	653.0
Top Conservation Pool, elevation	643.5
Top Inactive Pool, elevation	610.0
Tailwater, elevation	611.0
Penstock and Shaft	
Total length, feet	5,820
Diameter, feet	27
Head Loss, feet	40.0
Type of Turbine	Francis
Station Capacity, megawatts	1,000
No. of Units and Capacity, each	4-250,000 KW
Gross Heads, feet	
Maximum	1139
Rated	1089
Minimum	1046
Net Heads, feet	
Maximum	1099
Rated	1049
Minimum	1006
Discharge, c.f.s.	
Maximum through turbines	15,700
Rated head	13,100
Average Annual Energy (12% P.F.), kmwh	
Generation	1,051
Pumping (75% efficiency)	1,401

TABLE 17

PHYSICAL FEATURES AND ENGINEERING DATA
TUSKAHOMA DAM AND RESERVOIR

Feature	Authorized Plan	Proposed Plan
LOCATION		
Stream	Kiamichi River	Kiamichi River
River mile	118.5	118.5
Drainage area, square miles	347	347
GENERAL ELEVATION, FEET, M.S.L.		
Top of dam	674.0	676.5
Top of flood control pool	649.5	653.0
Top of conservation pool	639.5	643.5
RESERVOIR STORAGE, ACRE-FEET		
Flood control	138,600	140,000
Conservation	231,000	251,500
Inactive	4,400	35,500
Total	374,000	427,000
RESERVOIR AREA, ACRES		
Top of flood control pool	15,400	16,780
Top of conservation pool	11,600	13,000
DAM		
Type	Earthfill	Earthfill
Length of embankment, feet	6,770	8,010
Maximum height, feet	96	98.5
Crown width, feet	32	32
DIKES (dam extension)		
Crest length	230	250
Maximum height, feet	3	5.5
Crown width, feet	32	32
ALBION DIKE		
Crest length	3,900	3,980
Maximum height, feet	25	28
Crown width, feet	10	10
SPILLWAY		
Location (valley-saddle-abutment)	Saddle	Saddle
Type	Uncontrolled	Uncontrolled
Net crest width	200	200
Crest elevation, feet, m.s.l.	649.5	653.0
Discharge at maximum pool, c.f.s.	55,800	63,800
OUTLET WORKS		
Type	Gated conduit	Gated conduit
Number and size	1-16' dia.	1-16' dia.
Low flow (pipes)	1-24"	1-24"
Water supply (pipes)	1-24"	1-24"
CHANNEL CAPACITY, C.F.S.	7,000	7,000

TABLE 18

TUSKAHOMA PUMPED STORAGE PROJECT
SUMMARY OF ECONOMIC ANALYSIS

Item	Amount
1. ALLOCATED COSTS FOR POWER	
a. First cost	$108,700,000
b. Investment	115,766,000
c. Annual charges (50-year analysis)	
Interest and amortization, 3-1/4 percent	4,673,500
Operation and maintenance	255,000
Major replacements	23,600
Pumping costs, 1,401 million kwh at 2.3 mills	3,222,300
Total annual charges	8,174,400
d. Annual benefits	
1,000,000 kw capacity at $16.00	16,000,000
1,051,000,000 kwh av. annual energy at 1.9 mills	1,996,900
Total annual benefits	17,996,900
e. Benefit-cost ratio	2.20
2. COMPARABILITY ANALYSIS	
a. Alternate cost for power	
1,000,000 kw capacity at $7.50	$ 7,500,000
1,051,000,000 kwh av. annual energy at 1.9 mills	1,996,900
Total alternate cost for power	9,496,900
b. Allocated cost for power	
Investment	115,766,000
Annual charges (100-year analysis)	7,472,600
c. Comparability ratio	1.16

b. Sherwood Reservoir and Modified Broken Bow. Sherwood Dam would be located on the Mountain Fork River at river mile 44.4 near the upper reaches of the Broken Bow Reservoir. The project purposes would be generation of hydroelectric power, recreation, and fish and wildlife propagation, with generation of power the primary purpose. The Sherwood Project would have an installation of one conventional power unit of 100,000 kilowatts and five reversible power units of 100,000 kilowatts each operating under a rated net head of 155.0 feet. The project was developed on the basis that the Sherwood power plant would be operated on an 8.6 percent annual plant factor with a 75 percent over-all efficiency.

Sherwood Reservoir, backed up by a dam about 238 feet high, would have a usable storage of 844,000 acre-feet between elevations 761.0 and 795.0. The average net head for the critical period would be 159.0 feet. With the six turbines operating under the minimum net head, the discharge would be 58,000 c.f.s.

The modification to the existing Broken Bow project would consist of reallocation of power and flood control storages. The usable power storage in Broken Bow would be 223,200 acre-feet between elevations 590.0 and 606.0. Broken Bow would operate on an 11.4 percent plant factor.

The Sherwood pumpback units would normally be operated five days a week for a maximum weekly generation of 30 hours and would require six hours of generation daily. A 75 percent over-all efficiency would require about eight hours of pumping to replenish storage in the Sherwood Reservoir. The average annual plant factor for the system of reservoirs would be about 10 percent. The Sherwood plant would have dependable capacity of 690,000 kilowatts (115 percent of installed capacity) and would provide an additional 14,000 kilowatts of dependable capacity at the Broken Bow plant. The average annual generation at Sherwood would be 730,200,000 kilowatt-hours and average annual generation at Broken Bow would be increased by 8,400,000 kilowatt-hours as a result of Sherwood.

Storage would be provided, about 109,700 acre-feet, above the power pool in Sherwood Reservoir for flood control. The flood control benefits for the system would remain the same as Broken Bow Reservoir operating alone.

Based on preliminary studies, Sherwood Reservoir would have an uncontrolled limited service spillway, 600 feet in length, about one quarter-mile west of the right abutment. Two penstock tunnels, each 41.5 feet in diameter, would be constructed through the right abutment. The outlet works tunnel would be a 17-foot diameter conduit used for diversion of flows during construction. The outlet works tunnel would have a low-level intake and would enter the penstock just downstream of the intake structure. Flows would leave the penstock through another outlet works tunnel downstream of the embankment and would be dumped into the tailrace to the left of the powerhouse. The outlet works tunnel would have a valve near the exit, in addition to gates in the intake structure, to prevent releases when the penstock is being used for power generation.

Based on preliminary estimates, the first cost of construction of the Sherwood Reservoir project would be $154,400,000. The annual charges, including amortization and interest, operation and maintenance, major replacements and engineering studies, and the cost of pumping to replenish power storage, is estimated at $8,884,900. Annual benefits are summarized in table 19.

TABLE 19

SHERWOOD MULTIPLE-PURPOSE PROJECT
SUMMARY OF ANNUAL BENEFITS

Hydroelectric Power	
At Sherwood	
Dependable - 690,000 kw @ $15.50/kw	$10,695,000
Energy - 730.2 million kwh @ 2.1 mills/kwh	1,533,400
Average Annual Benefits at Sherwood	12,228,400
Added at Broken Bow	
Dependable - 14,000 kw @ $15.50/kw	$217,000
Energy - 4.8 million kwh @ 2.1 mills/kwh	17,700
Average Annual Benefits Added at Broken Bow	234,700
Total Annual Hydroelectric Power Benefits	$12,463,100
Recreation	1,681,000
Fish and Wildlife	19,000
Total Annual Benefits	$14,163,100

The total annual benefits of $14,163,100 compared to the total annual cost of $8,884,900 shows a benefit-cost ratio of 1.6 for the Sherwood multiple-purpose project. Pertinent data for the Sherwood Reservoir with Broken Bow modification, as related to power, are listed in table 20 and a summary of the economic analysis of power for the combined projects is given in table 21. The benefit-cost ratio for power is 1.66 and the comparability ratio is 1.06. Financial feasibility is under study at this time.

TABLE 20

SHERWOOD RESERVOIR WITH MODIFIED BROKEN BOW PERTINENT DATA

	Broken Bow Authorized	Broken Bow Modified
Broken Bow Reservoir		
Top of dam, elevation	645.0	645.0
Top of flood control pool, elevation	627.5	627.5
Top power & water supply pool, elevation	599.5	606.0
Bottom power & water supply pool, elevation	559.0	590.0
Flood control storage, acre-feet	450,000	350,000
Power & water supply storage, acre-feet	470,000	223,200

Sherwood Reservoir	
Top of dam, elevation	819.0
Top flood control pool, elevation	798.5
Top power pool, elevation	795.0
Bottom power pool, elevation	761.0
Flood control storage, acre-feet	109,700
Power storage, acre-feet	844,000

POWER DEVELOPMENT AT SHERWOOD RESERVOIR

Installed capacity, kw		600,000
Dependable capacity, kw		690,000 1/
Tailwater elevation, feet		614.0
Head loss, feet		5.0
Gross heads, feet:		
Maximum		181.0
Minimum		147.0
Average during critical period		164.0
Net heads, feet:		
Maximum		176.0
Minimum		142.0
Rated		155.0
Average during critical period		159.0
Generating units:		
Type and size (kw)	1-Conventional	100,000
	5-Reversible	500,000
Maximum discharge through turbines, c.f.s.		58,000
Average annual generation kmwh:		
Conventional		110.0
Reversible @ 12% P.F.		620.2
Average annual pumping energy, kmwh (75% efficiency)		
Reversible @ 12% P.F.		826.9
Penstocks:		
Length, feet		700
Number and diameter, feet		2 @ 41.5

1/ Units capable of continuous generation at 15% overload.

TABLE 21

SHERWOOD AND MODIFIED BROKEN BOW
Summary of Economic Analysis (Power Only)

1. ALLOCATED COSTS FOR POWER 1/	
a. First cost	$127,618,000
b. Investment	139,592,000
c. Annual charges (50-year analysis)	
Interest and amortization	5,585,800
Operation and maintenance	609,500
Major replacements	358,900
Pumping costs, 826.9 million kwh at 2.4 mills	1,984,600
Total annual charges	8,538,800
d. Annual benefits 2/	14,127,200
e. Benefit-cost ratio	1.66
2. COMPARABILITY ANALYSIS	
a. Alternate cost for power	
Broken Bow (86,000 kw under construction) allocation	$ 890,100
Sherwood (plus Broken Bow additional) capacity 704,000 kw at $7.50	5,280,000
Sherwood (plus Broken Bow additional) average annual energy, 738.6 3/ million kwh at 2.1 mills	1,551,100
Total alternate cost for power	7,721,200
b. Allocated cost for power	
Investment	139,592,000
Annual charges (separable - 100-year analysis)	7,293,400
c. Comparability ratio	1.06

1/ Includes proposed Sherwood (600,000 kw) and under-construction Broken Bow (100,000 kw), involving reconciliation of two different rates of interest.

2/ Includes power benefits from table 19, plus $1,664,100 power benefits at under-construction Broken Bow project.

3/ Includes 730.2 million kwh for Sherwood (620.2 reversible and 110.0 conventional), and 8.4 million kwh for Broken Bow modification.

25. LONG RANGE PLAN

a. General. The screening studies for development of hydroelectric power in the basin considered physical sites, both conventional and pumped storage as listed in tables 14 and 15, including those that did not qualify for the 10-15 year plan but merited inclusion in the long range plan. The projects showing the most potential for future hydroelectric power development are shown below.

b. Conventional hydroelectric projects.

(1) Upper Antlers Dam. This dam, located on the Kiamichi River, would have favorable heads and storage for power production.

(2) Caney Mountain Dam. This dam, located on the Little River, would also have favorable heads and storage for power production.

(3) Durant Dam. The Durant Dam, located on the Blue River, would have favorable heads, flows, and storage for power production.

(4) Buck Creek Dam. This dam, located on Buck Creek, would also have favorable heads and storage for power production.

(5) Hugo Dam. Hugo Dam is presently under construction on the Kiamichi River. Provisions for power were eliminated in pre-construction planning studies because the separable costs for including power in the project exceeded the costs of a comparably financed alternative. However, the potential of the site warrants inclusion of power in the long range plan.

(6) Pine Creek Dam. The Pine Creek Dam is presently under construction on the Little River. Power was eliminated from the project in pre-construction planning studies because estimated revenues would be less than allocated power facilities investment and operating costs plus marketing agency costs. However, the potential of the site warrants inclusion of the project in the long range plan.

(7) Lukfata Dam. Lukfata Dam is an authorized project to be located on Glover Creek. Provisions for power were eliminated in pre-construction planning studies because the separable costs for including power in the project exceeded the costs of a comparably financed alternative. However, the potential of the site warrants inclusion of the project in the long range plan.

(8) Dierks Dam. Dierks Dam is presently under construction on the Saline River. Provisions for power were eliminated in pre-construction planning studies because the separable costs for including power in the project exceeded the costs of a comparably financed alternative. However, the potential of the site warrants inclusion of the project in the long range plan.

(9) DeQueen Dam. The DeQueen Dam is presently under construction on the Rolling Fork River. Provisions for power were eliminated in pre-construction planning studies because the costs for including power in the project exceeded the costs of a comparably financed alternative. However, the potential of the site warrants inclusion of the project in the long range plan.

(10) Gillham Dam. The Gillham Dam is presently under construction on the Cossatot River. Power was eliminated in pre-construction planning studies because estimated revenues would be less than allocated power facilities investment and operating costs plus marketing agency costs. However, the potential of the site warrants inclusion of the project in the long range plan.

c. Pumped storage hydroelectric power.

(1) Clayton Reservoir. The mountainous country around the authorized Clayton Reservoir on Jackfork Creek contains several sites for potential forebay reservoirs. Because of the future need for peaking power and the potential of the site, this project is included in the long range plan.

(2) Broken Bow Reservoir. The under-construction Broken Bow Reservoir on Mountain Fork River is included in the long range plan for pumped storage hydroelectric production because of the potential of the site.

(3) Sherwood Reservoir. Several potential forebay sites exist near the proposed Sherwood Reservoir on Mountain Fork River. This project is included in the long range plan because of the future need for peaking power and the potential of the site.

(4) Gillham Reservoir. The authorized Gillham Reservoir on Cossatot River is included in the long range plan because of the future need for peaking power and the potential of the site.

(5) Hugo Reservoir. The authorized Hugo Reservoir on Kiamichi River is included in the long range plan since the potential for production of hydroelectric power exists at the site.