ARKANSAS STATE WATER PLAN

UPPER OUACHITA BASIN

Arkansas Soil and Water Conservation Commission

OCTOBER, 1987

STATE OF ARKANSAS

ARKANSAS SOIL AND WATER CONSERVATION COMMISSION
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PREFACE

The Arkansas Soil and Water Conservation Commission received statutory authority to begin work on the first Arkansas State Water Plan in 1969. Act 217 gave specific authority to the Commission to be the designated agency responsible for water resources planning at the state level. The act mandated the preparation of a comprehensive state water plan of sufficient detail to serve as the basic document for defining water policy for the development of land and water resources in the State of Arkansas.

The first State Water Plan was published in 1975 with five appendices that addressed specific problems and needs in the state. As more data have become available, it is apparent that the ever-changing nature and severity of water-resource problems and potential solutions require the planning process to be dynamic. Therefore, periodic revisions to the State Water Plan are necessary for the document to remain valid.

This report is the fifth of eight River Basin Reports to be published as a component of the 1986 Arkansas State Water Plan. The objectives of this plan are to incorporate new data available from recent research, re-evaluate new and existing problems, present specific solutions and recommendations, and satisfy the requirements of Act 1051 of 1985 for the Upper Ouachita River Basin.

ACKNOWLEDGEMENTS

The information and assistance provided by representatives of State and Federal agencies, organizations, and associations are gratefully acknowledged. Personnel from several agencies (Arkansas Department of Health, Arkansas Department of Pollution Control and Ecology, Arkansas Natural Heritage Commission, and the Soil Conservation Service) were especially helpful. Dr. Joe Nix of Ouachita Baptist University provided the majority of information on impoundment water quality in the basin. Mr. A. H. Ludwig of the U.S. Geological Survey provided information and advice on the hydrogeology of the basin.

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CHAPTER IV

ABSTRACT

The Upper Ouachita Basin encompasses approximately 3.5 million acres of land in the southwestern part of the state. Forestland is the major land use, accounting for about 76 percent of the total land use in the basin. The basin is characterized by two topographically distinct divisions. The northern half of the basin lies in the Ouachita Mountain section of the Interior Highlands and the southern half of the basin lies in the West Gulf Coastal Plain.

Water use in the study area totaled 53.3 million gallons per day (MGD) in 1980. By the year 2030, the amount of water use in the study area is projected to increase to 446 MGD. The possibility of an interbasin transfer of approximately 250 MGD of water to Little Rock and adjacent areas to supplement municipal water supplies represents approximately half of the total projected water use for the basin.

There are about 7400 lakes in the study area that impound a total of approximately 1.5 million acre-feet of water. The major impoundments in the basin are Lake Ouachita, DeGray Lake, Lake Greeson, Lake Hamilton, Lake Catherine, and White Oak Lake. The impoundments are operated for a variety of purposes including flood control, power generation, recreation, conservation, and water supply.

The principal streams in the Upper Ouachita Basin are the Ouachita, Little Missouri, and Caddo Rivers. Generally, streams in the northern half of the basin that drain the Ouachita Mountains have steep gradients and narrow valleys which result in rapid runoff. Streams in the southern half of the basin that drain the Coastal Plain have relatively flat slopes and generally are sluggish.

Streams in the Upper Ouachita Basin have a combined yield of approximately 5.4 million acre-feet of water on an average annual basis. Streamflow in the basin is adequate, on an average annual basis, to satisfy existing water needs in the basin. However, due to natural streamflow variability, the majority of flow is available during the winter and spring months of the year with considerably less water available during the summer and fall months when water-use demands are generally highest. Availability of streamflow can also be a problem downstream of reservoirs in the basin, especially in those areas downstream of hydroelectric power facilities. Of the total amount of water in the basin, 425,000 acre-feet is excess streamflow which is available on an average annual basis for other uses, such as interbasin transfer.

Water quality of the streams and lakes in the Upper Ouachita Basin is generally good. Concentrations of most constituents are within acceptable limits, therefore, streams

and reservoirs in the basin support most beneficial uses. Several water-quality problems do exist in the basin, however, and are as follows: water-quality degradation from municipal and industrial discharges and from land-use practices; naturally low buffering capacities of surface waters; and low dissolved oxygen concentrations in tailwater releases from the major reservoirs.

No streams in the Upper Ouachita Basin are designated as critical surface water areas based on quantity or quality problems. Shortages of water may exist, at times, on streams due to reservoir release patterns or natural streamflow variability. However, streamflow generally is adequate to support the needs of the basin. Water-quality problems do exist in the basin but the problems are generally localized and do not cause a significant shortage of useful water.

Recommendations for mitigation of surface-water problems in the Upper Ouachita Basin include: (1) development of alternate water sources, such as construction of water storage reservoirs and diversion of water from the Ouachita River; (2) reallocation of reservoir storage and (or) conjunctive management of reservoir releases; and (3) regulation and enforcement of municipal and industrial effluent discharges.

Geologic units from the Paleozoic, Mesozoic, and Cenozoic Eras are present on the surface and in the subsurface of the Upper Ouachita Basin. Formations and groups of formations from the Quaternary, Tertiary, and Cretaceous Systems, in addition to Paleozoic rocks, contain freshwater in the basin.

Yields from rocks of Paleozoic age are small (generally less than 10 gallons per minute) due to the limited storage in the consolidated units and withdrawals are used mainly for domestic purposes. Cretaceous units generally are non-water bearing or yield water of unsuitable quality for most uses. However, yields obtained from the Nacatoch Sand and the Tokio Formation are adequate to satisfy small public systems, and industrial and domestic needs. The Sparta Sand of Tertiary age is the best aquifer for high yields of good quality water in the basin. Quaternary terrace and alluvial deposits are principal aquifers in Clark, Hot Spring, and Pike Counties. Elsewhere, these deposits are thin and capable of supplying only small amounts of water to wells.

Groundwater withdrawals in the study area in 1980 totaled 12.97 MGD. Approximately 45 percent of the groundwater withdrawn was used for livestock and domestic supplies. Groundwater use has more than doubled since 1965, however, total withdrawals in the study area represent less than one percent of the groundwater withdrawn from all formations statewide.

In general, water from the Sparta Sand is the least mineralized water from any of the formations in the basin and is used for public supply and self-supplied industry with little treatment required. Water from the Nacatoch Sand and the Tokio Formation is utilized by eight public supply systems in the basin and is of good quality near the outcrop zone but changes rapidly downdip where it contains excessive concentrations of sodium, chloride, and iron. Paleozoic rocks contain water that is highly variable from area to area but commonly contains excessive iron.

No areas in the Upper Ouachita Basin have been designated as critical groundwater use areas. Limited water-level data indicate that water levels are declining in some areas of the basin, however, the present rate of decline does not meet the criteria established for critical areas. Similarly, groundwater quality problems do not meet the established criteria because they are either naturally occurring or are isolated problems in individual wells.

The most common groundwater problems in the basin are low yields and poor water quality both of which are inherent in the formations. Therefore, no solutions exist for these problems.

Potential hazards to groundwater in the basin include surface impoundments, landfills, hazardous and non-hazardous wastes, salt-water intrusion, and pollution of the Sparta Sand recharge zone. Legislation is already in place for controlling or denying construction of liquid waste-holding impoundments. Proper administration of the Resource Conservation and Recovery Act (RCRA) program should contribute to the control of groundwater contamination from hazardous wastes. Research is currently being conducted to address some of the problems associated with potential pollution of the Sparta Sand recharge zone. An investigation is currently being made on the recharge zone in Ouachita County. In addition, a study of the Sparta Sand aquifer in Arkansas and Louisiana is being conducted to develop a method for evaluating the impact of present and proposed aquifer development on water-level declines and groundwater availability.

CHAPTER 1

GENERAL DESCRIPTION

The Upper Ouachita River Basin consists of all the area that is drained by the Ouachita River, from it's headwaters near Oklahoma to a point on the river downstream of the city of Camden. The watershed, located in the southwestern part of the State, consists of about 5,410 square miles or approximately 3,462,000 acres. <82> (Numbers in angle brackets refer to the references found in the bibliography.) The shape of the basin, as shown in Figure 1-1, is basically elongated in a northwest to southeast direction with approximately 120 miles separating the most distant corners. Average width of the basin is approximately 70 miles. The principal stream in the Upper Ouachita Basin is the Ouachita River. Major tributaries to the Ouachita River in the basin are the Little Missouri River and the Caddo River. Six major reservoirs have been constructed in this basin (See Figure 1-1). Three of these reservoirs are U.S. Army Corps of Engineers multipurpose projects. Lake Greeson on the Little Missouri River, DeGray Lake on the Caddo River, and Lake Ouachita on the Ouachita River are owned and operated by the Corps of Engineers. Lake Hamilton and Lake Catherine are both on the Ouachita River downstream of Lake Ouachita. They were the first major impoundments in this basin and were built by the Arkansas Power and Light Company for hydroelectric energy production. White Oak Lake, located in the south-central part of the basin, was built as a Game and Fish Commission public fishing area.

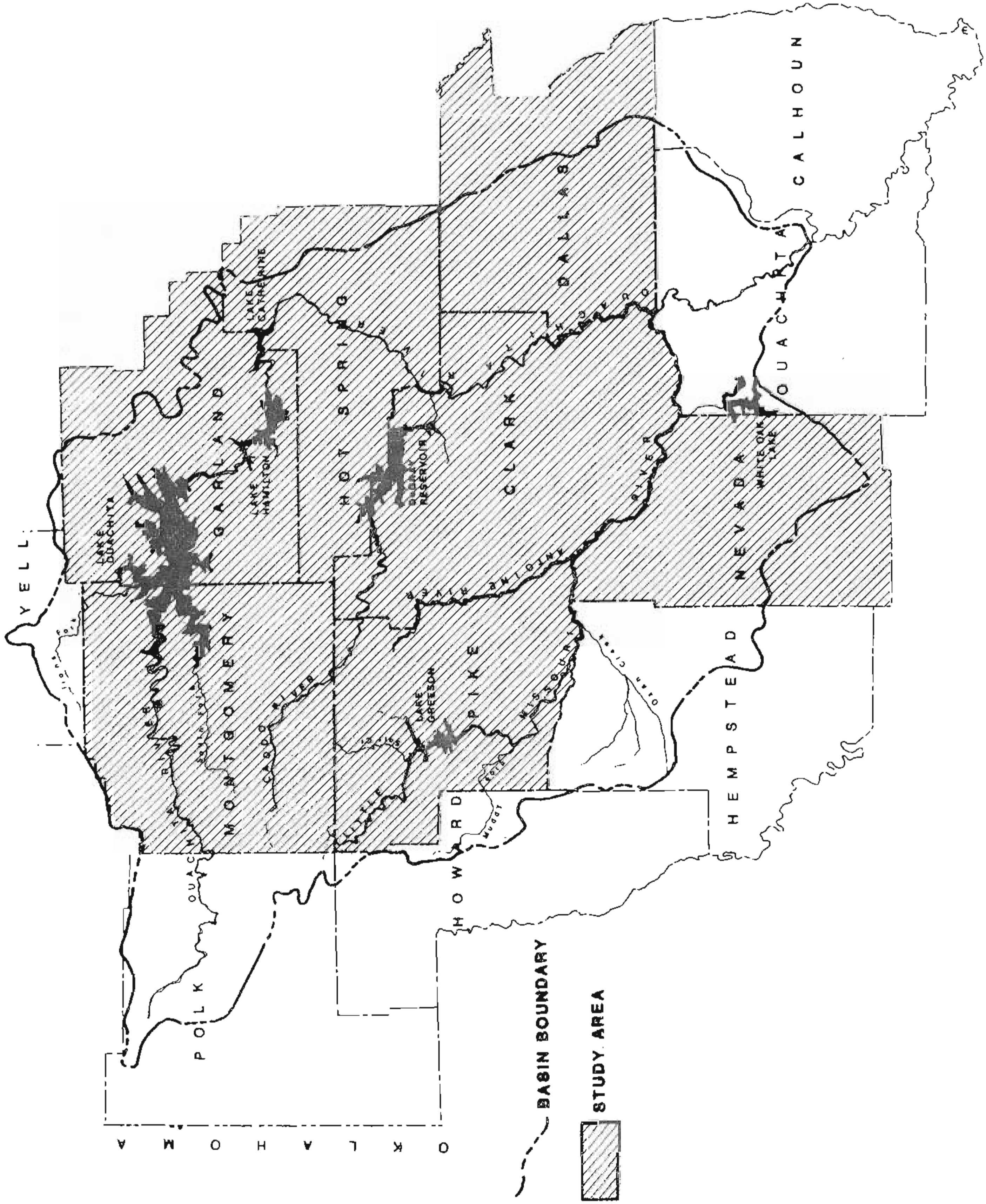
STUDY AREA

Seven counties comprise the study area of the Upper Ouachita Basin. The counties are: Clark, Dallas, Garland, Hot Springs, Montgomery, Nevada, and Pike (See Figure 1-1). Other counties are partially located within the basin, but were omitted from the study area. These counties would best be represented in other basin reports and inclusion of data from these counties in this report could be misleading.

Available data pertaining to this basin vary in format. Some data are available by county and other data are available by watershed area or hydrologic region. Where available, data by hydrologic regions will be used because these data best represent the basin area. Data by hydrologic regions will be referred to as basin totals. However, other data needs are best served by using county totals. Where county totals are used this will be referred to as study area or seven-county study area totals.

figure 1-1

UPPER OUACHITA BASIN and STUDY AREA



PHYSIOGRAPHY

Two physical divisions divide the basin into essentially equal halves (See Figure 1-2). A line from the dam at Lake Greeson to the dam at DeGray Lake and continuing to the Lake Catherine dam divides the Ouachita Mountain section of the Interior Highlands from the West Gulf Coastal Plain section of the Coastal Plain. <2> These physical divisions correspond to the major land resource areas discussed in Chapter 2.

The West Gulf Coastal Plain is characterized by a thick sequence of underlying unconsolidated sediments that gently dip toward the southeast. Sand, silt, clay, gravel and limestone make up the sediments which are of Cretaceous and Tertiary age. Cretaceous age deposits consist largely of clay, limestone, and chalk of marine origin. Tertiary age deposits consist of both marine and continental sediments. Within the flood plains of the major streams are deposits of Quaternary age. <34, 48, 59>

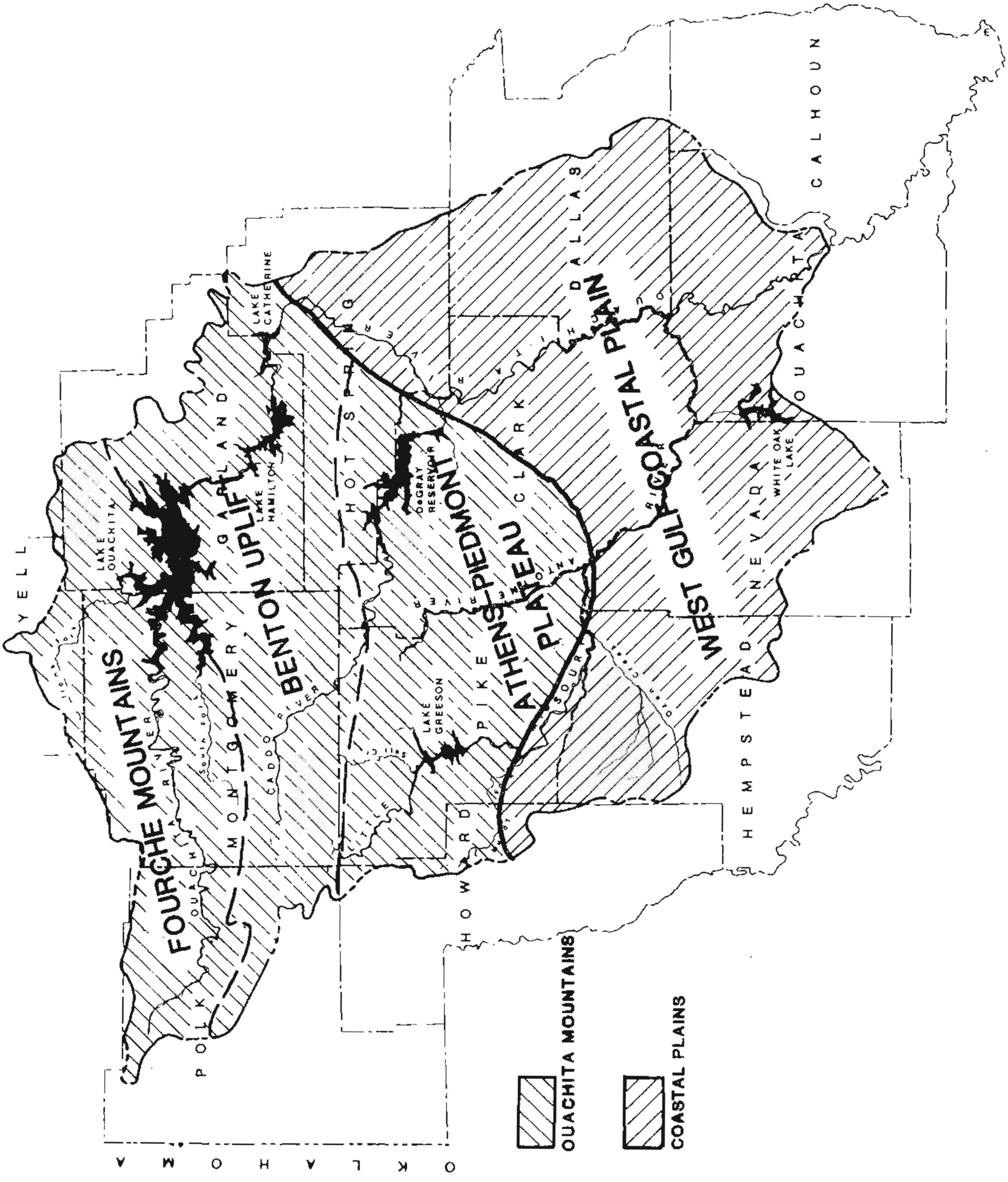
Two major land resource areas (MLRA) are located in the West Gulf Coastal Plain. The Blackland Prairie MLRA is characterized by areas of exposed or shallowly buried Cretaceous deposits. The other MLRA is the Coastal Plain and comprises the remainder of the West Gulf Coastal Plain within the Upper Ouachita River Basin. <84> See Chapter 2 for further descriptions of MLRA's and soil classifications.

The Ouachita Mountain section of the Interior Highlands was formed by a series of changes beginning with massive filling of a sinking trough. This was followed by orogenic movements, or folding, which squeezed the rocks into one half their original width. Complex and thrust faulted folds of nearly all types are present. The more recent changes, in a geologic time frame, include a long period of uplift which has been offset by erosion. A peneplain resulted from this erosional action and more recent uplifting action with increased erosion of softer rock layers resulted in the present conditions of long, even-crested ridges and flat basins. <2>

The Ouachita Mountains are subdivided into three physiographic subdivisions with all three described as the Ouachita Mountain Major Land Resource Area. <84> These subdivisions are known as the Fourche Mountains, the Benton Uplift, and the Piedmont Plateau. <2> Portions of all three subdivisions are located within the basin. In the northern counties of the basin are the Fourche Mountains and Benton Uplift. Both are characterized by east-west, long, even-crested ridges and flat basins. Rich Mountain, in the Fourche Mountains, is the highest peak in the basin at 2681 feet above

figure 1-2

UPPER OUACHITA BASIN
PHYSIOGRAPHIC PROVINCES



SOURCES: Albin ⟨2⟩

Fenneman and Johnson ⟨26⟩

sea level. South of these subdivisions is the Piedmont Plateau which has no mountains. The Piedmont Plateau is a newer peneplain than the older peneplain of the other two subdivisions of the Ouachita Mountains. Principal streams in the Fourche Mountains and Benton Uplift generally flow eastward. Streams in the Piedmont Plateau generally flow southward with the exception of the Caddo River. <2, 84>

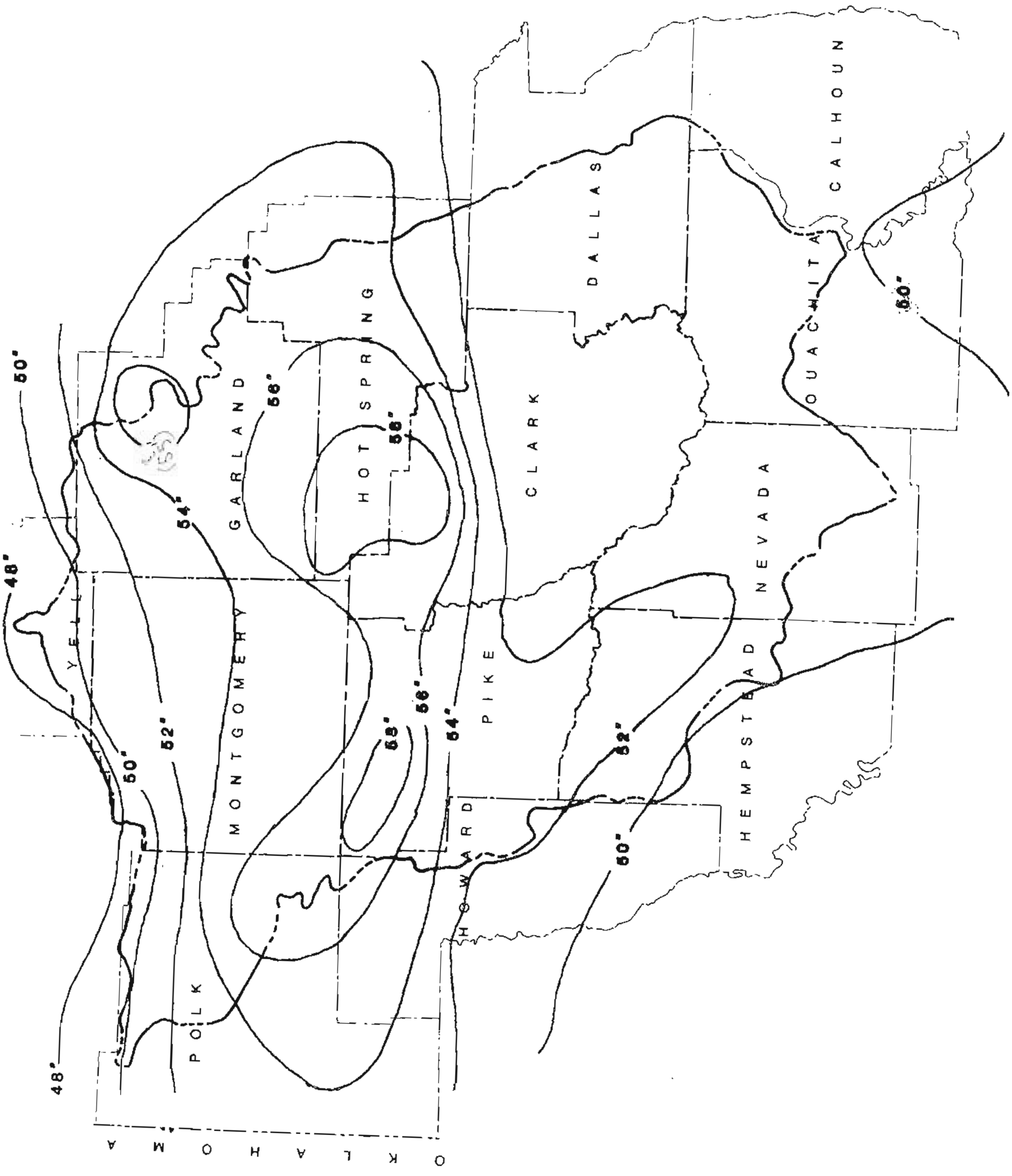
CLIMATE

Climate of the Upper Ouachita Basin is characterized by hot summers and mild winters. Precipitation is usually in the form of rain, with very light and infrequent snowfall. Average annual precipitation ranges from approximately 48 inches in the northwestern part of the basin to approximately 58 inches in the central part of the basin <29>, as shown in Figure 1-3.

Numerous weather stations operated by the National Oceanic and Atmospheric Administration (NOAA) are located throughout the Upper Ouachita Basin, as shown in Figure 1-4. Thirty-year averages of precipitation and temperature for 1951-80 were obtained from the National Climatic Center of NOAA for four weather stations in the basin (Camden, Hope, Mena, and Hot Springs). <95> These data, compiled in Table 1-1, show the monthly variation in precipitation and temperature at different locations in the Upper Ouachita Basin.

Average annual precipitation data for the period of 1951-80 have been statistically analyzed by NOAA <96> to determine the percent of time that a specified total annual precipitation can be expected to be equaled or exceeded at a particular location in the state. Annual precipitation probability data for the weather stations at Camden, Hope, Hot Springs, and Mena are compiled in Table 1-2. These data show, for example, that approximately 50 percent of the time, the total annual precipitation at Camden and Hope can be expected to be at least about 50 inches. The data for the four stations also show that approximately 10 percent of the time average annual rainfall can be expected to be less than approximately 37 inches at Camden or can be expected to exceed approximately 68 inches at Hot Springs.

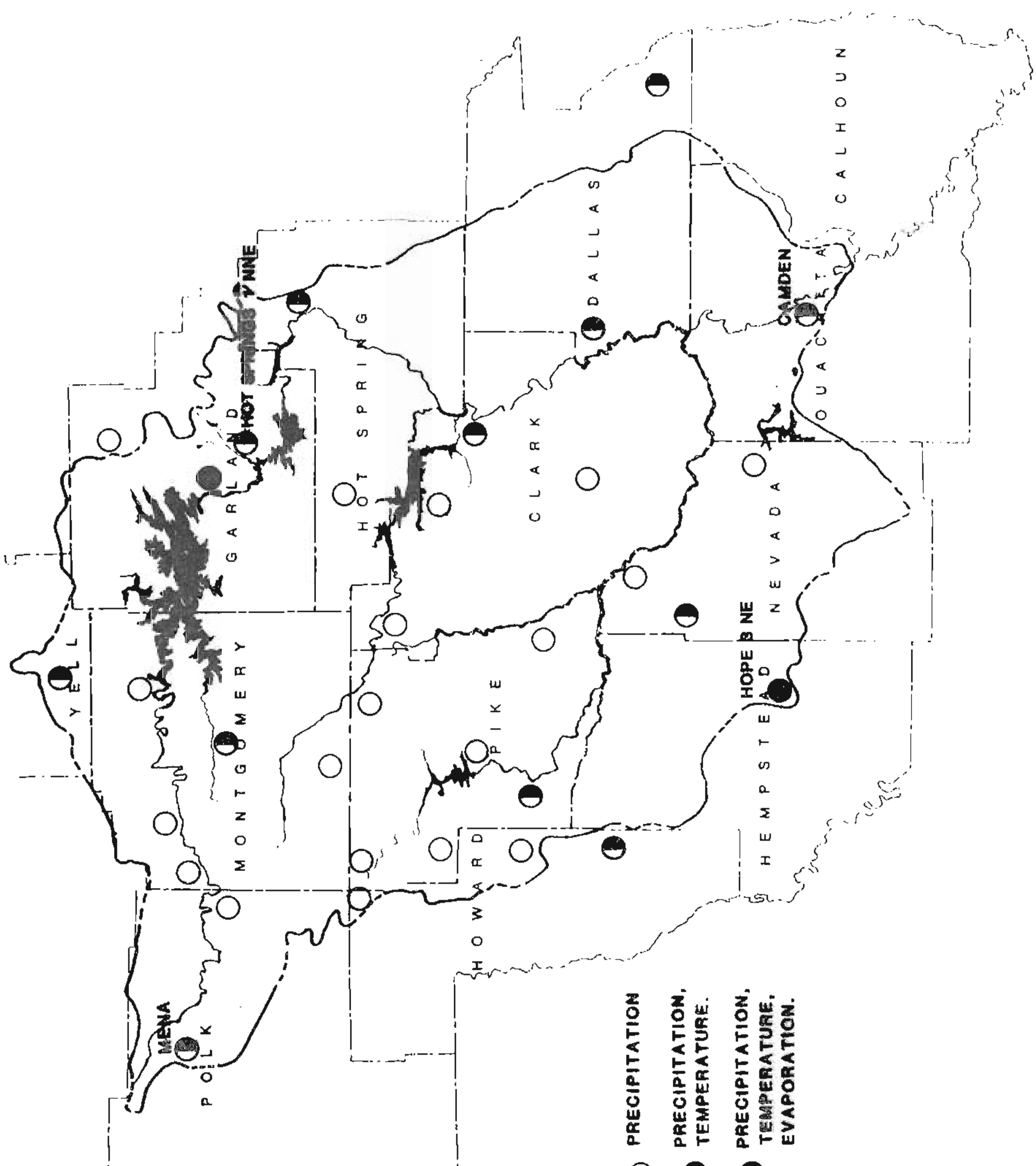
figure 1-3
AVERAGE ANNUAL RAINFALL



SOURCE: Freiwald ⟨29⟩

figure 1-4

WEATHER STATION LOCATIONS



SOURCE: National Oceanic and Atmospheric Administration ⟨95⟩

TABLE 1-1
AVERAGE MONTHLY PRECIPITATION AND TEMPERATURE (1951-80)
AT SELECTED WEATHER STATIONS

	MENA		HOT SPRINGS 1 NNE		CAMDEN		HOPE 3 NE	
	PRECIP.	TEMP.	PRECIP.	TEMP.	PRECIP.	TEMP.	PRECIP.	TEMP.
JAN	3.07"	39.9°	3.81"	41.4°	4.37"	42.4°	3.84"	41.0°
FEB	3.45"	44.2°	4.08"	45.5°	3.94"	46.5°	3.78"	45.0°
MAR	5.29"	51.6°	5.25"	53.2°	4.90"	54.2°	4.63"	52.4°
APR	5.80"	61.5°	5.89"	63.5°	5.12"	63.9°	5.55"	62.2°
MAY	5.67"	68.8°	6.43"	70.8°	4.74"	71.2°	5.40"	70.1°
JUN	4.29"	75.9°	4.40"	78.1°	3.65"	78.3°	4.25"	77.4°
JUL	4.65"	79.8°	5.17"	82.2°	4.08"	81.9°	3.67"	81.3°
AUG	2.85"	79.0°	3.35"	81.4°	3.08"	80.8°	4.01"	80.4°
SEP	4.74"	72.8°	4.37"	75.0°	4.50"	74.6°	4.28"	74.2°
OCT	4.26"	62.4°	3.36"	64.8°	2.77"	63.6°	3.29"	63.3°
NOV	4.23"	50.7°	4.80"	52.6°	4.57"	52.6°	4.40"	51.8°
DEC	3.92"	42.9°	4.47"	44.6°	4.60"	45.2°	4.07"	44.2°
AVG. ANNUAL	52.17"	60.8°	55.38"	62.8°	50.32"	62.9°	51.17"	61.9°

SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION <95>

TABLE 1-2

PROBABILITY THAT PRECIPITATION WILL EQUAL OR EXCEED THE INDICATED PRECIPITATION

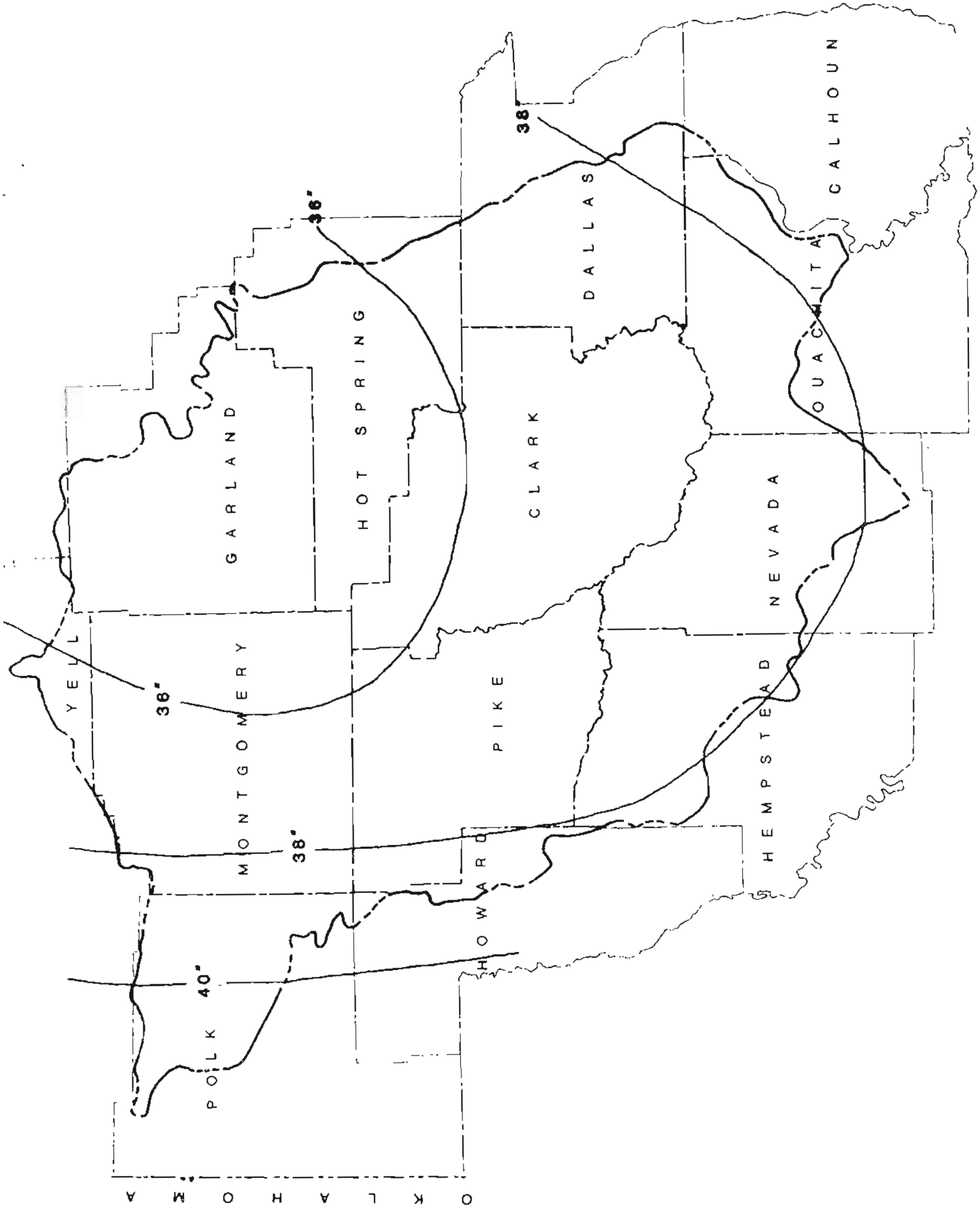
	PROBABILITY	ANNUAL PRECIPITATION
CAMDEN	10%	≥64.76"
	50%	≥49.53"
	90%	≥36.91"
HOPE	10%	≥65.88"
	50%	≥50.38"
	90%	≥37.52"
HOT SPRINGS	10%	≥68.55"
	50%	≥54.78"
	90%	≥43.00"
MENA	10%	≥67.06"
	50%	≥51.39"
	90%	≥38.38"

SOURCE: NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION <96>

As previously discussed, average annual precipitation ranges from approximately 48 to 58 inches in the Upper Ouachita Basin. Much of this precipitation, however, is not available for use because it is evaporated from streams, lakes, ponds, and irrigated cropland. The average annual free water surface evaporation for the Upper Ouachita Basin, shown in Figure 1-5, ranges from about 36 inches in the northeastern part of the basin to approximately 40 inches in the northwestern part of the basin. Much of the free water surface evaporation during the year occurs during the irrigation season of May through October, as shown in Figure 1-6. Free water surface evaporation is defined as "the evaporation from a thin film of water having no appreciable heat storage." <25> Since the surface waters in the Upper

figure 1-5

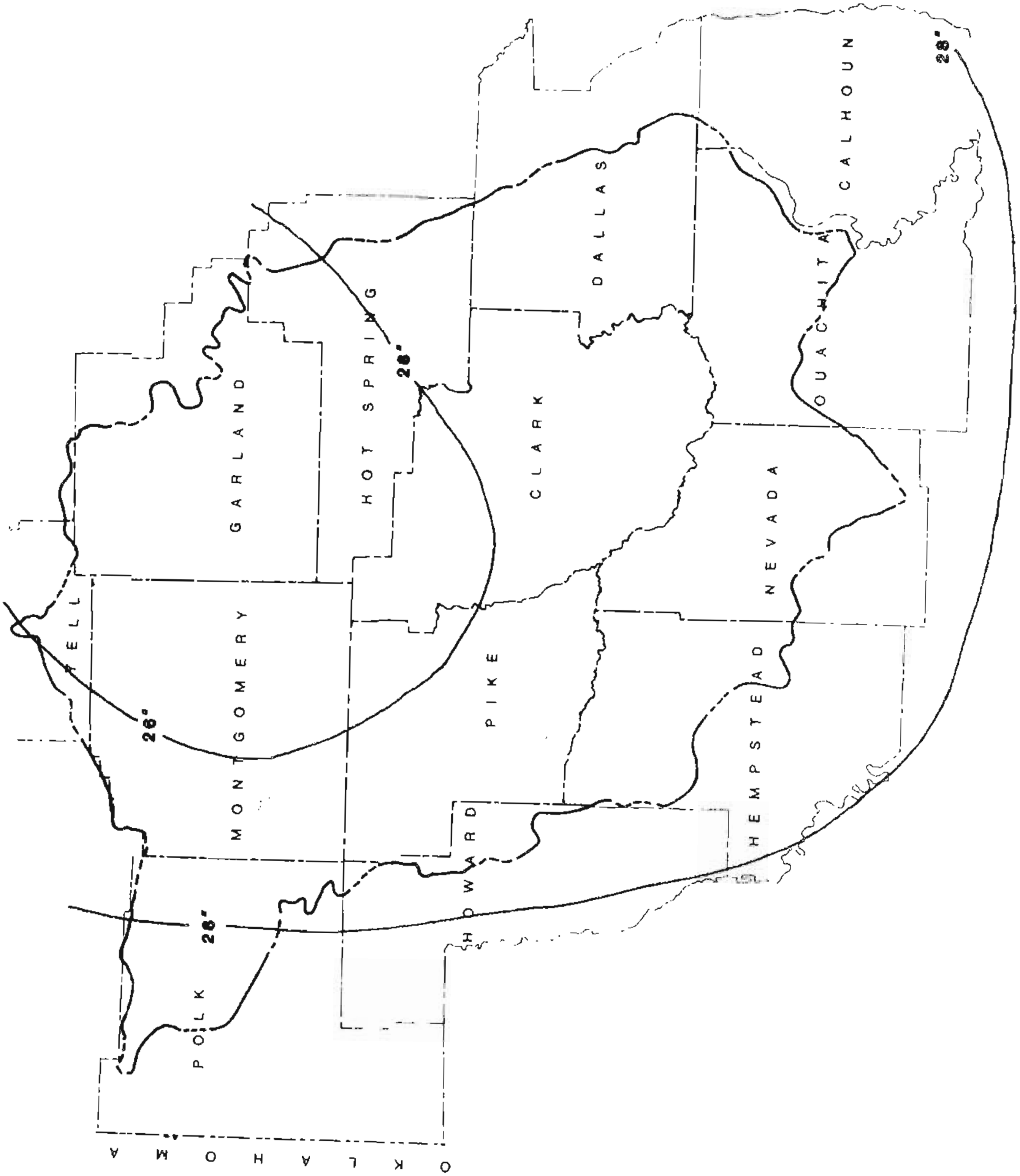
AVERAGE ANNUAL FWS EVAPORATION 1956-1970



SOURCE: Farnsworth and Others ⟨25⟩

figure 1- 6

AVERAGE FWS EVAPORATION
MAY-OCTOBER 1956-1970



SOURCE: Farnsworth and Others ⟨25⟩

Ouachita Basin (the lakes, in particular) may contain appreciable heat storage at times during the year, actual evaporation in the basin may be significantly different than the free water surface evaporation.

POPULATION

Population census data of the study area show that slightly more than 100,000 people lived in the area at the turn of the century (See Table 1-3). An increase of approximately 40,000 people occurred between 1900 and 1940, then a gradual decrease in population until 1960 when the population of the study area totaled about 124,000 (See Figure 1-7). The 1970 and 1980 census showed the renewal of an increasing trend. Population of the study area in 1980 totaled approximately 160,000, an increase of about 28,000 since the 1970 census. <94>

POPULATION PROJECTIONS

Predictions of future populations can be derived by various methods including graphical, mathematical, decreasing rate of increase, and ratio and correlation methods. <46> The Arkansas Department of Pollution Control and Ecology has prepared county population projections to the year 1990. <4> In addition, data are available from the University of Arkansas at Little Rock, Division of Demographic Research for population projections to the year 2000. <69> For this document, projections are needed to the year 2030. Data do exist for population projections to this year, however, the data are not compiled in a format that is useable on this small of an area. Therefore, a graphical approach was used to extend population projections to the year 2030. First, a line was fit using the data from 1960 to 2000. The 1960 to 1980 period was included because it was the beginning of the increasing trend after the end of the post-World War II decreasing trend. The line was then extended to 2030 resulting in a projected population for the study area of 230,000.

table 1- 3

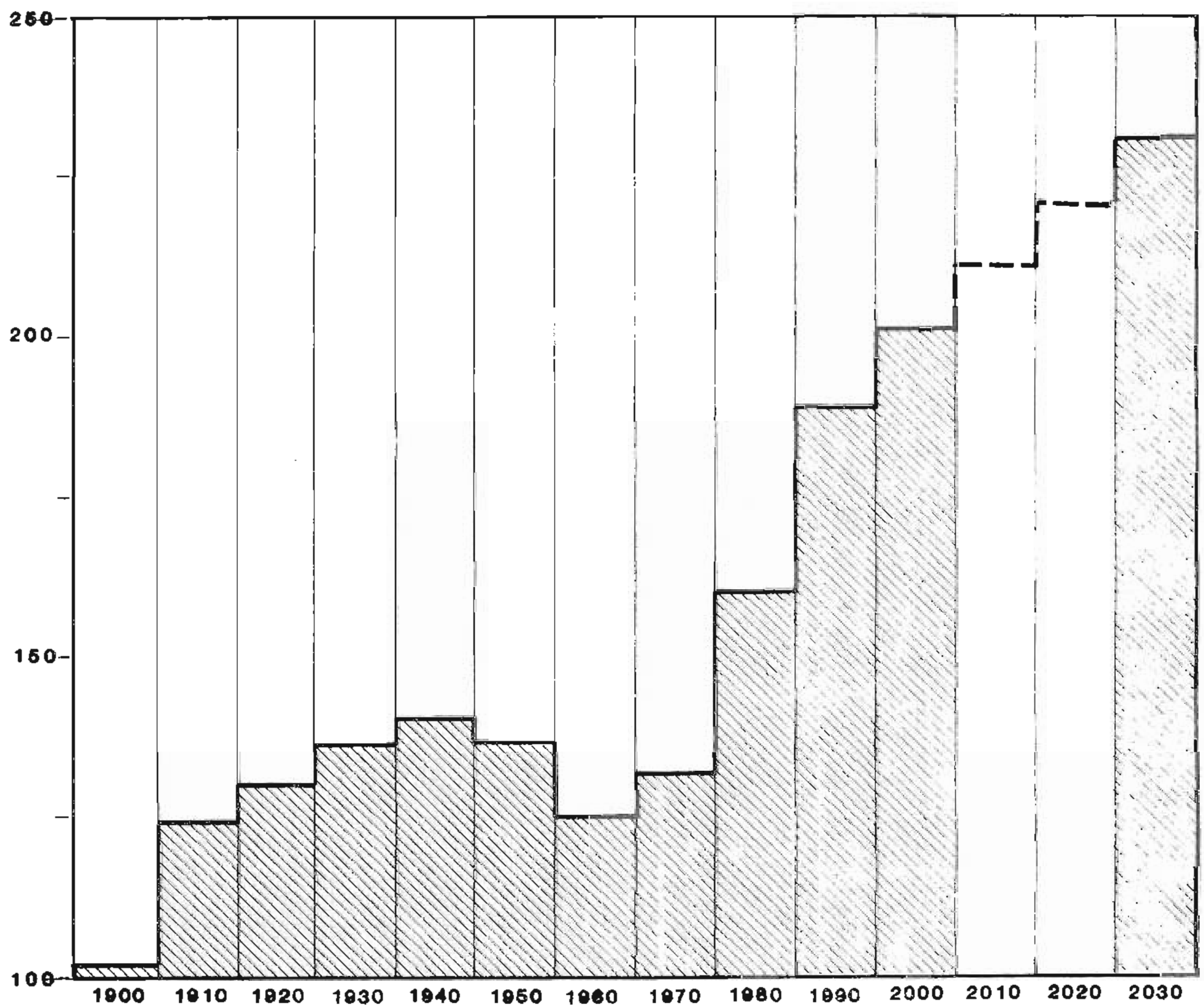
POPULATION TRENDS and PROJECTIONS
STUDY AREA TOTALS

YEAR

1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010	2020	2030
100.7	123.0	129.1	136.7	140.0	136.2	124.0	132.3	160.0	188.2	200.6	— —	— —	230.0

POPULATION (IN THOUSANDS)

figure 1- 7



REFERENCE: U.S.Department of Commerce ⟨94⟩

University of Arkansas at Little Rock⟨69⟩

Arkansas Department of Pollution Control and Ecology⟨4⟩

WATER USE

Study area water use amounted to 53.3 million gallons per day (MGD) in 1980. The 1980 amount is 125% more than the 1965 water use of 23.67 MGD and 39% more than the 1975 use of 38.4 MGD. (See Figure 1-8A and Table 1-4). <31, 33, 40>. Surface water is the predominant source of water for use in the study area. In fact, according to the data compiled in Table 1-4, approximately 76 percent of the total amount of water used in 1975 and 1980 was obtained from surface-water sources.

Water use is divided into the following categories: public supply, rural domestic, self-supplied industry, agricultural non-irrigation, and agricultural irrigation. In 1980, water use for thermo-electric cooling and hydroelectric generation was 574.63 MGD and 2653 MGD, respectively. Because these uses are essentially non-consumptive and do not reduce the supply of water to downstream users, these categories are not included in the water use totals.

Groundwater storage in the Ouachita Mountains is limited to the cracks and fissures of the underlying consolidated formations. Yields are generally small, with many wells yielding only enough to supply single households (rural domestic use). South of the mountains are Cretaceous formations that lack the potential to yield large quantities of water and Tertiary formations that are a mixture of good and poor yielding aquifers. Better Tertiary aquifers are generally in the southeastern part of the basin. Quaternary deposits in the principal stream floodplains may yield adequate quantities of water for domestic supplies.

Water used by public supply systems includes commercial, domestic, and public-supplied industrial users. There are 41 public water supplies in the study area. <3> A population of 111,010 people was served by these systems, and in 1980 public supply use was 16.53 MGD. Since 1965,this category of water use has increased 111%, from 7.83 MGD to 16.53 MGD used in 1980. (See Figure 1-8B and Table 1-4). Daily per person use was almost 150 gallons in 1980.

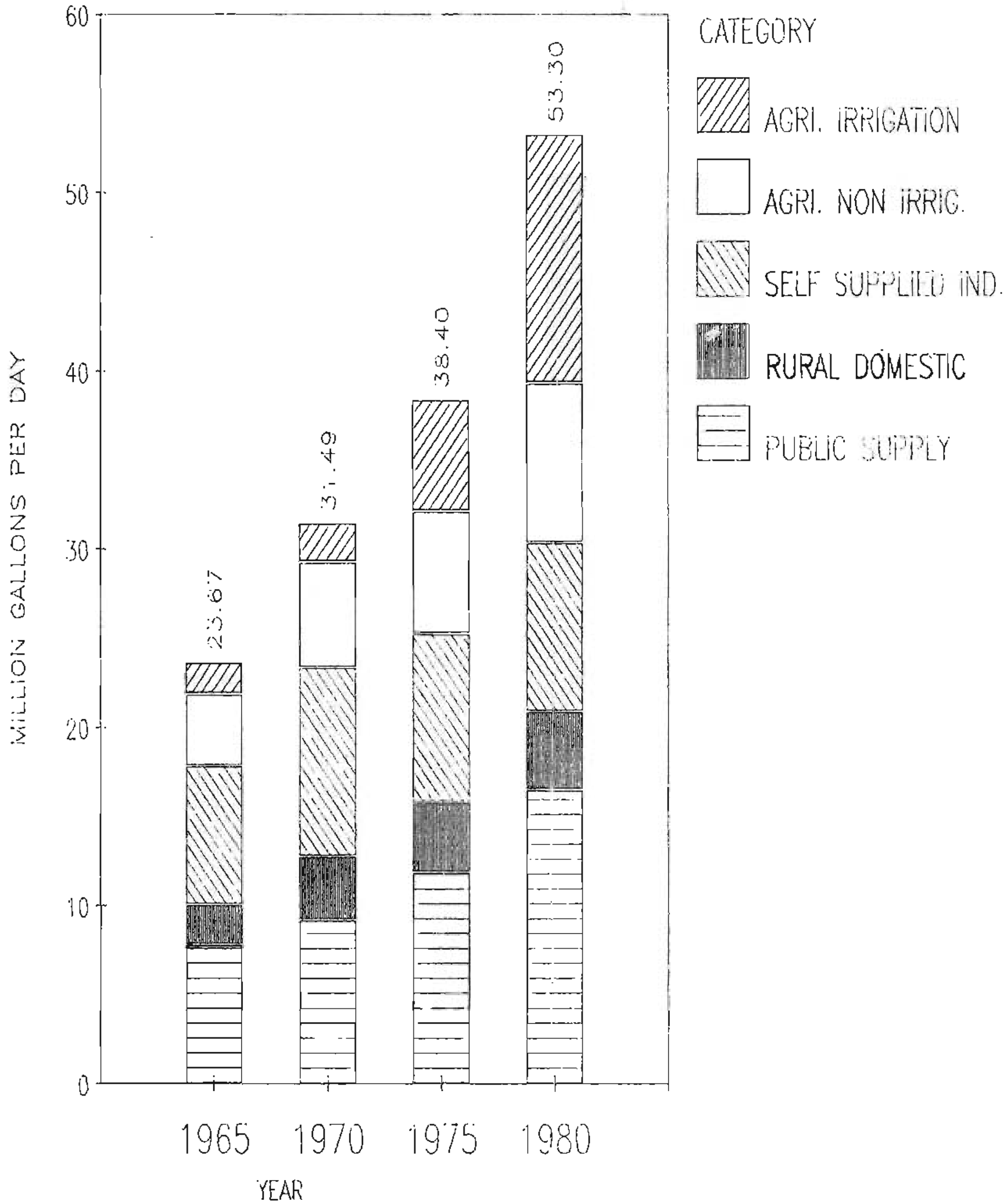
Rural domestic use is water for household use by people not served by a public supply. Approximately 49,420 people are in this category. This is based on totaling the 1980 census for the study area (160,432) and subtracting the number of people served by public supply systems (111,010). Rural domestic use in 1980 amounted to 4.38 MGD. (See Figure 1-8B and Table 1-4). Daily use per person was almost 90 gallons in 1980.

Self-supplied industrial water use has not increased significantly over the 1965-80 period and generally has stayed between 8 and 10 MGD. (See Figure 1-8B and Table 1-4). Use

FIGURE 1-8A

STUDY AREA WATER USE

1965--1980



SOURCES: Halberg <31, 32, 33>. Holland and Ludwig <40>.

TABLE 1-4

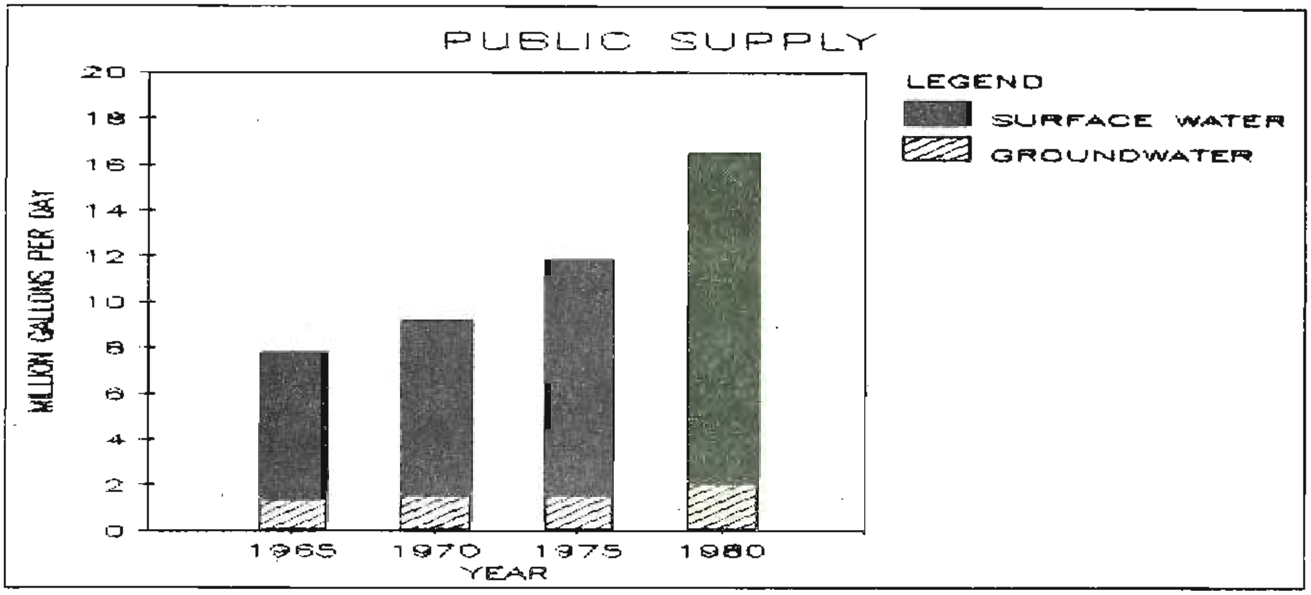
WATER USE

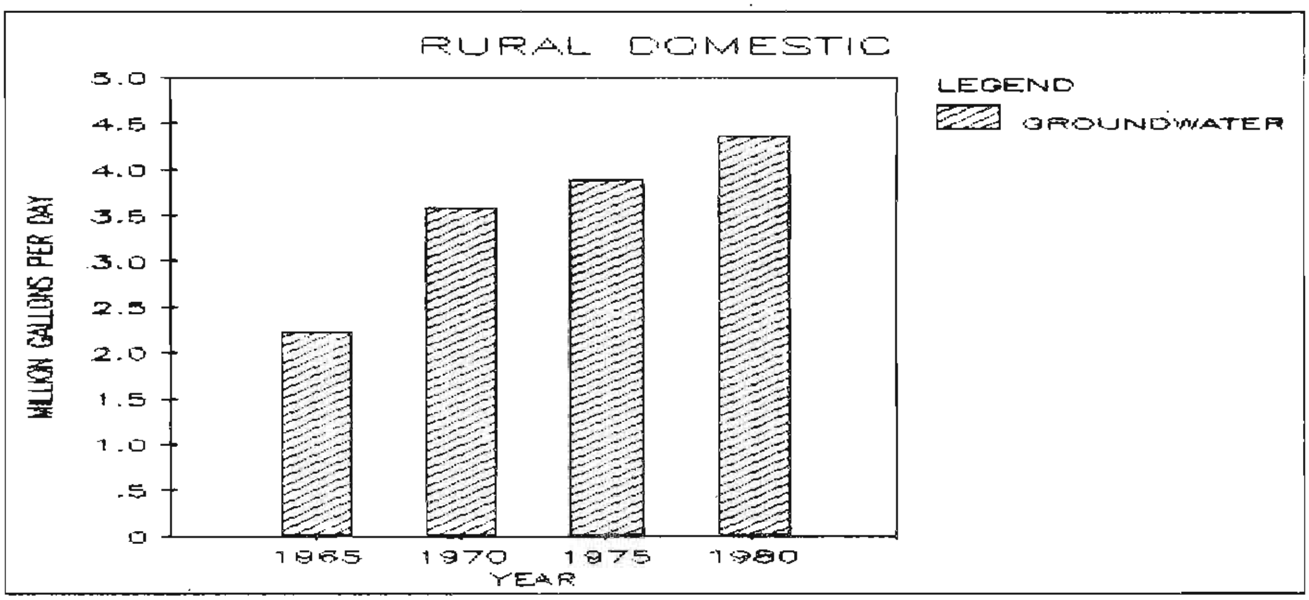
CATEGORY	1965	1970	1975	1980
PUBLIC SUPPLY				
(GROUNDWATER)	1.42	1.63	1.65	2.14
(SURFACE WATER)	6.41	7.57	10.26	14.39
TOTAL	7.83	9.20	11.91	16.53
RURAL DOMESTIC				
(GROUNDWATER)	2.24	3.60	3.90	4.38
(SURFACE WATER)	0	0	0	0
TOTAL	2.24	3.60	3.90	4.38
SELF SUPPLIED IND.				
(GROUNDWATER)	0.59	1.78	1.41	1.46
(SURFACE WATER)	7.21	8.29	8.06	7.98
TOTAL	7.80	10.57	9.47	9.44
AGRICULTURE NON-IRRIGATION				
(GROUNDWATER)	2.87	3.72	2.24	2.92
(SURFACE WATER)	1.16	2.20	4.58	6.05
TOTAL	4.03	5.92	6.82	8.97
IRRIGATION				
(GROUNDWATER)	0	0	0.03	2.12
(SURFACE WATER)	1.77	2.20	6.27	11.86
TOTAL	1.77	2.20	6.30	13.98
ALL AGRI. USE	5.80	8.12	13.12	22.95
ALL CATEGORIES				
(GROUNDWATER)	7.12	10.73	9.23	13.02
(SURFACE WATER)	16.55	20.73	29.17	40.28
TOTAL	23.67	31.49	38.40	53.30

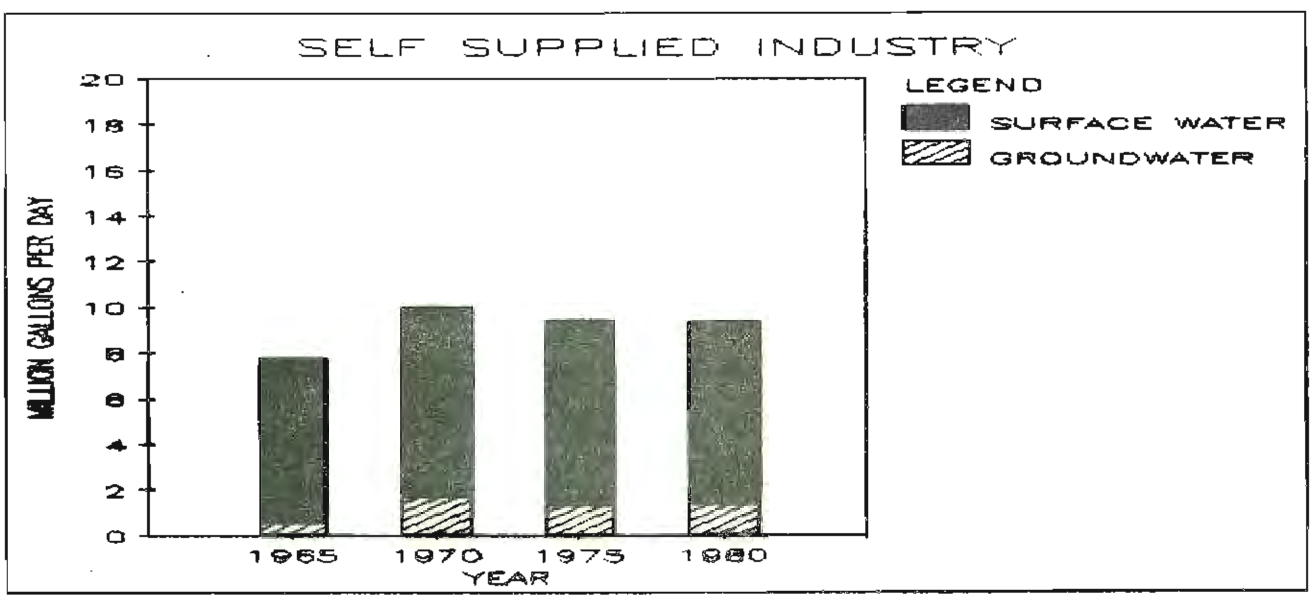
SOURCES: HALBERG <31, 32, 33>
HOLLAND AND LUDWIG <40>

figure 1-8B

WATER USE BY CATEGORY







SOURCE: Halberg <31, 32, 33>
Holland and Ludwig <40>

in 1965 amounted to 7.8 MGD and in 1980 amounted to 9.44 MGD. Since 1980, two of the larger self-supplied industries in the basin have closed.

Agricultural water use for non-irrigation purposes amounted to 8.97 MGD in 1980. Non-irrigation uses include water for livestock, poultry and fish farming. Water use for livestock and poultry accounted for 3.61 MGD and 5.36 MGD was used for fish farming in 1980. Use in 1965 equaled 4.03 MGD. (See Figure 1-8C and Table 1-4). In the fifteen year period, water use for this category has more than doubled.

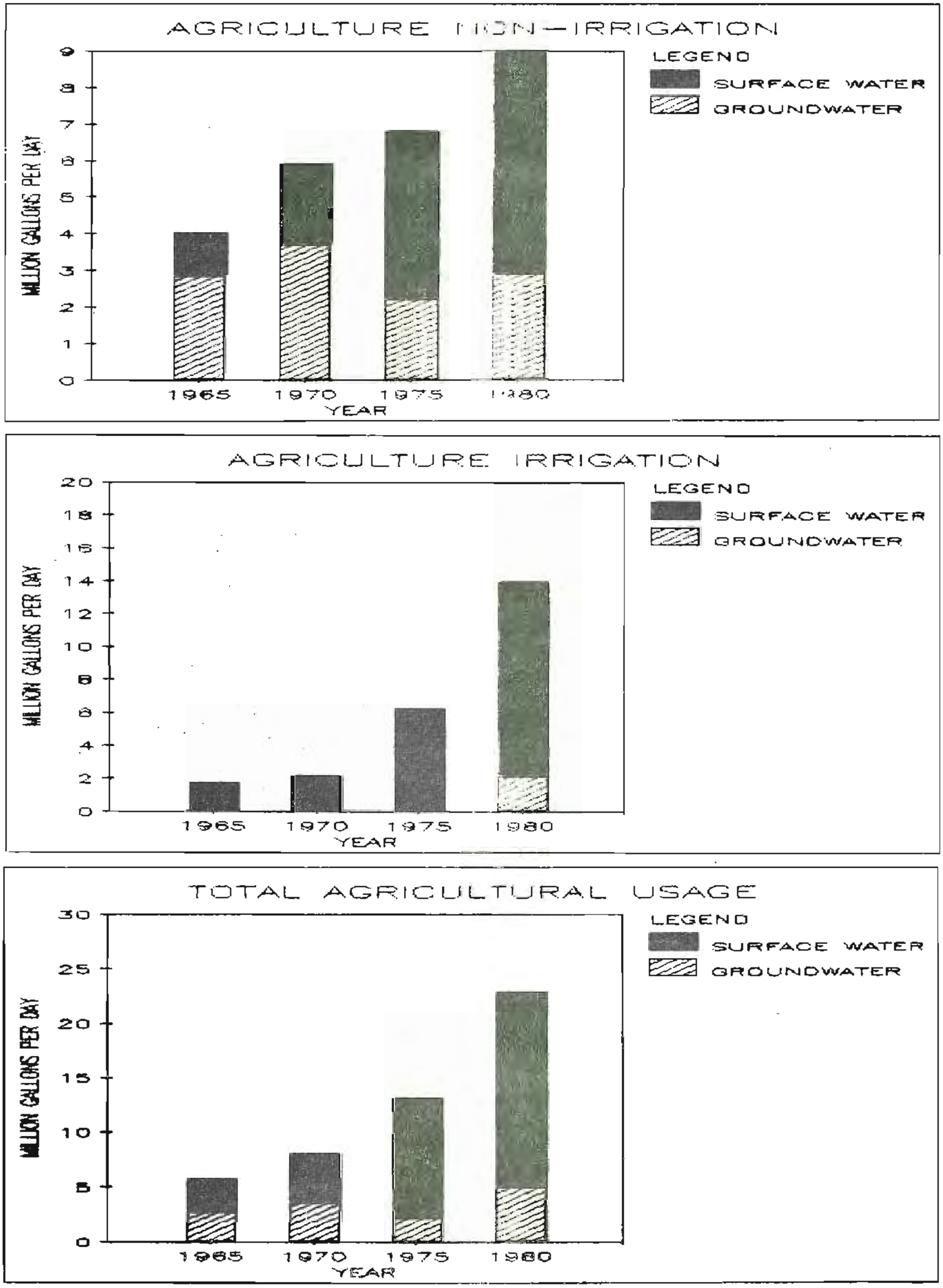
Irrigation occurred on 20,400 acres of cropland in the study area in 1980. <88> Water use for irrigation during that year amounted to 13.98 MGD, an increase of 800% over 1965 irrigation use of 1.77 MGD. (See Figure 1-8C and Table 1-4). Application rates for each crop vary, with rice requiring the most water per acre. On the average, the amount of water applied to cropland was about 9 inches.

Water use for cooling in thermoelectric energy production amounted to 574.63 MGD. Since consumption is generally less than 1% of the total amount of water withdrawn, water use for this category was not included as part of the total use.

WATER USE PROJECTIONS

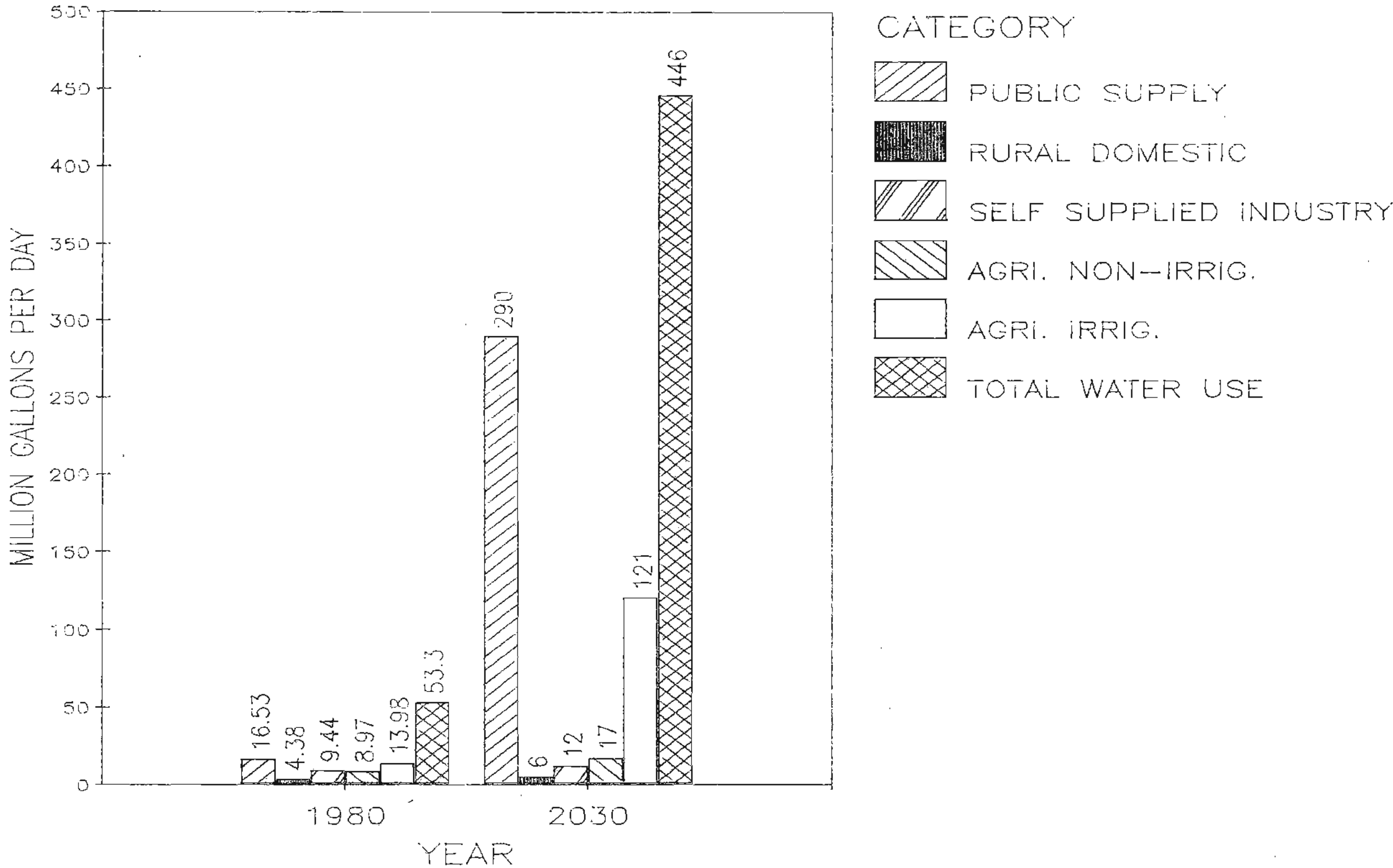
Projected use for public supplies and rural domestic use will be discussed together because both are population related. In 1980, the public supply systems served 69% of the population. The remaining 31% were self supplied by household wells. Applying these percentages to the 2030 population projection of 230,000 people resulted in an estimate of 159,000 people using public supply systems and 71,000 rural self-supplied people. Water use per person on public supply systems during peak conditions is approximately 250 gallons per day with average useage about 150 gallons per day. Since public systems have to be able to supply water during peak conditions, the peak useage per person was used to compute future needs. Rural water use averages 90 gallons per day and this rate was used to compute the projected 2030 rural domestic useage. Applying the population projections to the current daily use rates resulted in an estimate of almost 40 MGD of water needed for public supply use and over 6.0 MGD of water needed for rural domestic use in 2030. (See Figure 1-9).

figure 1-8C
WATER USE BY CATEGORY



SOURCE: Halberg <31, 32, 33>
Hoiland and Ludwig <40>

figure 1-9
STUDY AREA WATER USE
1980 VERSUS 2030



SOURCE: 1980 Data from Holland and Ludwig. <40>

The DeGray Reservoir project in the Upper Ouachita Basin is designed to release 250 MGD for water supply. According to information supplied by the Vicksburg District of the Corps of Engineers (written communication, 1987 - See Appendix A), 98 MGD are currently released for water quality and water supply needs. The remaining 152 MGD are available for future municipal and industrial water supply uses. It was assumed that the 250 MGD of water supply storage from DeGray Reservoir would be used in the future for use within the basin or for interbasin transfer to other areas that may need additional water, such as the City of Little Rock. Therefore, the 250 MGD from DeGray Reservoir was included in the projected needs resulting in a total projected public supply use of 290 MGD.

Projections for non-irrigation use are based on a straight line projection of the 1965-80 water-use data. Based on the extension of a straight line, use for 2030 is projected to be about 17 MGD.

Self-supplied industrial useage will probably show a decreasing trend in the near future because of the closing of two industries in the study area. However, should the plants be bought and used by other corporations, water use will once again be at the present level or possibly even higher. Based on past maximum levels of useage, water use for this category is projected to be about 12 MGD in 2030. Should other water-intensive industries locate in the basin, this estimate will probably be low.

Irrigation practices are expected to continue to expand as dry land farming becomes too risky. Based on projected cropping patterns shown in Chapter 2 and application totals appropriate for each crop, the study area is projected to use 121 MGD for irrigation in the future. To reach this level of useage, essentially all the area currently used as cropland would be irrigated. Application rates used for these projections were as follows: 3 feet for rice; 1.5 feet for cotton, corn, and sorghum; and 1.0 foot for soybeans.

Based on the methods previously outlined, water use is projected to increase from 53.3 MGD in 1980 to 446 MGD in 2030. (See Figure 1-9). Projected public supply use of 290 MGD represents the highest category of projected water use for the basin. The second highest use category will be for irrigation (121 MGD), followed by non-irrigation useage (17 MGD), self supplied industrial needs (12 MGD), and rural domestic use (6 MGD).

250 MGD = 386.8 cfs available for water supply below DeGray.

CHAPTER II

LAND RESOURCES INVENTORY

An inventory of land resources and related land uses is presented in this report in order to provide background information to assist in understanding related water-resource problems. Forest land, pastureland, and cropland areas are addressed, as are wetland areas. Additionally, livestock and poultry concentrated feeding operations are inventoried as a land use due to the number of operations that are located in the basin.

A description of the major land resource areas in the basin is presented. General soil units, soil surveys, and soil erosion are also addressed.

LAND USE

The Upper Ouachita River Basin is composed primarily of forest land. There are 3,462,252 acres in the basin of which approximately 2,638,000 acres (76.2%) is forest land. Grassland occupies about 537,000 acres (15.5%) and cropland covers about 96,000 acres (2.8%) of the basin. Urban and built-up lands occupy about 86,000 acres (2.5%) and water and other areas account for the remaining 105,000 acres (3%). Land use in the Upper Ouachita Basin is shown in Figure 2-1. More detailed information on land use is compiled in Table 2-1 for each of the counties in the basin. Land use for Table 2-1 and Figure 2-1 was compiled from the 1977 Resource Information Data System (RIDS). <82>

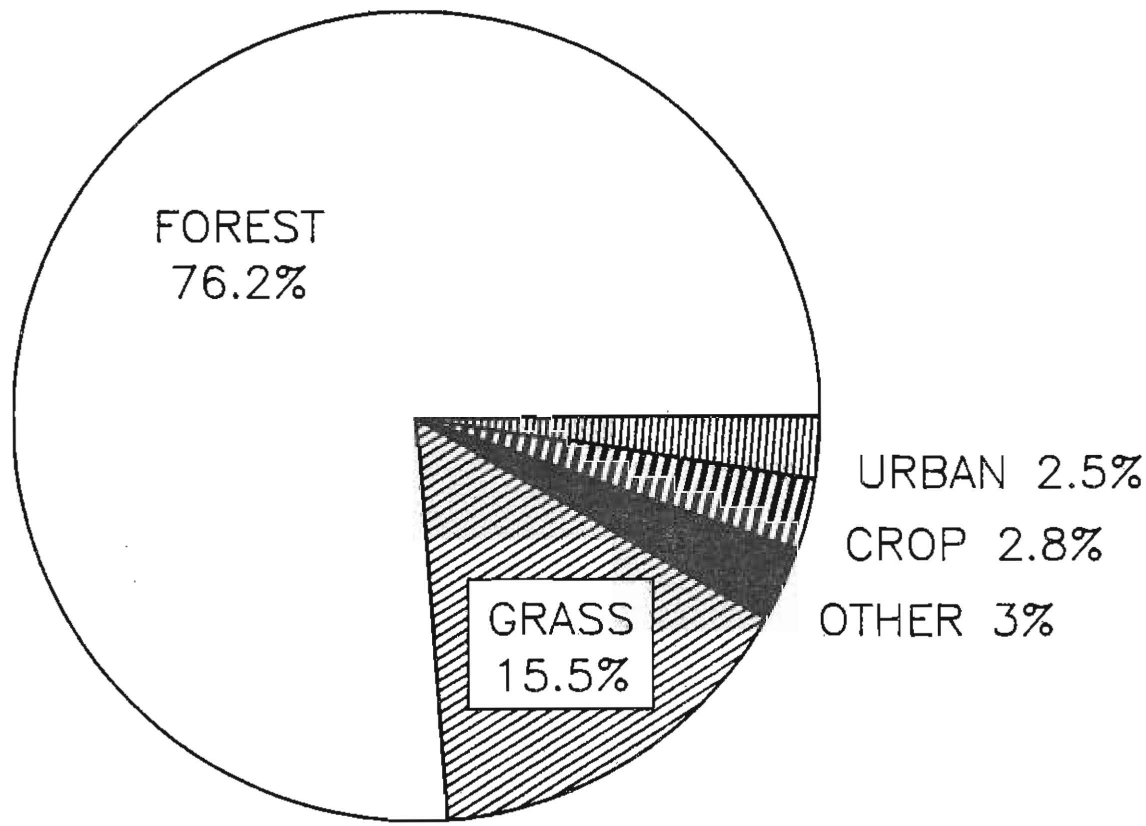
The RIDS data <82> were updated in 1982 by the National Resource Inventory (NRI-82). <85> Each inventory has advantages and disadvantages for presenting data relative to this report; therefore, both inventories were used in preparing this report. Similar data from each inventory is quite difficult to compare because of the procedural and technological improvements in the data collection and statistical estimation processes. <92> Where the RIDS or NRI data are used, it will be noted as such.

Forest Land

The Ouachita National Forest is partially located in this basin and accounts for about 609,000 acres (23 percent) of the forest land in the basin (See Table 2-2). Most of the forest land is owned by the forest industry and private individuals, and more than 99% of the forest land in this basin is used for commercial purposes. Table 2-3 indicates that the forest land is mostly of the Loblolly-Shortleaf Pine type. <82>

figure 2-1

LAND USE
IN THE
UPPER OUACHITA BASIN



SOURCE: USDA, SOIL CONSERVATION SERVICE <82>

TABLE 2-1

LAND USE
IN THE
UPPER OUACHITA RIVER BASIN

COUNTY	CROP-LAND	GRASS-LAND	FOREST LAND	URBAN AND BUILTUP	OTHER	ACRES IN BASIN 1/	ACRES IN COUNTY 2/	PERCENT OF COUNTY IN BASIN
CALHOUN	—	—	6,964	—	—	6,964	402,163	1.7
CLARK	25,887	75,961	443,074	2,474	14,587	561,983	561,983	100.0
DALLAS	9,477	35,160	233,316	—	2,687	280,640	430,369	65.2
GARLAND	2,130	42,280	232,935	59,000	41,875	378,220	470,381	80.4
HEMPSTEAD	20,904	68,260	111,771	—	2,867	203,802	474,880	42.9
HOT SPRING	5,174	55,858	245,137	10,944	13,281	330,394	398,863	82.8
HOWARD	—	10,598	38,184	—	—	48,782	384,000	12.7
MONTGOMERY	—	67,405	435,299	2,060	4,945	509,709	512,640	99.4
NEVADA	14,717	47,772	208,045	—	2,650	273,184	394,240	69.3
OUACHITA	9,937	22,841	186,194	5,694	—	224,666	472,934	47.5
PERRY	—	—	4,019	—	—	4,019	359,041	1.1
PIKE	7,943	75,306	290,754	—	19,691	393,694	393,694	100.0
POLK	—	35,442	151,973	6,003	2,363	195,781	550,400	35.6
SALINE	—	—	397	—	—	397	465,920	0.1
SCOTT	—	—	2,170	—	—	2,170	574,270	0.4
YELL	—	—	47,847	—	—	47,847	606,720	7.9
TOTAL	96,169	536,883	2,638,079	86,175	104,946	3,462,252	—	—
PERCENT	2.8	15.5	76.2	2.5	3.0	—	—	—

SOURCE: USDA, SOIL CONSERVATION SERVICE <82>

1/ SCS FILE DATA

2/ USDA,SOIL CONSERVATION SERVICE <88>

TABLE 2-2

FOREST LAND BY OWNERSHIP

OWNER	ACRES	PERCENT
FEDERAL	609,396	23.1
STATE	21,105	0.8
FOREST INDUSTRY	1,065,784	40.4
MISC., PRIVATE	941,794	35.7
TOTAL	2,638,079	100.0

SOURCE: USDA, SOIL CONSERVATION SERVICE <82>

TABLE 2-3

FOREST LAND BY TYPE

TYPE	ACRES	PERCENT
LOBLOLLY-SHORTLEAF PINE	1,337,506	50.7
OAK-PINE	970,813	36.8
OAK-HICKORY	147,732	5.6
OAK-GUM-CYPRESS	179,389	6.8
ELM-ASH-COTTONWOOD	2,639	0.1
TOTAL	2,638,079	100.0

SOURCE: USDA, SOIL CONSERVATION SERVICE <82>

Pastureland

According to the NRI-82 results, there are about 507,000 acres of pastureland in the basin. Approximately 215,000 acres of pastureland are in good condition while about 175,000 acres are in fair condition and about 117,000 acres are in poor condition. The major use of the pastureland is for the grazing of livestock. <85>

Irrigation of pastureland has not been included in irrigated cropland estimates; however, irrigation of pastureland has become an established practice in the basin. There were about 1400 acres of pastureland irrigated during 1980. <88>

Cropland

There are 96,200 acres of cropland within the Upper Ouachita Basin according to 1977 RIDS data. This represents about three percent of the total land use within the basin. <82> Cotton was the major crop grown in the seven county study area during the 1940's and 50's. During recent years, however, soybeans have replaced cotton as the major crop in the area, and in 1980 soybeans accounted for approximately 85 percent of the crops grown in the study area. <77> The trends of major crops grown in the study area are shown in Figure 2-2.

Irrigated Cropland

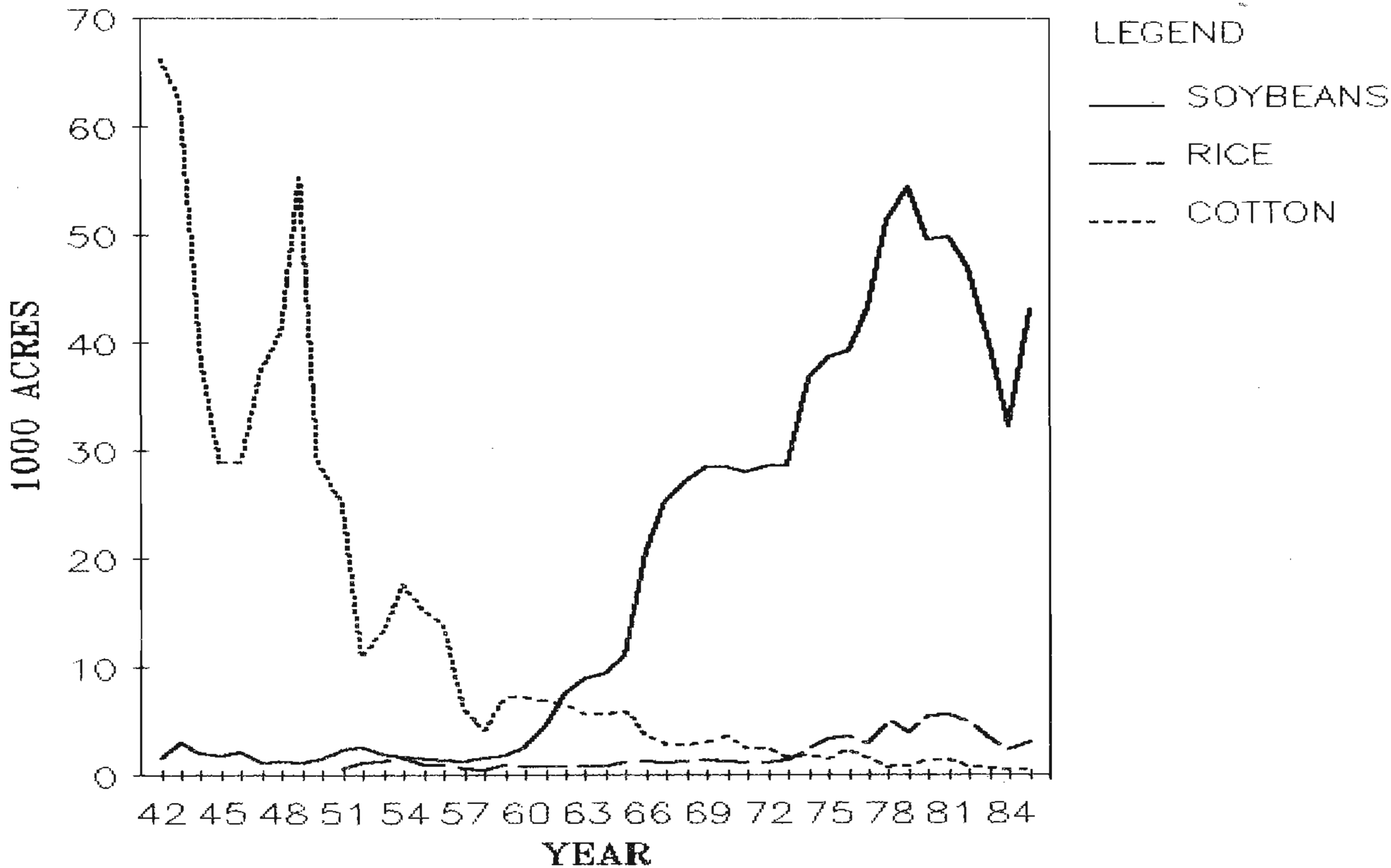
Since irrigation is a major use of water in this basin, it is important to know how much cropland is currently irrigated and how much cropland will be irrigated in the future. There were approximately 1700 acres of cotton, 5500 acres of soybeans, 12,000 acres of rice, 100 acres of corn, and 100 acres of sorghum irrigated in the basin during 1980. Total irrigated cropland acreage (excluding wheat, vegetables, orchards and vineyards, and hayland) amounted to 20,400 acres during 1980. (See Table 2-4). <88>

Potential for Irrigation

Projections for irrigated cropland have been made in conjunction with the Arkansas Statewide Study, Phase V, by the USDA Economic Research Service (ERS) and are presented in Table 2-4 and Figure 2-3. <88> A profit maximization linear programming model was used to aid in estimating irrigated acres for 2030.

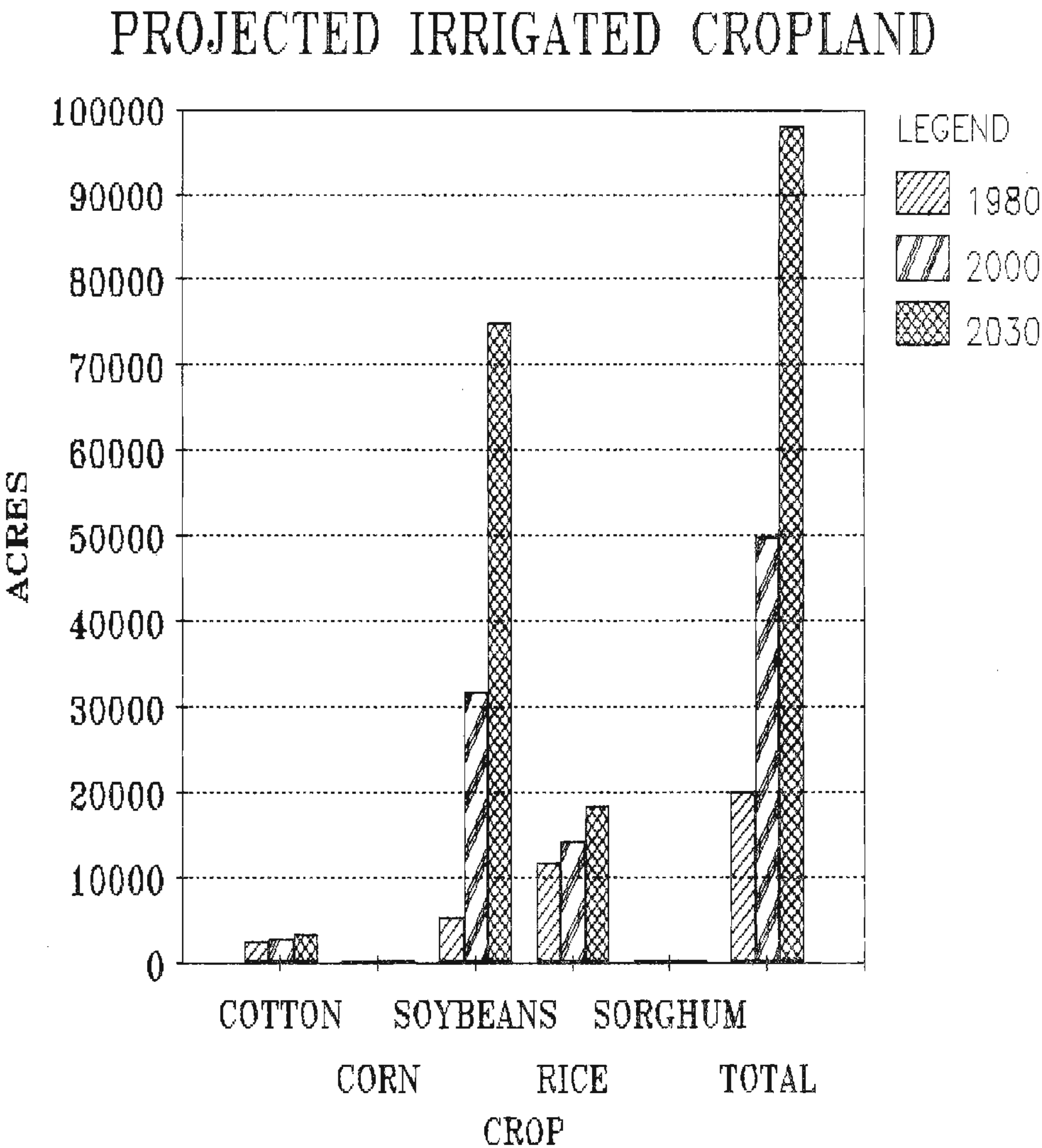
FIGURE 2—2

TREND OF CROPS IN THE STUDY AREA



SOURCE: USDA, CROP AND LIVESTOCK REPORTING SERVICE. <77>

FIGURE 2-3



SOURCE: U.S.D.A., Soil Conservation Service. <88>

TABLE 2-4
CURRENT AND PROJECTED IRRIGATED CROPLAND

YEAR	COTTON	CORN	SOYBEANS	RICE	SORGHUM	TOTAL[1]/
1980	2,700	100	5,500	12,000	100	20,400
2000	3,000	300	32,000	14,500	200	50,000
2030	3,600	600	75,000	18,500	400	98,100

SOURCE: USDA, SOIL CONSERVATION SERVICE <88>

1/ EXCLUDES ACREAGE ON WHEAT, VEGETABLES, ORCHARDS AND VINEYARDS, AND HAYLAND.

The projections made by ERS were evaluated on a statewide basis. During the analysis, it was assumed that the total acreage of cropland in the state would remain the same. Additional cropland projected in some basins would be offset by reversion of cropland to other uses in other basins. <88>

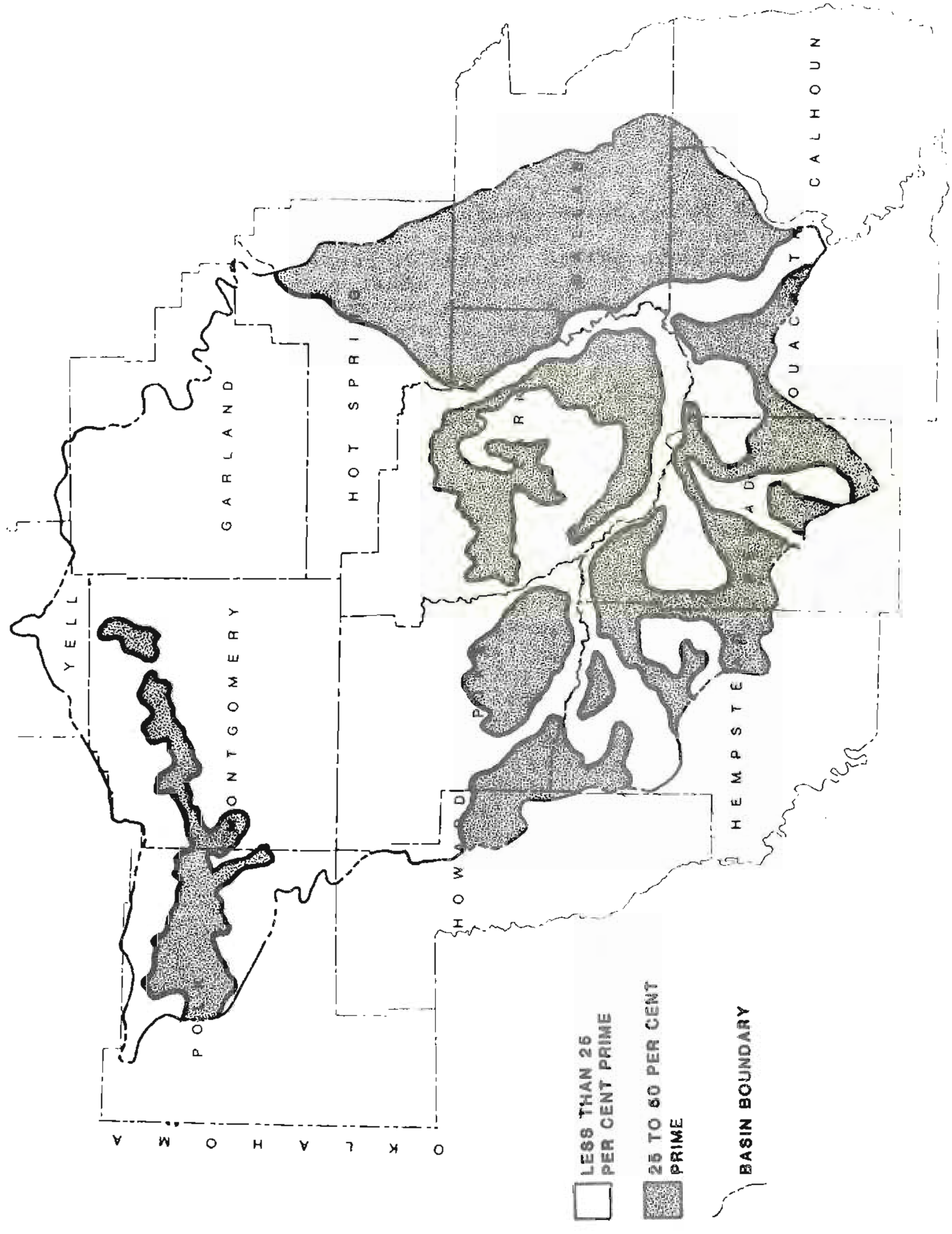
NRI-82 data were utilized to evaluate ERS projections. According to the NRI-82 data, there are 117,800 acres of cropland in the basin. Additionally, there is potential for the conversion of other land uses to cropland within the basin. There are about 46,200 acres with a high potential and 343,000 acres with a medium potential for conversion to cropland. The sum of these figures indicates that there are 507,000 acres of cropland or land with at least a medium potential for conversion to cropland. If all the land with a high potential for conversion to cropland is converted, there will be approximately 164,000 acres of cropland in the basin. Approximately 60 percent of this area would need to be irrigated in order for the ERS projections of 89,100 acres to be met; therefore, the irrigated cropland projections made by ERS are viewed as reasonable for this basin.

Prime Farmland

Prime farmland is land that is well suited to the production of food and fiber. This land has the quality needed to produce sustained yields of crops economically, if managed according to acceptable farm practices. The land use could be cropland, pastureland, rangeland, forest land, or other land, but not urban land, built-up land, or water. Most of the land in this basin is in the less than 25 percent prime farmland region as shown in Figure 2-4.

figure 2-4

PRIME FARMLAND IN THE UPPER OUACHITA BASIN



SOURCE: U.S.D.A. - Soil Conservation Service File Data

There are about 588,000 acres of prime farmland in this basin which is five percent of the 11,624,500 acres of prime farmland located within the state. The land uses in the basin and the amount of prime farmland occurring on each land use are as follows: forest land - 341,800 acres, pastureland - 175,100 acres, cropland - 64,200 acres, and minor land uses - 6,700 acres. More than 218,000 acres (37%) of the prime farmland in this basin is in Clark County. <85>

Cropland Problems

Several water-related characteristics of the basin are causing problems on cropland. Because of these characteristics, about 45 percent of the cropland in the basin exists on non-prime land. According to NRI 82 data, erosion is the major problem on about 64,700 acres of the 117,800 total cropland acres. Excess water, from flooding and/or lack of drainage, is the major problem on the remaining 53,100 acres of cropland. All cropland in the basin has an erosion and/or a wetness problem. <85> Flooding, drainage, and erosion are discussed in more detail in subsequent sections of this report.

Wetlands

Wetlands are areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support a prevalence of plants which are adapted for life in saturated soil conditions. Such areas in Arkansas are commonly referred to as swamps, sloughs, shallow lakes, ponds, and river-overflow lands.

As part of the National Resource Inventory (NRI-82), the Soil Conservation Service collected data about wetlands in 1982. <85> Inventory sample areas were classified with respect to types of wetlands as described in Wetlands of the United States, Circular 39. <63> Within the Upper Ouachita Basin, a total of 93,200 acres of wetlands, including river-overflow lands and permanently flooded sloughs and swamps, were estimated to occur. <85>

Livestock and Poultry Operations

An inventory of confined animal feeding operations was conducted in 1983 by the Soil Conservation Service. <90> This inventory covered 22 western Arkansas counties. Data have been compiled for the area shown in Figure 2-5 to identify waste management problems in the Upper Ouachita Basin. The area outlined on Figure 2-5 will be referred to as the waste study area for this report. The waste study area includes all of Montgomery, Nevada, and Pike Counties, and a portion of Hempstead and Polk Counties.

A listing of the number of animals for each of the animal types inventoried by county within the waste study area is presented in Table 2-5. There were many more broilers (40,217,500) than any other type of animal, and the number of broiler operations was fairly well distributed (See Table 2-6) throughout the waste study area.

Throughout the waste study area, wastes from confined operations are spread onto the land as fertilizers. Most of the waste is applied to pastureland; however, a small portion of the waste is applied to cropland. The quantities of nitrogen and phosphorus applied to the land are listed in Table 2-7. About 35 percent of the nitrogen and almost 31 percent of the phosphorus, are applied to land in Pike County. The rate of application of nitrogen and phosphorus per square mile is the highest in Polk County (See Table 2-8). High application rates also occur in Pike and Hempstead Counties.

figure 2-5

CONFINED ANIMAL WASTE INVENTORY
WASTE STUDY AREA FOR UPPER OUACHITA BASIN

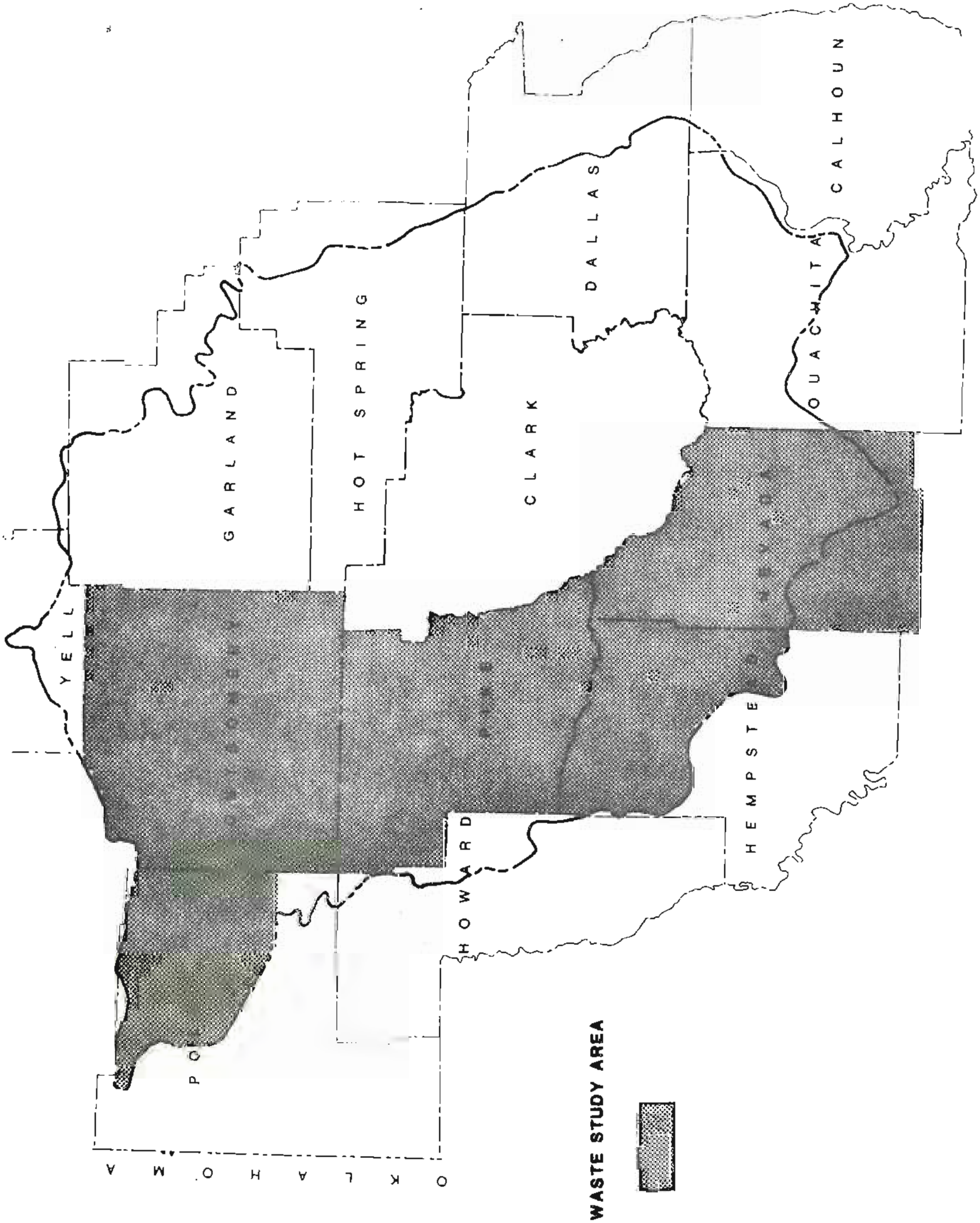


TABLE 2-5

NUMBER OF CONFINED ANIMALS

BY COUNTY IN WASTE STUDY AREA

COUNTY	BROILERS	LAYERS	BREEDERS	PULLETS GROW-OUT	TURKEYS	ROOSTER	SWINE SOW-PIG	SWINE FEED-OUT	DAIRY	BEEF
	OPERATION TYPE									
HEMPSTEAD	4,020,000	103,200	646,400	240,000	-	-	-	150	120	-
MONTGOMERY	9,055,000	225,000	120,000	517,000	-	-	8,600	19,700	-	-
NEVADA	7,792,000	212,000	-	240,000	-	-	-	500	-	-
PIKE	10,750,500	311,000	283,800	158,000	-	7,007,500	945	2,000	-	-
POLK	8,600,000	291,500	-	77,000	-	-	24,280	1,160	365	-
TOTAL	40,217,500	1,172,700	1,050,200	1,232,000	0	7,007,500	33,825	23,510	485	0

SOURCE: MODIFIED FROM USDA, SOIL CONSERVATION SERVICE FILE DATA <90>

TABLE 2-6

OPERATIONS SUMMARY

BY COUNTY IN WASTE STUDY AREA

	OPERATION TYPE									
COUNTY	BROILERS	LAYERS	BREEDERS	PULLETS GROW-OUT	TURKEYS	ROOSTER	SWINE SOW-PIG	SWINE FEED-OUT	DAIRY	BEEF
HEMPSTEAD	22	3	11	5	-	-	-	1	3	-
MONTGOMERY	91	20	2	16	-	-	2	7	-	-
NEVADA	54	7	-	2	-	-	-	1	-	-
PIKE	71	10	26	8	-	55	1	1	-	-
POLK	92	26	-	4	-	-	11	3	3	-
TOTAL	330	66	39	35	0	55	14	13	6	0

SOURCE: MODIFIED FROM USDA, SOIL CONSERVATION SERVICE FILE DATA <90>

TABLE 2-7

QUANTITY OF NITROGEN AND PHOSPHORUS APPLIED TO THE LAND BY COUNTY IN THE WASTE STUDY AREA

COUNTY	NITROGEN APPLIED TONS/YEAR	NITROGEN APPLIED PERCENT	PHOSPHORUS APPLIED TONS/YEAR	PHOSPHORUS APPLIED PERCENT
HEMPSTEAD	520	13.7	430	19.4
MONTGOMERY	720	19.0	430	19.4
NEVADA	440	11.6	240	10.8
PIKE	1330	35.1	680	30.6
POLK	780	20.6	440	19.8
	3790	100.0	2220	100.0

SOURCE: MODIFIED FROM SOIL CONSERVATION SERVICE FILE DATA <90>

SOIL RESOURCES

Major Land Resource Areas

There are three major land resource areas in this basin, as shown in Figure 2-6. General descriptions of these resource areas are presented in the following paragraphs.

Ouachita Mountains

The Ouachita Mountains are a series of east-west ridges and valleys in the northern part of the basin. This area covers approximately 51 percent of the basin. Common bedrock is shale, slate, quartzite, novaculite, and sandstone. The rocks are generally steeply inclined, fractured, and folded causing great variation in parent material such that soils change frequently over lateral distances. <84>

Depth of soils range from shallow to deep and slope of the land surface ranges from level to gently sloping in the valleys to very steep on mountainsides. <84> Permeability of these soils ranges from moderate to slow. <83>

TABLE 2-8

RATE OF APPLICATION OF NITROGEN AND PHOSPHORUS
BY COUNTY IN THE WASTE STUDY AREA

COUNTY	AREA (SQ MI)	TOTAL NITROGEN APPLIED (TONS/YR)	RATE OF APPLICATION (TONS/MI²/YR)	TOTAL PHOSPHORUS APPLIED (TONS/YR)	RATE OF APPLICATION (TONS/MI²/YR)
HEMPSTEAD	318.4[1]/	520	1.64	430	1.36
MONTGOMERY	801.0[2]/	720	0.90	430	0.54
NEVADA	616.0[2]/	440	0.71	240	0.38
PIKE	615.1[2]/	1330	2.16	680	1.11
POLK	270.2[1]/	780	2.88	440	1.63
	2621.0	3790	1.44	2220	0.85

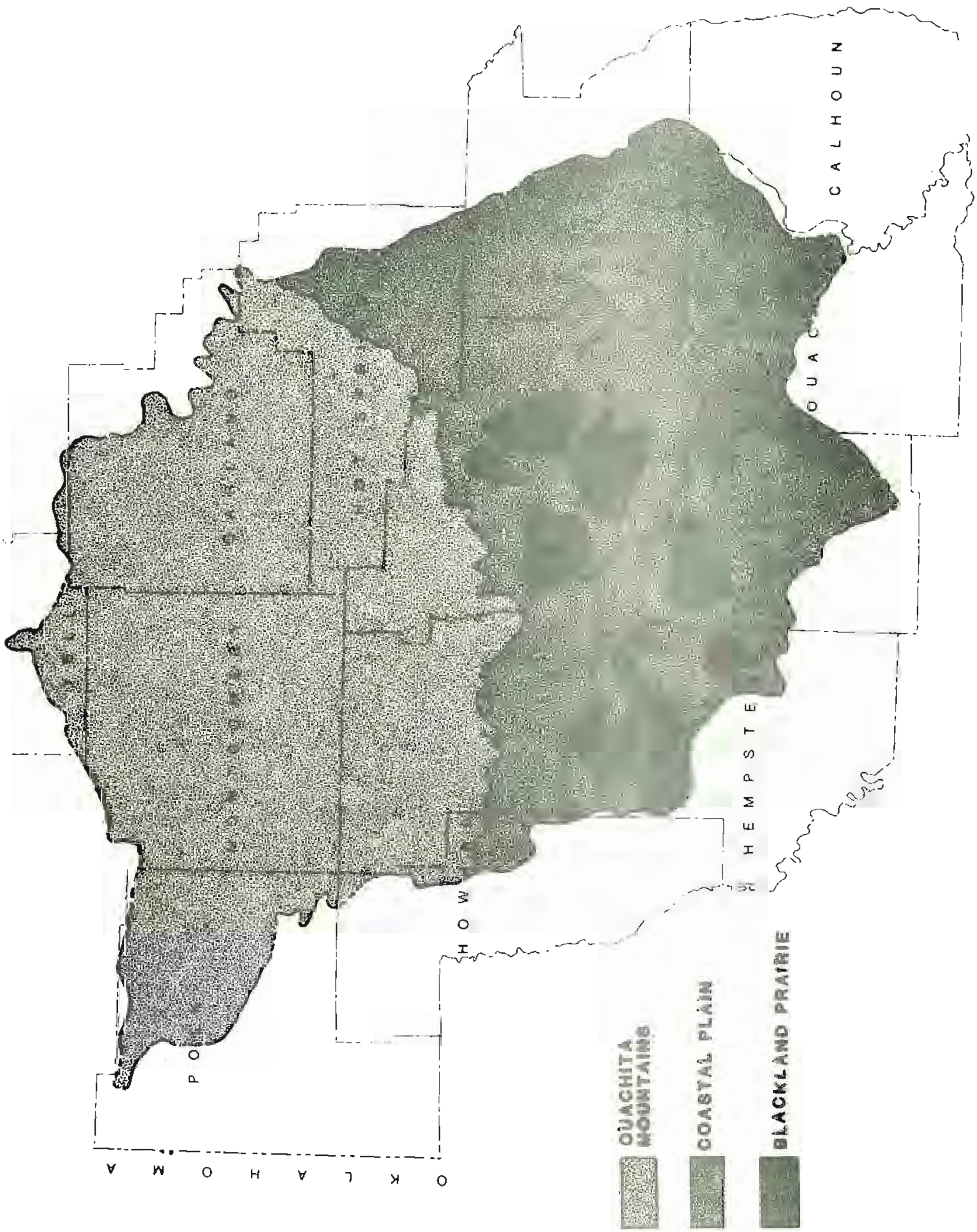
SOURCE: MODIFIED FROM SOIL CONSERVATION SERVICE FILE DATA <90>

[1]/USDA, SOIL CONSERVATION SERVICE <82>

[2]/USDA, SOIL CONSERVATION SERVICE <88>

figure 2-6

MAJOR LAND RESOURCE AREAS



SOURCE: U.S.D.A., Soil Conservation Service (84)

The geologic and hydrologic characteristics of the Ouachita Mountains have a significant effect on water resources of the area. The streams have steep gradients and generally surface runoff is rapid causing the streams to crest and recede quickly. Also, the consolidated bedrock has a relatively low permeability which limits the amount of groundwater available and hinders groundwater movement. <2>

Most of this area is used for timber production. However, some of the less sloping areas have been cleared and are used for pasture production. <84>

Coastal Plain

This area consists of rolling terrain broken by stream valleys in the southern part of this basin. The Coastal Plain covers approximately 42 percent of this basin. Soils in this area developed from deep marine sediments. Slopes range from level to moderately steep <84> and permeabilities range from rapid to slow. <83> This area is used mainly for timber production and pastureland. <84>

Geologic and hydrologic characteristics of the Coastal Plain have a definite influence on the water resources of the area. Streams are generally sluggish in this area because the gradients of the stream channels are relatively flat. Also, some of the Coastal Plain sediments have higher permeabilities than the consolidated rocks of the Ouachita Mountains. These sediments favor transmission and storage of groundwater. <2>

Blackland Prairie

The Blackland Prairie consists of gently rolling to rolling uplands in the central and southwestern parts of the basin. The soils developed from the clayey sediments overlying beds of marly clay or chalk, or from marly clay or chalk. Slopes range from nearly level to moderately steep. The permeability of these soils ranges from slow to very slow. This area is used mainly for pastureland and forest land. There is, however, a relatively large amount of cropland in the Blackland Prairie. This area covers about 7 percent of the basin and yet almost 30 percent of the total amount of cropland in the basin is located in this resource area. <83, 84, 85>

This resource area exists because it is the outcrop area for Upper Cretaceous age chalks and marls. (The Blackland Prairie will be referred to as the Upper Cretaceous outcrop area in Chapter 4 and portions of Chapter 3.) These chalks and marls have a relatively low permeability and do not yield much water to streams. <48> Therefore, streams in the Blackland Prairie area such as Ozan Creek, Terre Rouge Creek, and Terre Noire Creek generally have lower sustained flows during low-flow periods than streams in the Coastal Plain area which usually exhibit sustained base flow conditions as a result of the higher permeability of Coastal Plain sediments that favor the transmission of water. Furthermore, since the permeability of Blackland Prairie soils is generally less than the permeability of Coastal Plain soils, runoff during storm events should generally be greater from the Blackland Prairie area than from the Coastal Plain area, if all other basin and climatic characteristics are similar.

The Blackland Prairie resource area is considered fragile <87> since the topsoil is generally quite thin. Excessive soil erosion in this area will not only cause water quality problems, but the land resource base may be severely impacted as well. Cropland areas located in the Blackland Prairie may need some form of erosion protection (see Water-Quality Recommendations).

General Soil Units

There are eleven general soil units covering the three resource areas in this basin. There are four general soil units in the Ouachita Mountains, six general soil units in the Coastal Plain, and one general soil unit in the Blackland Prairie. These soil units are listed by resource area in Table 2-9 and their locations are shown in Figure 2-7. Specific information for individual soil units is available in published Soil Surveys.

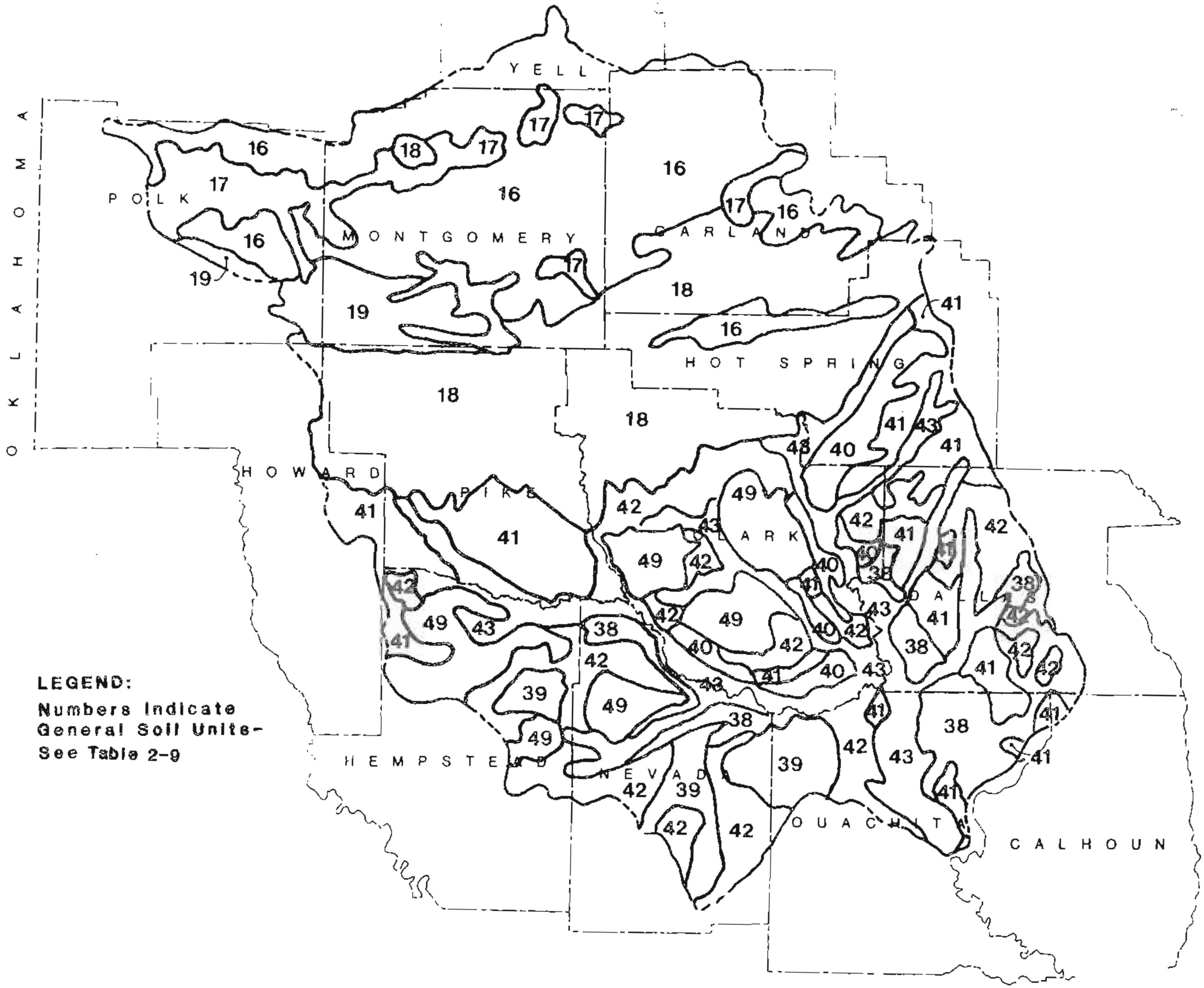
TABLE 2-9
GENERAL SOIL UNITS BY MAJOR LAND RESOURCE AREAS

OUACHITA MOUNTAINS	
16	Carnasaw - Pirum - Clebit
17	Kenn - Ceda - Avilla
18	Carnasaw - Sherwood - Bismarck
19	Carnasaw - Bismarck
COASTAL PLAIN	
38	Amy - Smithton - Pheba
39	Darco - Briley - Smithdale
40	Pheba - Amy - Savannah
41	Smithdale - Sacul - Savannah
42	Sacul - Smithdale - Sawyer
43	Guyton - Ouachita - Sardis
BLACKLAND PRAIRIE	
49	Oktibbeha - Sumter

SOURCE: U.S.D.A. SOIL CONSERVATION SERVICE <84>

figure 2-7

GENERAL SOILS MAP



LEGEND:

Numbers Indicate General Soil Units- See Table 2-9

SOURCE: USDA, Soil Conservation Service. <84>

Soil Surveys <87>

The Soil Conservation Service (SCS) is responsible for all Soil Survey activities of the U.S. Department of Agriculture. The Soil Surveys and interpretations are made cooperatively with the University of Arkansas Agricultural Experiment Station, Agricultural Extension Service, U.S. Forest Service, Arkansas Highway Department, the 76 Soil and Water Conservation Districts, and other State and Federal Agencies.

Seven of the soil surveys for the sixteen counties located within this basin have been published. The counties and the date of publication are as follows: Calhoun and Dallas - published as one report (1980), Hempstead (1979), Howard (1975), Ouachita (1973), Perry (1982), and Saline (1979). Hot Spring and Clark Counties will be published in one report in 1987. Garland County is scheduled to be published in 1987. The remaining six counties (Montgomery, Nevada, Pike, Polk, Scott and Yell) do not have, at this time, dates set for their publication.

Erosion

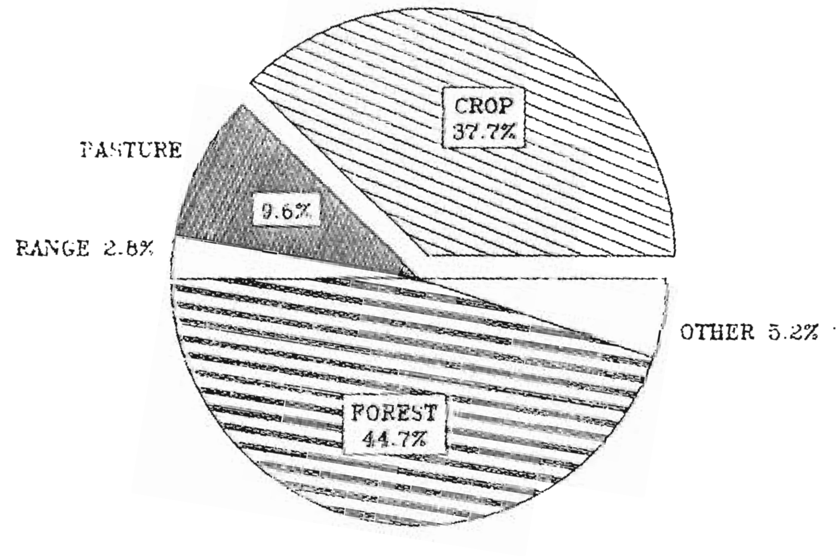
Sources of erosion that are occurring in the basin include road surface, road bank, gully, streambank, and sheet and rill. The major source of erosion in the basin is sheet and rill erosion which accounts for approximately 75 percent of the total amount of erosion occurring in the basin. <10>

Sheet and rill erosion on non-federal rural land in the Ouachita Basin amounts to 1,683,000 tons per year over 2,667,000 acres. The average erosion rate occurring on all non-federal rural land is 0.6 tons per acre. <85>

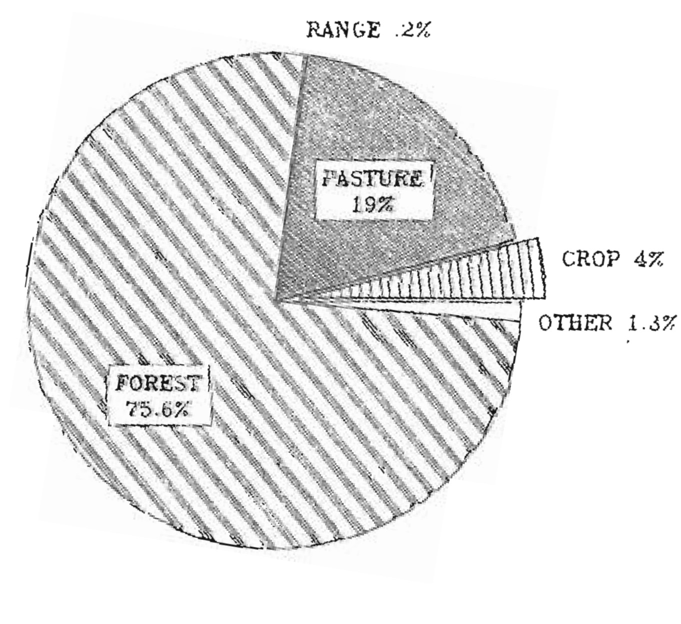
Sheet and rill erosion is shown by land use in Table 2-10. Forest land accounts for the largest quantity of sheet and rill erosion (753,000 tons/year); however, this erosion is occurring on 2,015,000 acres so that the average rate of erosion is only 0.4 tons per acre. Cropland covers only four percent of the area inventoried and yet it accounts for approximately 38 percent of the total sheet and rill erosion. (See Figure 2-8). The average rate of erosion occurring on cropland is 6.0 tons per acre. Erosion rates on rangeland are estimated to be 9.5 tons per acre but the results for rangeland should not be used for interpretation. Due to the small acreage inventoried, accuracy of NRI-82 data for erosion estimates on rangeland is limited. <85, 92>

FIGURE 2-8

SHEET AND RILL EROSION
NON-FEDERAL RURAL LAND



TONS/YR



ACRES

SOURCE: USDA, SOIL CONSERVATION SERVICE <85>

TABLE 2-10

SHEET AND RILL EROSION ON NON-FEDERAL RURAL LAND

LAND USE	TONS PER YEAR	ACRES	TONS PER ACRE
CROPLAND	635,000	106,000	6.0
PASTURELAND	161,000	507,000	0.3
RANGELAND	47,000	5,000	9.5
FOREST LAND	753,000	2,015,000	0.4
OTHER RURAL LAND	87,000	34,000	2.6
TOTAL	1,683,000	2,667,000	0.6

SOURCE: USDA, SOIL CONSERVATION SERVICE <85>

The NRI erosion data do not estimate the amount of erosion that actually occurred during 1982. The erosion rates computed from the NRI data are estimated average annual (or expected) rates based upon the cropping practices, management practices, and resource conditions over a period of at least four years. The climatic factors included in the erosion equations are based upon long-term average conditions and not upon one year's actual climatic events. <92>

Excessive soil erosion can cause significant water-quality problems. For this reason, excessive soil erosion is addressed in the water quality problems section of this report.

CHAPTER III

SURFACE WATER

INTRODUCTION

The principal streams in the Upper Ouachita Basin are the Ouachita, Little Missouri, and Caddo Rivers. Other major streams in the basin include the Antoine River, Ozan Creek, Terre Rouge Creek, and Terre Noire Creek. Streams in the northern half of the basin that drain the Ouachita Mountains have steep gradients and narrow valleys which result in rapid runoff. Streams in the southern half of the basin that drain the Coastal Plains have relatively flat slopes which contribute to sluggish streamflow in many parts of the basin.

The average annual runoff in the Upper Ouachita Basin ranges from approximately 12.5 inches in the southwestern part of the basin to approximately 31 inches in the northwestern part of the basin <29>. Runoff varies seasonally as well as annually, with the area subject to extremes of both flood and drought. The seasonal variability is characterized by low flows which usually occur during August through October each year. Optimum development of surface-water resources in the Upper Ouachita Basin requires storage of high winter and spring flows to meet the summer and fall water-use demands.

Surface-water storage is available in approximately 7400 impoundments within the the seven-county study area, but most of the impounded streamflow is stored in three Corps of Engineers' reservoirs. Lakes Ouachita, DeGray, and Greeson have capacities (at permanent pool elevation) of 865,000 acre-feet, 261,500 acre-feet, and 77,600 acre-feet, respectively. Total storage of all impoundments is approximately 1,480,000 acre-feet of water.

Significant improvements have been made in the surface-water resources of the basin by federal projects other than the Corps of Engineers' impoundments. Channel improvements have been made on the Ouachita River, Little Missouri River, Ozan Creek, and Terre Noire Creek by the Corps of Engineers. Multiple purpose projects, including municipal water supply, are under construction near Mena and Mount Ida by the Soil Conservation Service. Flood control structures have been authorized for Ozan Creek Watershed and are under construction in the North Fork of Ozan Creek.

Water quality of the streams and lakes in the Upper Ouachita Basin is generally good. Concentrations of most constituents are within acceptable limits, and therefore, streams in the basin support most beneficial uses. The Little Missouri River above Lake Greeson and the entire reach of the Caddo River have been designated as having extraordinary recreational and aesthetic value.

The following sections in Chapter III of the report present an inventory of the surface-water resources of the Upper Ouachita Basin. Present water use and estimated future water needs are also quantified. In addition, problems affecting existing water resources are outlined and solutions and recommendations to solve existing problems are suggested. This information will provide a guide for the future use, management, and development of the water resources of the Upper Ouachita Basin.

SURFACE-WATER INVENTORY

Streamflow Data Collection Network

Streamflow data are collected in the Upper Ouachita Basin primarily by the U.S. Army Corps of Engineers and the U.S. Geological Survey. Locations of 13 streamflow data collection sites are shown in Figure 3-1. There are many additional sites in the basin where streamflow data have been collected, however, the sites selected have relatively long-term records available for study. Additional information on the streamflow sites is summarized in Table 3-1.

Streamflow Characteristics

Distribution of streamflow is dependent upon climate, physiography, geology, and land use in the basin. Basins where these conditions are similar may have similar streamflow characteristics. Generally, the distribution of high flows is governed largely by the climate, the physiography, and the plant cover of the basin. The distribution of low flows is controlled mainly by the basin geology. Streamflow variability is the result of variability in precipitation as modified by the basin characteristics previously mentioned. The variability is reduced by storage, either on the surface or in the ground <62>.

Streamflow Variability

The Upper Ouachita Basin is characterized by two topographically distinct divisions. Streams in the southern half of the basin drain the gently rolling hills and lowlands of the Coastal Plain. Streams in this part of the Upper Ouachita Basin generally are sluggish. Some streams are not sufficiently incised to intersect the water table, and therefore cease to flow during extended dry periods <59>. In contrast, streams in the northern half of the basin drain the Ouachita Mountains. Streams in this part of the Upper Ouachita Basin have steep gradients and narrow valleys,

figure 3-1
STREAMFLOW DATA COLLECTION SITES

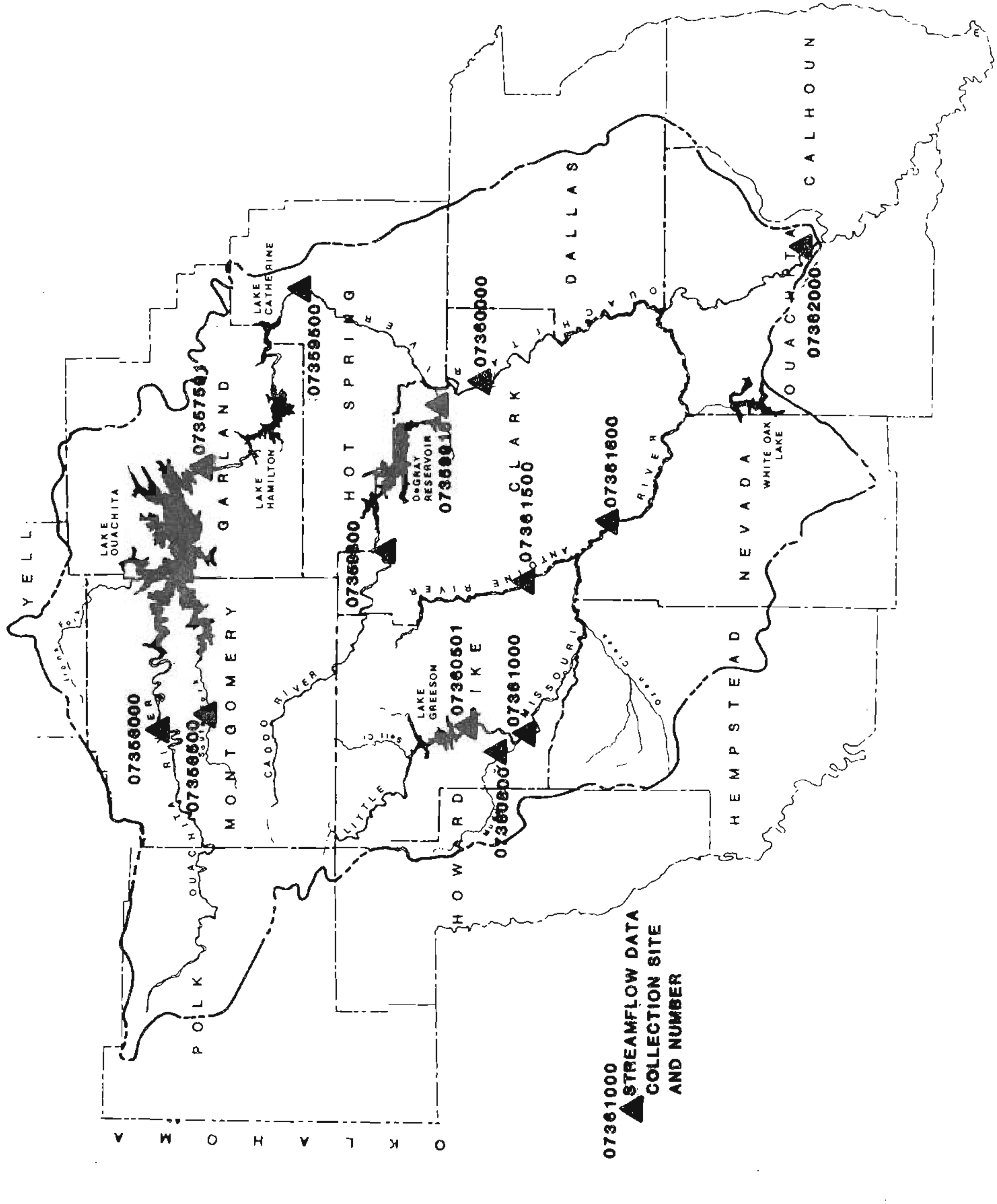


TABLE 3-1
SUMMARY OF SELECTED STREAMFLOW DATA-COLLECTION SITES
(DATA COLLECTED BY U.S. GEOLOGICAL SURVEY UNLESS OTHERWISE NOTED.)

USGS STATION NUMBER	NAME	DRAINAGE AREA (mi²)	PERIOD OF RECORD	EXTREMES FOR PERIOD OF RECORD: MAXIMUM DISCHARGE (CFS) AND DATE	EXTREMES FOR PERIOD OF RECORD: MINIMUM DISCHARGE (CFS) AND DATE	AVERAGE DISCHARGE (CFS) AND YEARS OF RECORD USED TO COMPUTE DISCHARGE	REMARKS
07356000	OUACHITA RIVER NR. MOUNT IDA	414	1942-85	102,000 12-3-82	2.3 8-25-54	725 (1942-85)	AS OF AUGUST, 1977, FLOW FROM 34.3 mi² UPSTREAM FROM THIS STATION IS CONTROLLED BY ONE FLOOD-WATER DETENTION RESERVOIR THAT HAS A CAPACITY OF 15,661 AC-FT.
07356500	SOUTH FORK OUACHITA RIVER AT MOUNT IDA	61.0	JUN 1949-70	20,000 5-13-68	NO FLOW 8-19 TO 9-5-54 8-3 TO 8-8-64	91.8 (1950-70)	------------
07357501	OUACHITA RIVER AT BLAKELY MOUNTAIN DAM NR. HOT SPRINGS	1102	1951-77 1/	9550 (6-13-68) MAXIMUM DAILY DISCHARGE (SINCE STORAGE BEGAN)	15 (9-1-73) MINIMUM DAILY DISCHARGE (ESTIMATED LEAKAGE)	1485 (1951-77)	DISCHARGE COMPUTED FROM FLOWMETER AND ESTIMATED LEAKAGE. FLOW COMPLETELY REGULATED BY LAKE OUACHITA SINCE 1952.
07359500	OUACHITA RIVER NR. MALVERN	1585	OCT 1925-APR 1927; JAN 1928-85	140,000 5-15-23	34 5-15-77	2412 (1925-26, 1928-85)	FLOW REGULATED SINCE 1925 BY LAKE CATHERINE, SINCE 1932 BY LAKE HAMILTON, AND SINCE 1952 BY LAKE OUACHITA
07359800	CADDO RIVER NR. ALPINE	301	1939-41; JUN 1946-70 1/	85,000 5-13-68	4.4 8-20,21-54	510 (1939-41, 1947-70)	------------
07359910	CADDO RIVER AT DEGRAY REGULATING DAM NR. ARKADELPHIA	463	JAN 1967-81 1/	44,300 5-14-68 (AFFECTED BY TEMPORARY STORAGE BEHIND DAM, THEN UNDER CONSTRUCTION)	NO FLOW AT TIMES	790 (1968-77)	FLOW REGULATED BY DEGRAY LAKE SINCE AUGUST, 1969, AND BY DEGRAY REGULATING DAM SINCE JANUARY, 1971.
07360000	OUACHITA RIVER AT ARKADELPHIA	2314	SEP 1905-DEC 1906; MAY 1929-77 1/	170,000 3-30-45	74 (MINIMUM DAILY) 10-5-31	3504 (1906, 1930-77)	FLOW REGULATED BY LAKE CATHERINE SINCE 1925, BY LAKE HAMILTON SINCE 1932, BY LAKE OUACHITA SINCE 1952, AND BY DEGRAY LAKE SINCE AUGUST, 1969.
07360501	LITTLE MISSOURI RIVER AT NARROWS DAM NR. MURFREESBORO	239	JAN 1946-77 1/	5210 6-2-57 (MAXIMUM DAILY SINCE POWER GENERATION BEGAN)	10 (MINIMUM DAILY; ESTIMATED LEAKAGE)	408 (1947-77)	DISCHARGE COMPUTED FROM FLOWMETER AND ESTIMATED LEAKAGE. LEAKAGE WAS NOT INCLUDED IN PUBLISHED FLOWS PRIOR TO JANUARY 1, 1954. FLOW COMPLETELY REGULATED BY LAKE GREESON SINCE NOVEMBER 30, 1949.
07360800	MUDDY FORK CREEK NR. MURFREESBORO	120	APR 1940-SEP 1942; APR 1946-59	(--)	(--)	185 (1947-59)	------------
07361000	LITTLE MISSOURI RIVER NR. MURFREESBORO	383	FEB 1928-31; JUL 1937-77 1/	120,000 3-30-45	2.9 9-1-43	620 (1929-31, 1938-77)	SOME REGULATION BY LAKE GREESON SINCE NOVEMBER, 1949.
07361500	ANTOINE RIVER AT ANTOINE	178	1955-85	35,500 5-2-58	NO FLOW AT TIMES	277 (1955-85)	------------
07361600	LITTLE MISSOURI RIVER NR. BOUGHTON	1079	1938-42; 1946-77 1/	66,000 5-3-58	10 9-20 TO 9-30-39	1521 (1938-42, 1946-77)	SOME REGULATION BY LAKE GREESON SINCE NOVEMBER, 1949.
07362000	OUACHITA RIVER AT CAMDEN	5357	1929-85 1/	243,000 4-3-45	125 9-16,24,25,26-43	7564 (1929-85)	FLOW REGULATED SINCE 1925 BY LAKE CATHERINE, SINCE 1932 BY LAKE HAMILTON, SINCE 1949 BY LAKE GREESON, SINCE 1952 BY LAKE OUACHITA, AND SINCE AUGUST, 1969 BY DEGRAY LAKE.

1/ DATA COLLECTED BY U.S. ARMY CORPS OF ENGINEERS.

resulting in rapid runoff. The larger tributaries generally have narrow flood plains because lateral movement of the streams has been restricted by resistant rocks in the Ouachita Mountains. <34>

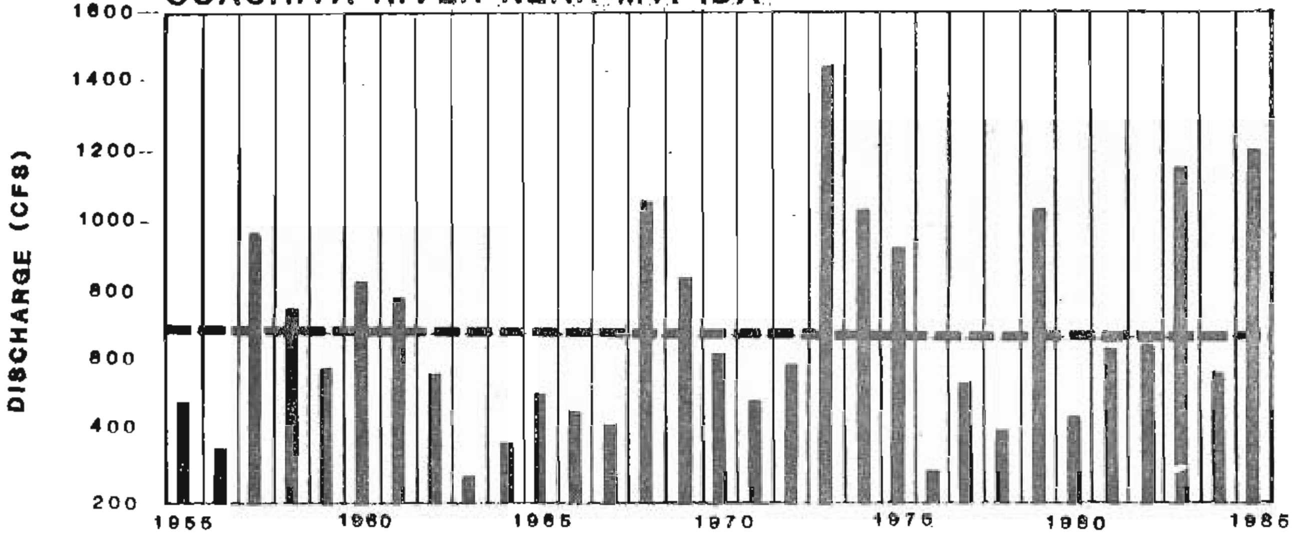
Streamflow in the Upper Ouachita Basin is extremely variable, as illustrated by the annual streamflow for three stations in the basin for the period of 1955-85 (Figure 3-2). Significant variation in annual streamflow has occurred at the three sites during this period. For example, the annual mean discharge for the Ouachita River near Mount Ida ranged from 263 cfs in 1963 to 1,453 cfs in 1973. The mean annual discharge for the period of record is also shown in Figure 3-2 for each of the three sites. Comparison of the mean annual discharge with the annual discharge for each year during the period shows that the mean discharge for a particular year may be significantly different than the mean annual discharge computed for the period of record.

In the Upper Ouachita Basin, streamflow is generally highest during December through May because of the large amount of precipitation during this period. Similarly, streamflow is generally lowest during June through November due to a decrease in precipitation and an increase in evapotranspiration that occurs during the growing season. Mean monthly discharges at selected gaging stations are summarized in Table 3-2. The mean monthly discharges were computed based on streamflow records that most closely represent current streamflow conditions. Therefore, if a gaging station is currently affected by regulation from an upstream reservoir, streamflow records collected prior to the regulation were not used in the computations. It should also be noted that for the Caddo River at DeGray Dam and the Ouachita River at Arkadelphia, data for water years 1979 and 1980 were not used in the computations of mean monthly discharge since, at times during these two water years, the amount of water released from DeGray Reservoir was significantly reduced during maintenance on the regulating dam.

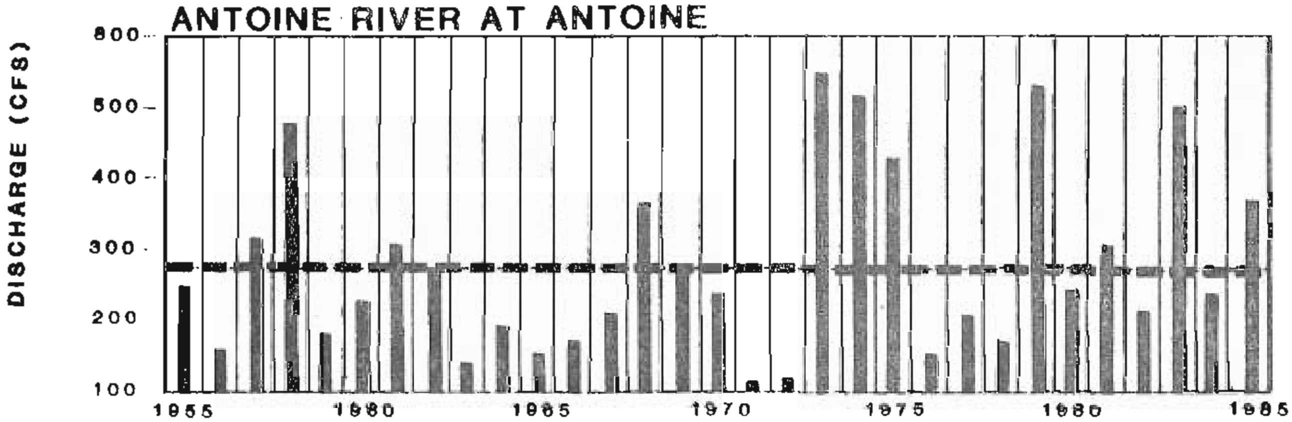
The computation of mean monthly discharges at selected locations indicates the seasonal variability of streamflow in the basin. There is also significant variability of streamflow on a daily basis, as shown by the hydrograph of daily discharge at Ouachita River near Mount Ida for the 1983 water year (Figure 3-3). Daily mean discharge ranged from 18 cfs to 79,800 cfs at this station during the 1983 water year.

ANNUAL MEAN DISCHARGE FOR SELECTED SITES FOR THE PERIOD 1955-1985

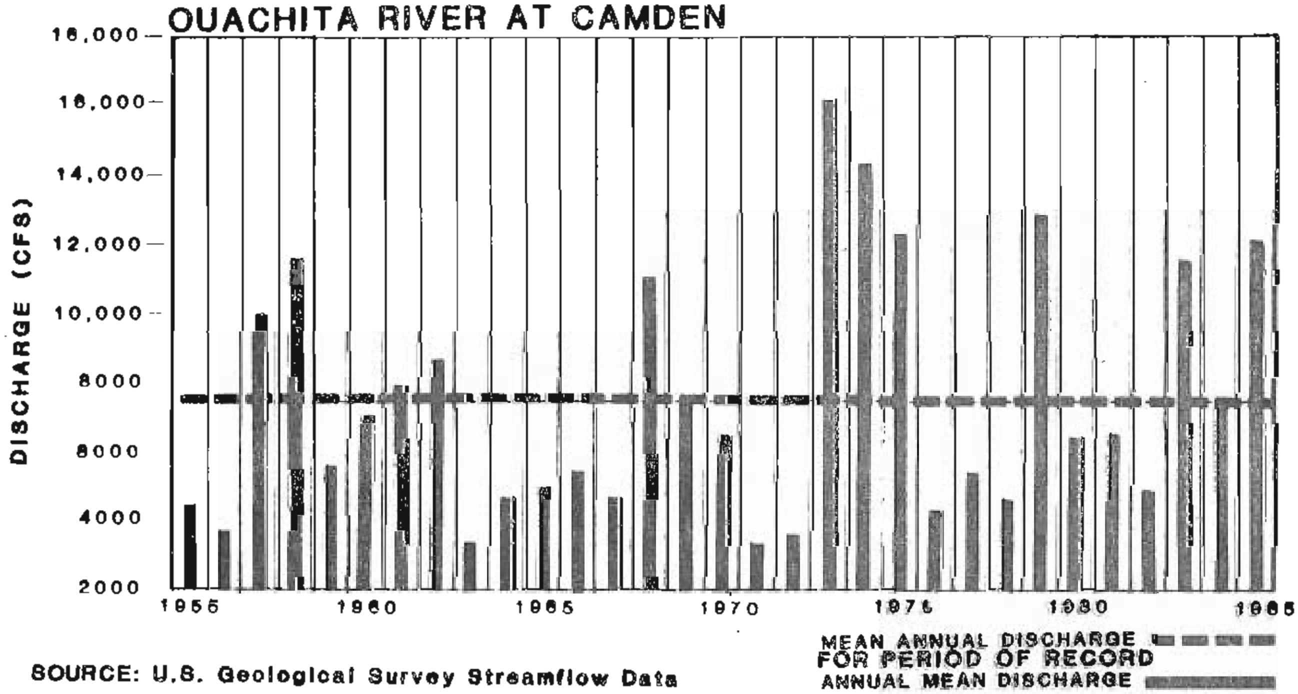
OUACHITA RIVER NEAR MT. IDA



ANTOINE RIVER AT ANTOINE



OUACHITA RIVER AT CAMDEN



SOURCE: U.S. Geological Survey Streamflow Data

TABLE 3-2
MEAN MONTHLY DISCHARGES AT SELECTED GAGING STATIONS

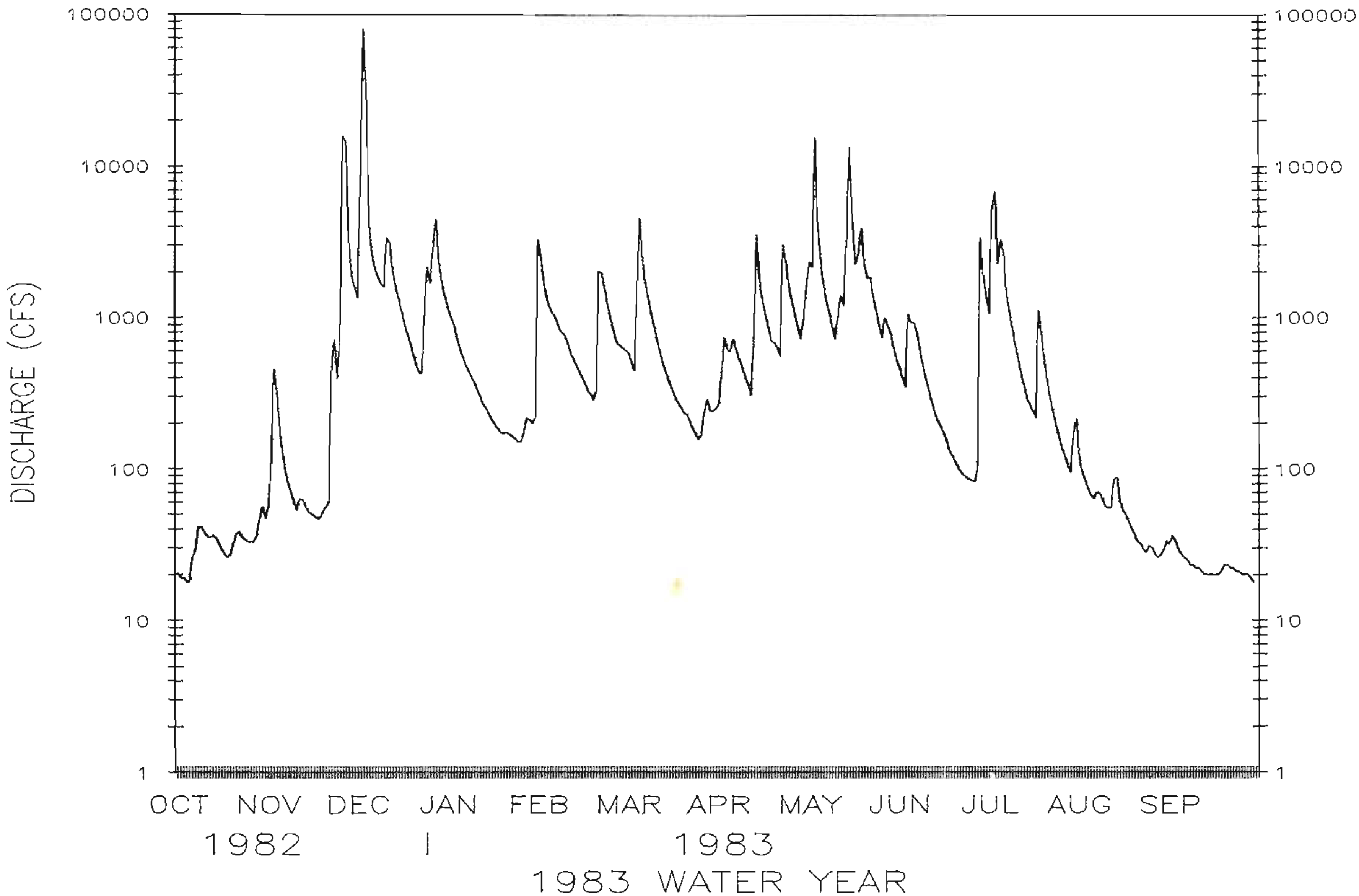
	YEARS USED FOR COMPUTATION	MEAN MONTHLY DISCHARGE (CUBIC FEET PER SECOND) OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
07356000 - OUACHITA RIVER NR. MOUNT IDA	1942 - 85	348	622	965	861	1149	1412	1156	1142	503	251	98.5	215
07356500 - SOUTH FORK OUACHITA RIVER AT MOUNT IDA	1950 - 70	28.3	69.6	90.6	129	156	183	161	167	38.1	38.1	14.2	29.8
07357501 - OUACHITA RIVER AT BLAKELY MOUNTAIN DAM NR. HOT SPRINGS	1956 - 77	1477	1453	1801	1814	1732	1445	1842	1911	1653	1192	1421	1378
07359500 - OUACHITA RIVER NR. MALVERN	1955 - 85	1815	2591	3243	2779	2826	2854	3402	3294	2051	1404	1395	1441
07359800 - CADDO RIVER NR. ALPINE	1939 - 41; 1947 - 70	146	401	590	731	911	884	931	933	225	159	92.5	127
07359910 - CADDO RIVER AT DEGRAY REGULATING DAM NR. ARKADELPHIA	1973 - 78; 1981 - 84 1/	488	1203	1696	806	787	1401	1091	1386	1225	630	416	428
07360000 - OUACHITA RIVER AT ARKADELPHIA	1973 - 78; 1981 - 84 1/	2221	5224	6612	4301	4148	5587	5973	5795	4629	2122	1367	1548
07360501 - LITTLE MISSOURI RIVER AT NARROWS DAM NR. MURFREESBORO	1958 - 77	259	349	451	367	382	456	438	641	443	439	406	322
07360800 - MUDDY FORK CREEK NR. MURFREESBORO	1947 - 59	66.8	125	135	263	314	314	378	415	85.1	50.8	12.0	70.9
07361000 - LITTLE MISSOURI RIVER NR. MURFREESBORO	1951 - 77	303	473	595	557	672	812	919	1025	603	494	460	392
07361500 - ANTOINE RIVER AT ANTOINE	1955 - 85	108	269	369	301	422	514	489	458	208	96.3	45.3	49.3
07361600 - LITTLE MISSOURI RIVER NR. BOUGHTON	1951 - 77	463	1214	1506	1635	2182	2431	2756	2601	1281	664	492	528
07362000 - OUACHITA RIVER AT CAMDEN	1955 - 85	3383	6246	9568	8377	10680	11510	12500	12990	6091	3181	2671	2996

1/ MONTHLY DISCHARGES FOR THE PERIOD OF 1982 - 84 ARE FROM UNPUBLISHED CORPS' RECORDS AND ARE SUBJECT TO REVISION
SOURCE: U.S. GEOLOGICAL SURVEY AND U.S. ARMY CORPS OF ENGINEERS STREAMFLOW RECORDS.

FIGURE 3-3

DAILY DISCHARGE HYDROGRAPH

OUACHITA RIVER NEAR MOUNT IDA



Flow Duration

Annual and seasonal variability of streamflow in the Upper Ouachita Basin affect the water-supply potential of streams on a year-round basis. The percentage of time specified stream discharges are available is one factor that determines the water-supply potential of a stream without storage. Flow-duration curves were developed for streams at gaging station locations in the basin to analyze the water-supply potential of streams at selected locations. The flow-duration curve is a cumulative frequency curve of daily mean flows that shows the percent of time that specified discharges were equaled or exceeded. The method outlined by Searcy <62> was used to develop the flow-duration curves and selected points from the curves are summarized in Table 3-3. It should be noted that the flow-duration curve applies only to the period for which data were used to develop the curve <62>. However, these data may be used to estimate the probability of occurrence of future streamflow if the period used is representative of the long-term flow of the stream. Analysis of the data presented in Table 3-3 indicates that several streams in the Upper Ouachita Basin would not provide a sustained water supply without storage. South Fork of the Ouachita River at Mount Ida, Muddy Fork Creek near Murfreesboro and Antoine River at Antoine have had no flow at times in the past. Therefore, storage would be necessary to provide a sustained water supply at these locations.

The flow-duration curve is also a valuable medium for comparing drainage basin characteristics. Flow-duration curves for Antoine River at Antoine and Little Missouri River near Boughton were plotted in Figure 3-4 to illustrate the significant difference between the streamflow characteristics at the two sites. The flow-duration curve for Antoine River at Antoine has a relatively steep slope throughout which denotes highly variable streamflow that is mainly from direct surface runoff. The curve for Little Missouri River has a flat slope which indicates streamflow that is from delayed surface runoff and ground-water storage. The flat slope at the lower end of the curve for Little Missouri River indicates sustained base flow, whereas the steep slope for the Antoine River curve indicates a negligible base flow.

Flow-duration curves can also be used to analyze changes that have occurred in streamflow characteristics over time at a single location. For example, flow-duration curves were plotted for two periods of record for Ouachita River near Malvern in Figure 3-5. The first curve was developed for the period of record prior to regulation of the streamflow by Lake

TABLE 3-3

FLOW DURATION OF STREAMS AT SELECTED CONTINUOUS RECORD GAGING STATIONS

	DRAINAGE AREA (mi²)	RECORDS USED (water years)	FLOW, IN CUBIC FEET PER SECOND, WHICH WAS EQUALED OR EXCEEDED FOR PERCENTAGE OF TIME INDICATED IN COLUMN SUBHEADS																	
			99.9	99.5	99	98	95	90	80	70	60	50	40	30	20	10	5	2	1	0.5
07356000 - OUACHITA RIVER NR. MOUNT IDA	414	1942 - 85	3.7	6.3	9.0	12	20	30	50	88	149	237	354	520	820	1550	2800	5300	7950	11500
07356500 - SOUTH FORK OUACHITA RIVER AT MOUNT IDA	61.0	1950 - 70	0	0.17	0.5	1.3	2.9	4.4	7.0	11	16	22	33	50	83	170	335	835	1380	2030
07357501 - OUACHITA RIVER AT BLAKELY MOUNTAIN DAM NR. HOT SPRINGS	1102	1956 - 77	15	16	17	18	20	22	230	375	545	970	1570	2130	2740	3800	5500	7000	7800	8350
07359500 - OUACHITA RIVER NR. MALVERN	1585	1955 - 85	140	200	230	255	308	385	485	690	1130	1600	2130	2750	3400	5650	8200	10300	12000	14600
07359800 - CADDO RIVER NR. ALPINE	301	1939 - 41; 1947 - 70	7.7	13	16	21	29	38	54	71	97	143	210	315	530	1070	1940	4100	6250	9250
07359910 - CADDO RIVER AT DEGRAY REGULATING DAM NR. ARKADELPHIA	463	1973 - 78; 1981 - 84 1/	126	132	135	140	141	145	150	159	180	270	535	900	1450	2800	4300	5600	6200	6900
07360000 - OUACHITA RIVER AT ARKADELPHIA	2314	1973 - 78; 1981 - 84 1/	120	160	210	310	500	640	860	1250	1920	2650	3430	4300	5900	10200	14400	18600	21800	26800
07360501 - LITTLE MISSOURI RIVER AT NARROWS DAM NR. MURFREESBORO	239	1958 - 77	10	10	10	10	10	11	14	16	79	197	300	530	760	1120	1570	2040	2400	2900
07360800 - MUDDY FORK CREEK NR. MURFREESBORO	120	1941 - 42; 1947 - 59	0	0	0	0	0	0.22	1.5	5.6	16	35	62	98	169	350	695	1500	2750	4450
07361000 - LITTLE MISSOURI RIVER NR. MURFREESBORO	383	1951 - 77	7.2	9.3	11	13	18	29	58	128	203	300	435	620	890	1530	2220	3220	4230	5700
07361500 - ANTOINE RIVER AT ANTOINE	178	1955 - 85	0	0	0	0.10	0.51	1.5	5.0	16	34	67	120	200	320	560	1040	2380	3700	5250
07361600 - LITTLE MISSOURI RIVER NR. BOUGHTON	1079	1951 - 77	21	31	38	46	63	92	175	267	380	520	730	1090	1820	3470	5630	10300	15600	21600
07362000 - OUACHITA RIVER AT CAMDEN	5357	1955 - 85	450	585	645	740	875	1080	1500	2120	2780	3600	4800	6800	10800	18400	26700	38500	50000	67500

1/ DATA FOR THE PERIOD OF 1982 - 84 ARE FROM UNPUBLISHED CORPS' RECORDS AND ARE SUBJECT TO REVISION.

figure 3-4

DURATION OF DAILY MEAN DISCHARGE FOR ANTOINE RIVER AT ANTOINE AND LITTLE MISSOURI RIVER NEAR BOUGHTON

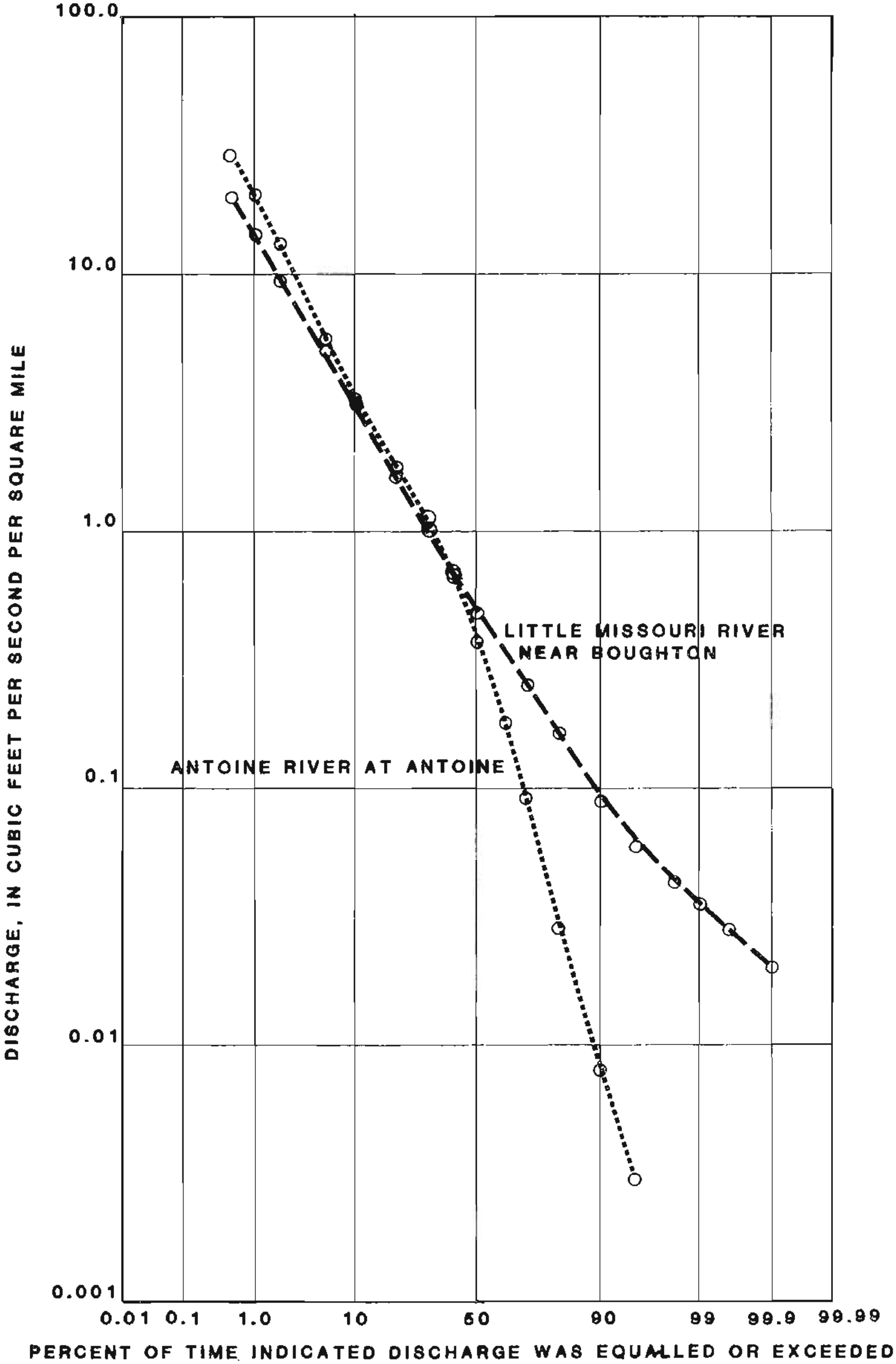
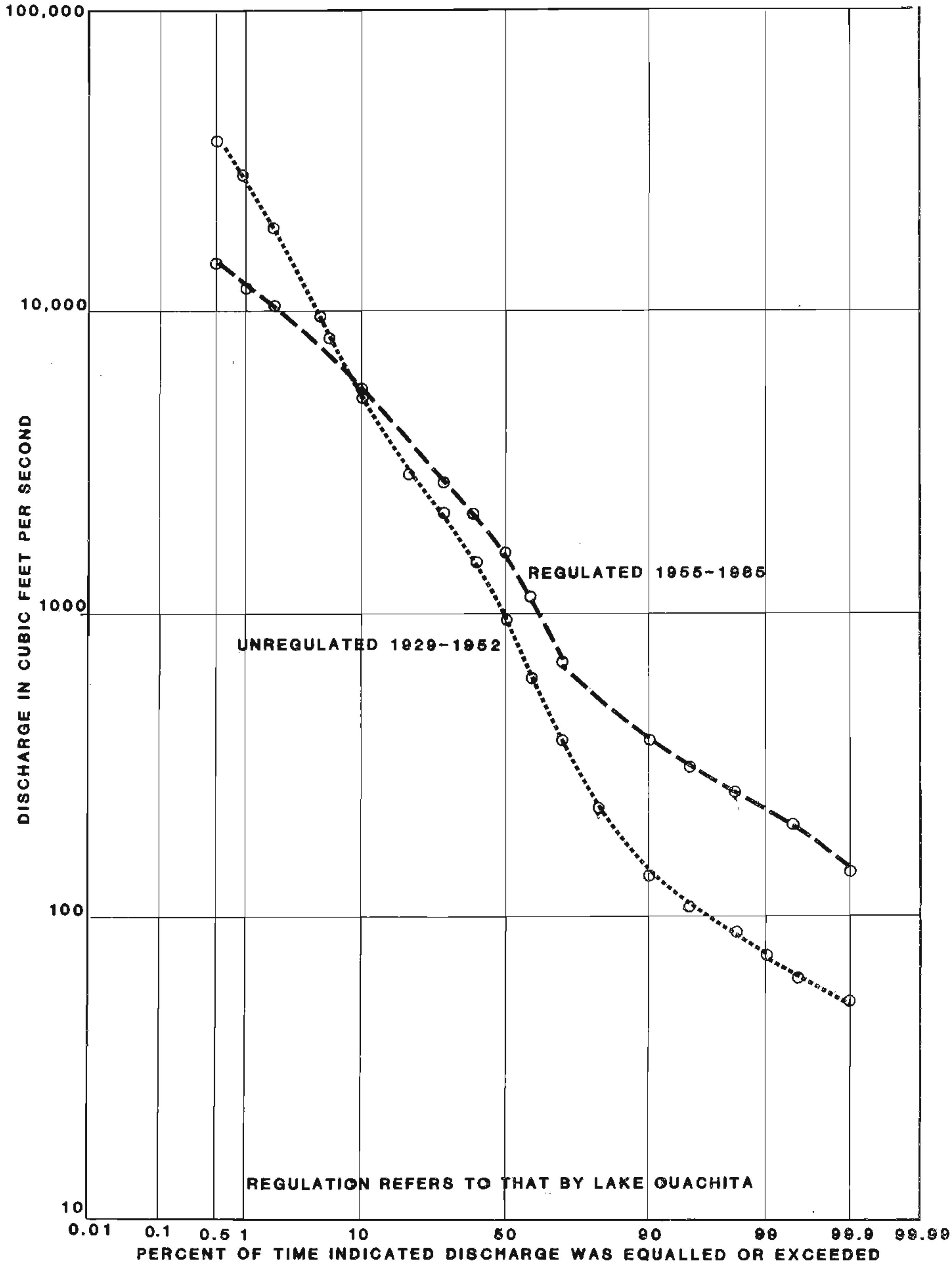


figure 3-5

DURATION OF DAILY MEAN DISCHARGE FOR OUACHITA RIVER NEAR MALVERN FOR THE PERIOD OF 1929-1952 / 1955-1985



Ouachita (1929-52), and the second curve represents the regulated period (1955-85). The differences between the two curves are primarily the result of the effects of regulation by Lake Ouachita. Regulation of the streamflow by Lake Ouachita has reduced the peak flows of the Ouachita River near Malvern and increased the base flow of the river at this location. Reservoirs on the Little Missouri River and the Caddo River have similar effects on streamflow characteristics downstream of the reservoirs.

Flood Frequency

Maximum streamflows generally occur during December through May in the Upper Ouachita Basin. Although floods provide an opportunity to replenish depleted stores of water, flooding can cause considerable local damage. Information pertaining to the magnitude and frequency of floods is essential for determining design characteristics of structures that control floodflows or that are subject to possible flooding, for establishing flood-insurance rates, and for determining the best land use that could be made of the flood plain. To determine the magnitude and frequency of floods in the Upper Ouachita Basin, flood peaks at selected gaging station locations in the basin were analyzed by the annual-flood series method in which only the maximum peak discharge for each year was used <51>. As recommended by the Hydrology Subcommittee of the Interagency Advisory Committee on Water Data <43>, the mathematically fitted log-Pearson Type III probability distribution was used to define the frequency curves. Peak discharges for selected recurrence intervals are compiled in Table 3-4 for nine gaging stations in the Upper Ouachita Basin. Flood frequencies for locations affected by regulation from upstream reservoirs were determined based on records which represent the current, regulated streamflow conditions.

The recurrence interval is the probable average interval between floods of a given magnitude over an extended period of time. The recurrence interval does not imply any regularity of occurrence. For instance, two 100-year-interval floods could conceivably occur in consecutive years, or even in the same year.

TABLE 3-4
FLOOD PEAK DISCHARGES FOR SELECTED RECURRENCE INTERVALS

STATION	PERIOD OF RECORD	PEAK DISCHARGE, IN CUBIC FEET PER SECOND, FOR INDICATED RECURRENCE INTERVAL, IN YEARS				
		2	5	10	50	100
07356000 - OUACHITA RIVER NR. MOUNT IDA	1942-84	22,200	38,200	50,400	81,500	96,400
07356500 - SOUTH FORK OUACHITA RIVER AT MOUNT IDA	1950-78	6,760	11,600	15,200	23,500	27,200
07359500 - OUACHITA RIVER NR. MALVERN	1953-84	28,200	51,200	71,300	131,000	164,000
07359800 - CADDO RIVER NR. ALPINE	1939-70	25,900	39,500	48,600	68,400	76,700
07360800 - MUDDY FORK CREEK NR. MURFREESBORO	1940-80	10,900	18,700	24,800	40,400	48,000
07361000 - LITTLE MISSOURI RIVER NR. MURFREESBORO	1951-77	12,400	19,900	25,100	36,700	41,600
07361500 - ANTOINE RIVER AT ANTOINE	1951-84	12,000	18,800	23,600	35,100	40,300
07361600 - LITTLE MISSOURI RIVER NR. BOUGHTON	1951-80	25,400	40,500	50,200	69,900	77,500
07362000 - OUACHITA RIVER AT CAMDEN	1953-84	58,300	101,000	134,000	213,000	250,000

SOURCE: COMPILED FROM U.S. GEOLOGICAL SURVEY AND U.S. ARMY CORPS OF ENGINEERS' STREAMFLOW DATA.

Low-Flow Frequency

Minimum streamflows generally occur during August through October of each year in the Upper Ouachita Basin. Management and development of surface-water supplies depend on the rate of sustained streamflow during these dry periods. The flow of streams during dry periods is governed by the volume of water in ground storage and by the rate at which the ground water discharges into the streams. The character and distribution of the geologic formations of the drainage basins exert a major influence on the quantity of the low flows of streams <64>. Indices generally used to define the low-flow characteristics of streams are the lowest mean discharges for seven consecutive days having recurrence intervals of 2 and 10 years. For simplicity, these indices are referred to as the 7-day 2-year ($7Q_2$) and 7-day 10-year ($7Q_{10}$) discharges, respectively. These discharges are taken from a frequency curve of annual values of the lowest mean discharge for seven consecutive days.

Low-flow characteristics at gaging stations on streams in the Upper Ouachita Basin are summarized in Table 3-5. The $7Q_2$ and $7Q_{10}$ values were determined using U.S. Geological Survey and U.S. Army Corps of Engineers streamflow data and the log Pearson Type III probability distribution program <61>. This program mathematically fits a frequency curve to the discharge data, and the $7Q_2$ and $7Q_{10}$ values are then taken from the curve generated by the program. If a stream is dry during any part of the year, however, this procedure is not directly applicable and a graphical solution for determining the low-flow characteristics must be used. To eliminate the effect of variation in drainage area size between sites, the $7Q_2$ and $7Q_{10}$ discharges per square mile were computed and were included in Table 3-5 for comparison purposes.

Low-flow characteristics at partial-record stations on streams in the Upper Ouachita Basin have been estimated by Hines <39> and Ludwig <48>, and are summarized in Table 3-6. These estimates were made based on the correlation of several low-flow discharge measurements at the partial-record station with concurrent daily mean discharges at two or more continuous-record gaging stations.

The contrasting geologic conditions of the Ouachita Mountains in the northern part of the Upper Ouachita Basin and of the Coastal Plains in the southern part of the basin have a definite effect on the low-flow characteristics of streams in the basin. As shown by the data compiled in Tables 3-5 and 3-6, low-flow characteristics of streams in the Upper Ouachita Basin are extremely variable. For example, tributary streams lying entirely within the Ouachita Mountains of the basin have

TABLE 3-5
LOW-FLOW FREQUENCY AT GAGING STATIONS ON STREAMS IN THE UPPER OUACHITA BASIN
[O.M. = OUACHITA MOUNTAINS; C.P. = COASTAL PLAINS]

STATION NUMBER	NAME	PERIOD OF RECORD	DRAINAGE BASIN PHYSIOGRAPHY	$7Q_2$ (CFS)	$7Q_2/mi^2$ (CFSM)	$7Q_{10}$ (CFS)	$7Q_{10}/mi^2$ (CFSM)
07356000	OUACHITA RIVER NR. MOUNT IDA	1943-85	O.M.	20	0.05	7.1	0.02
07356500	SOUTH FORK OUACHITA RIVER AT MOUNT IDA	1951-70	O.M.	2.6	0.04	0.1	0.002
07357501	OUACHITA RIVER AT BLAKELY MOUNTAIN DAM NR. HOT SPRINGS 1/	1957-77	O.M.	41	0.04	14	0.01
07359500	OUACHITA RIVER NR. MALVERN 1/	1956-85	O.M.	389	0.24	256	0.16
07359800	CADDO RIVER NR. ALPINE	1940-70	O.M.	27	0.09	13	0.04
07359910	CADDO RIVER AT DEGRAY REGULATING DAM NR. ARKADELPHIA 1/	1973-78; 1981-84	O.M.&C.P.	147	0.32	130	0.28
07360000	OUACHITA RIVER AT ARKADELPHIA 1/	1973-78; 1981-84	O.M.&C.P.	560	0.24	170	0.07
07360501	LITTLE MISSOURI RIVER AT NARROWS DAM NR. MURFREESBORO 1/	1958-77	O.M.	12	0.05	10 2/	0.04
07360800	MUDDY FORK CREEK NR. MURFREESBORO	1941-59	O.M.&C.P.	0	0	0	0
07361000	LITTLE MISSOURI RIVER NR. MURFREESBORO 1/	1952-77	O.M.&C.P.	21	0.05	9.3	0.02
07361500	ANTOINE RIVER AT ANTOINE	1956-85	O.M.&C.P.	0.5	0.003	0	0
07361600	LITTLE MISSOURI RIVER NR. BOUGHTON 1/	1952-77	O.M.&C.P.	64	0.06	28	0.03
07362000	OUACHITA RIVER AT CAMDEN 1/	1956-85	O.M.&C.P.	904	0.17	576	0.11

1/ LOW-FLOW CHARACTERISTICS ARE APPLICABLE ONLY AS LONG AS THE EXISTING PATTERN OF REGULATION AND (OR) DIVERSION EXISTS.

2/ ESTIMATED LEAKAGE

TABLE 3-6
ESTIMATES OF LOW-FLOW FREQUENCY AT PARTIAL-RECORD STATIONS
ON STREAMS IN THE UPPER OUACHITA BASIN
[MODIFIED FROM HINES <39>; O.M. = OUACHITA MOUNTAINS; C.P. = COASTAL PLAINS]

STATION NUMBER	NAME	DRAINAGE AREA (mi²)	DRAINAGE BASIN PHYSIOGRAPHY	$7Q_2$ (CFS)	$7Q_2$ /mi² (CFSM)	$7Q_{10}$ (CFS)
07355810	OUACHITA RIVER NR. MENA	39.6	O.M.	0.1	0.002	<0.1
07355900	BIG FORK TRIBUTARY AT BIG FORK	0.19	O.M.	<0.1	--	<0.1
07356300	IRONS FORK NR. ALY	47.2	O.M.	<0.1	--	<0.1
07357710	GLAZYPEAU CREEK AT MOUNTAIN PINE	30.1	O.M.	2.2	0.07	1.1
07358010	FOURCHE A LOUPE CREEK NR. HOT SPRINGS	4.37	O.M.	0.1	0.02	<0.1
07358700	GULPHA CREEK NR. HOT SPRINGS	38.8	O.M.	1.1	0.03	0.5
07359570	TENMILE CREEK NR. DONALDSON	7.45	C.P.	<0.1	--	<0.1
07359590	CADDO RIVER NR. BLACK SPRINGS	14.7	O.M.	5.8	0.39	4.4
07359600	CADDO RIVER AT CADDO GAP	125	O.M.	22	0.18	13
07360100	L'EAU FRAIS CREEK AT JOAN	74.2	C.P.	2.6	0.04	0.7
07360160	CYPRESS CREEK AT MANNING	55.9	C.P.	1.3	0.02	0.1
07360200	LITTLE MISSOURI RIVER NR. LANGLEY	68.4	O.M.	9.9	0.14	4.6
07361025	PRAIRIE CREEK NR. MURFREESBORO	33.7	O.M.&C.P.	0.2	0.006	<0.1
07361150	NORTH FORK OZAN CREEK ABOVE MCCASKILL 1/	29.3	C.P.	0.2	0.007	--
07361160	NORTH FORK OZAN CREEK NEAR MCCASKILL 1/	97.3	C.P.	0.2	0.002	--
07361200	OZAN CREEK NR. MCCASKILL 1/	144	C.P.	0	0	--
07361210	OZAN CREEK NR. BLEVINS 1/	161 2/	C.P.	0.2	0.001	--
07361540	WOLF CREEK NR. ANTOINE	37.4	O.M.&C.P.	0.8	0.02	--
07361630	TERRE ROUGE CREEK NR. HOPE	37.6	C.P.	0.9	0.02	0.2
07361640	LITTLE TERRE ROUGE CREEK NR. EMMET	40.5	C.P.	0.2	0.005	<0.1
07361650	TERRE ROUGE CREEK NR. PRESCOTT	232	C.P.	1.1	0.005	0.2
07361700	CANEY CREEK NR. BLUFF CITY	181	C.P.	0.1	0.001	--
07361800	TERRE NOIRE CREEK NR. GURDON	258	O.M.&C.P.	0.5	0.002	--
07361850	TULIP CREEK NR. PINE GROVE	130	C.P.	1.5	0.01	0.5
07361900	BAYOU FREEO NR. EAGLE MILLS	78.0	C.P.	0.4	0.005	<0.1

1/ LOW-FLOW FREQUENCY FROM LUDWIG <48>
2/ ESTIMATED

estimated $7Q_2$ low-flow indices ranging from less than 0.002 cfs/square mile to 0.39 cfs/square mile. Streams lying entirely within the Coastal Plains of the basin have estimated $7Q_2$ low-flow indices ranging from zero to 0.04 cfs/square mile.

According to Speer and others <64>, differences in low-flow indices are primarily due to the porosity and permeability of the aquifers in the basin, the depth of incision of the stream, and the relation of the water table to the bed of the stream. The porosity and permeability of the aquifers of the Ouachita Mountains and of the Coastal Plains in the Upper Ouachita Basin are considerably different. The consolidated rocks of the Ouachita Mountains have relatively low permeabilities which limit the amount of ground water available and hinder ground-water movement. In contrast, some of the Coastal Plain sediments have higher permeabilities that favor the transmission of water, and greater amounts of ground water are generally available than in the consolidated rocks <59>. However, according to data in Tables 3-5 and 3-6, the Caddo River upstream of DeGray Reservoir, which lies entirely in the Ouachita Mountains, has the highest low-flow yield ($7Q_2$=0.39 cfs/square mile) of streams that have been investigated in the Upper Ouachita Basin. Therefore, other factors such as the depth of incision of the stream and the relation of the water table to the bed of the stream are also important factors affecting low flow in streams.

Of the streams in the Upper Ouachita Basin for which low-flow data are available, L'Eau Frais and Cypress Creeks, eastern tributaries of the Ouachita River, and Terre Rouge Creek, tributary of the Little Missouri River, have the highest low-flow yields of tributary streams lying entirely within the Coastal Plain. However, streamflow yield may be significantly different at different locations on the same stream. For example, Terre Rouge Creek near Hope has an estimated $7Q_2$ of 0.02 cfs/square mile. According to Ludwig <48>, low flow of this stream is sustained by ground-water discharge from the Nacatoch Sand, which underlies the upper part of the drainage basin. However, at the downstream station near Prescott, the estimated $7Q_2$ is only 0.005 cfs/square mile which indicates that geologic units downstream of Hope contribute very little water to Terre Rouge Creek during baseflow conditions.

Low-flow yields are also extremely variable for different reaches of Ozan Creek, a tributary of the Little Missouri River in the Coastal Plain region. According to Ludwig <48>, streamflow of Ozan Creek is sustained by base flow from sands in the outcrop of the Tokio Formation, which underlies the upper part of the basin, and by discharge from flowing wells which tap the Tokio Formation. North Fork Ozan Creek above McCaskill has an estimated $7Q_2$ of 0.2 cfs (0.007 cfs/square mile). Downstream on North Fork Ozan Creek, the estimated $7Q_2$ near McCaskill is also 0.2 cfs (0.002 cfs/square mile) which indicates that there is no significant contribution of water to the stream from geologic units in the 68 square miles of additional drainage area at the downstream site. The estimated $7Q_2$ for Ozan Creek near McCaskill is zero and for Ozan Creek near Blevins is 0.2 cfs (0.001 cfs/square mile). The variation in low-flow yields at points along Ozan Creek is an indication of the variability of the geohydrology of the basin.

Low-flow indices for several tributary streams that head in the Ouachita Mountains with the lower part of the drainage basin in the Coastal Plains have been estimated by Hines <39>. The estimated $7Q_2$ indices for four of these tributary streams ranged from zero for Muddy Fork Creek near Murfreesboro to 0.02 cfs/square mile for Wolf Creek near Antoine. Generally, streams in the Ouachita Mountains that are incised to sufficient depth to intercept the ground water have high low-flow indices <64>. The streamflow yields for streams that head in the Ouachita Mountains and flow into the Coastal Plains are considerably less than the yields of many of the streams which lie entirely within the Ouachita Mountains. According to Speer and others <64>, the low-flow yield of some streams may decrease as they enter the broad alluvial valleys of the Coastal Plain which may in part be due to flow entering the unconsolidated materials in the streambed.

As previously discussed, streamflow yield in the Upper Ouachita Basin may be significantly different at different locations on the same stream due to variations in the geohydrology of a basin. Regulation of flow of the Caddo, Ouachita, and Little Missouri Rivers in the Upper Ouachita Basin may also cause significant differences in low-flow characteristics downstream of the reservoirs. For example, the estimated $7Q_2$ low-flow index for the Caddo River near Black Springs was 0.39 cfs/square mile. The estimated yield decreased at the downstream sites at Caddo Gap ($7Q_2$ = 0.18 cfs/square mile) and Alpine ($7Q_2$ = 0.09 cfs/square mile). Downstream of DeGray Reservoir, however, the low-flow yield of the Caddo River increased to 0.32 cfs/square mile which indicates that regulation by DeGray Reservoir probably maintains a higher baseflow in the Caddo River downstream of the dam than would be maintained under natural conditions.

Low-flow indices of the Ouachita River have been affected by storage in Lake Catherine since 1925, Lake Hamilton since 1932, and Lake Ouachita since 1952, and by storage in Lake

Greeson on the Little Missouri River since 1949. The effect that Lake Ouachita has had on the low flow of the Ouachita River can be illustrated by comparison of streamflow records before and after impoundment. As an example, the $7Q_2$ of the Ouachita River near Malvern was 133 cfs prior to impoundment of Lake Ouachita <39> as compared with 389 cfs for the period since impoundment. In Table 3-5, the $7Q_2$ low-flow indices were computed for five continuous discharge stations on the Ouachita River based on current streamflow conditions. The low-flow indices are, therefore, applicable only as long as the pattern of regulation is maintained. Hines <39> also estimated the $7Q_2$ for Ouachita River near Mena (Table 3-6). There is considerable variation in the low-flow yields for different locations on the Ouachita River ranging from 0.002 cfs/square mile near Mena (unregulated site) to 0.24 cfs/square mile near Malvern and at Arkadelphia (regulated sites).

Available low-flow information indicates that reservoirs on the Caddo and Ouachita Rivers contribute to an increase in low flow downstream of the reservoirs. However, low-flow indices at four locations on the Little Missouri River (Tables 3-5 and 3-6) did not show a similar increase in baseflow downstream of Lake Greeson. The $7Q_2$ was the highest for the station near Langley (0.14 cfs/square mile), which is upstream of the reservoir. The low-flow indices were considerably lower at the three sites downstream of Lake Greeson, ranging from 0.05 cfs/square mile to 0.06 cfs/square mile. These data do not indicate an increase in baseflow downstream of the reservoir . However, comparison of the $7Q_2$ index prior to regulation (0.02 cfs/square mile) <39> with the $7Q_2$ index representing current, regulated streamflow conditions (0.05 cfs/square mile) for the Little Missouri River near Murfreesboro does show that Lake Greeson has contributed to an increase in low flow of the Little Missouri River downstream of the reservoir.

Comparison of the low-flow characteristics of streams in the Upper Ouachita Basin was made on the basis of unit runoff per square mile. Because of the wide variation in the yield of streams in the basin and variation in yield between reaches on the same stream, it is not possible to generalize that in an area where one stream shows an index of a given yield, all streams in the area have the same index. Interpolation of low-flow data should not be made to estimate the low flow at ungaged sites on the basis of drainage area without sufficient knowledge of the geohydrology, manmade changes, and other factors affecting the low flow.

Instream Flow Requirements

Instream flow requirements are generally defined as "the quantity of water needed to maintain the existing and planned in-place uses of water in or along a stream channel or other water body and to maintain the natural character of the aquatic system and its dependent systems". <76> Instream flow requirements are established at a level at which the flow regime best meets the individual and collective instream uses and off-stream withdrawals of water. Instream uses of water include uses of water in the stream channel for navigation, recreation, fisheries, riparian vegetation, aesthetics, and hydropower. Off-stream water withdrawals include uses such as irrigation, municipal and industrial water supplies, and cooling water.

Section 2 of Act 1051 of 1985 requires the Arkansas Soil and Water Conservation Commission to determine instream flow requirements for: (1) water quality, (2) fish and wildlife, (3) navigation, (4) interstate compacts, (5) aquifer recharge, and (6) needs of all other users in the basin such as industry, agriculture, and public water supply. Determination of the amount of water required to satisfy instream needs in the Upper Ouachita Basin is necessary so that streamflow available for use within the basin as well as the amount of excess water available for interbasin transfer can be quantified.

In order to determine instream flow requirements for the categories mentioned above, information was obtained from other agencies such as the Arkansas Department of Pollution Control and Ecology, the Arkansas Game and Fish Commission, and the Corps of Engineers. The flows recommended for the different categories (as provided by the appropriate agencies) were then evaluated with respect to all other instream needs in order to determine the flow regime which best meets the collective instream uses and off-stream withdrawals. This resulted in a two-part solution for the process of determining instream flow requirements. The first approach was to determine the amount of water necessary to satisfy instream needs in the basin based on the flows recommended by other agencies before interbasin transfer of water could take place. The information compiled in the following sections on instream flow requirements pertains to this first approach. The second approach was to determine the amount of water necessary to satisfy minimum instream flow requirements in order to determine the streamflow available for use within the basin. This second approach is described in more detail in the minimum streamflow section of the report.

Computations of instream flow requirements at selected locations in the basin are based on streamflow data that represent the current streamflow conditions. As previously stated in the Streamflow Characteristics section of the report, regulation of streamflow by reservoirs in the Upper Ouachita Basin has reduced the peak flows and has increased the base flows of the Ouachita, Little Missouri, and Caddo Rivers downstream of the reservoirs. If the pattern of reservoir regulation changes in the future, the streamflow available to satisfy the instream flow requirements may be significantly different from the streamflow that has been historically available downstream of the reservoirs in the basin.

Water-Quality Requirements

The $7Q_{10}$ low-flow characteristic is a common criterion used by State and Federal agencies to determine the permissible rate of waste disposal into a given stream since one of the most important factors influencing the concentration of dissolved solids in streamflow is the volume of water available for dilution. The Arkansas Department of Pollution Control and Ecology is responsible for the management of water-quality conditions in the Upper Ouachita Basin. The $7Q_{10}$ discharge for streams and rivers in the basin is the minimum flow at which the ADPC&E is responsible for maintaining streamflow contaminant concentrations at acceptable levels. The ADPC&E continues to monitor point-source discharges below the $7Q_{10}$ discharge and requires concentrations of certain pollutants to be maintained below critical levels. However, since sufficient water is not available at times during the year to dilute the effluent discharges, streamflow water quality may not meet the quality standards during all times of the year.

Streams that are regulated are addressed by ADPC&E on a case-by-case basis to determine the minimum flow required to maintain streamflow contaminant concentrations at acceptable levels. The Ouachita, Caddo, and Little Missouri Rivers in the Upper Ouachita Basin are significantly affected by regulation. To determine the $7Q_{10}$ low-flow characteristics for these regulated rivers, only those streamflow records which are representative of the existing pattern of regulation are used in the computations. If significant changes are made in the methods of reservoir regulation in this basin, the $7Q_{10}$ values determined for regulated reaches of the Ouachita, Caddo, and Little Missouri Rivers must be recomputed.

The $7Q_{10}$ discharges were determined at 13 gaging station locations in the Upper Ouachita Basin. The discharges required to meet water-quality standards at gaging station locations in the basin are as follows:

Ouachita River:
- 7.1 cfs nr. Mount Ida
- 14 cfs downstream of Blakely Mountain Dam nr. Hot Springs
- 256 cfs nr. Malvern 1/
- 170 cfs at Arkadelphia 1/
- 576 cfs at Camden 1/

Caddo River:
- 13 cfs nr. Alpine
- 130 cfs at DeGray regulating dam nr. Arkadelphia 1/

Little Missouri River:
- 10 cfs downstream of Narrows dam nr. Murfreesboro 1/
- 9.3 cfs nr. Murfreesboro 1/
- 28 cfs nr. Boughton 1/

South Fork Ouachita River:
- 0.1 cfs at Mount Ida

Muddy Fork Creek:
- No flow nr. Murfreesboro

Antoine River:
- No flow at Antoine

1/ $7Q_{10}$ discharges are applicable only as long as the existing pattern of regulation exists.

The $7Q_{10}$ discharge of 170 cfs for the Ouachita River at Arkadelphia appears to be inconsistent with the $7Q_{10}$ discharge of 256 cfs upstream near Malvern and the $7Q_{10}$ discharge of 576 cfs downstream at Camden. Computation of the $7Q_{10}$ discharge for the Ouachita River at Arkadelphia was based on a significantly different period of record than the period of record used for other gaging stations on the Ouachita River. The data used in the analysis for the Arkadelphia gaging station were selected so that the effects of DeGray Reservoir on the streamflow at this location would be taken into consideration. However, the period of record representative of current streamflow conditions included only 10 years of record. The $7Q_{10}$ discharge for the Ouachita River at Arkadelphia may significantly change with the collection of additional streamflow data at this location in the future.

Fish and Wildlife Requirements

Several methods are currently available for determining instream flow requirements for fisheries. Some of these methods, however, require considerable field work to characterize fish habitats in the basin. On the other hand, Tennant <66> developed a method (often referred to as the "Montana Method") which requires limited field work and utilizes historic hydrologic records to estimate instream flow requirements for fish and other aquatic life by correlating the condition of the aquatic habitat with the percent of the average flow present in the stream. The Montana Method was tested by field studies which involved physical, chemical, and biological analyses conducted on 11 streams in three states. Additional analyses of hundreds of additional flow regimens in 21 different states substantiated the correlation between the condition of the aquatic habitat and the percent of the average flow present in the stream. Tennant's comprehensive study resulted in the following conclusions:

(A) "Ten percent (10%) of the average flow: This is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms. Channel widths, depths, and velocities will all be significantly reduced and the aquatic habitat degraded. The stream substrate or wetted perimeter may be about one-half exposed, except in wide, shallow riffle or shoal areas where exposure could be higher. Most side channels will be severely or totally dewatered. Most gravel bars will be substantially dewatered, and islands will usually no longer function as wildlife nesting, denning, nursery, and refuge habitat. Streambank cover for fish and fur animal denning habitat will be severely diminished. Many wetted areas will be so shallow they no longer will serve as cover, and fish will generally be crowded into the deepest pools. Riparian vegetation may suffer from lack of water. Large fish may have difficulty migrating upstream over many riffle areas. Water temperature may become a limiting factor, especially in the lower reaches of the stream in July and August. Invertebrate life will be severely reduced."

(B) "Thirty percent (30%) of the average flow: This is a base flow recommended to sustain good survival habitat for most aquatic life forms. Widths, depths, and velocities will generally be satisfactory. The majority of the substrate will be covered with water, except for very wide, shallow riffle or shoal areas. Most side channels will carry some water. Most gravel bars will be partially covered with water and many islands will provide wildlife nesting, denning, nursery, and refuge habitat. Streambanks will provide cover for fish and wildlife denning habitat in many reaches. Many runs and most pools will be deep enough to serve as cover for fishes. Riparian vegetation should not suffer from lack of water. Large fish should have no trouble moving over most riffle areas. Water temperatures are not expected to become limiting in most stream segments. Invertebrate life is reduced but not expected to become a limiting factor in fish production."

(C) "Sixty percent (60%) of the average flow: This is a base flow recommended to provide excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreational uses. Channel widths, depths, and velocities will provide excellent aquatic habitat. Most of the normal channel substrate will be covered with water, including many shallow riffle and shoal areas. Side channels that normally carry water will have adequate flows. Few gravel bars will be exposed, and the majority of islands will serve as wildlife nesting, denning, nursery, and refuge habitat. The majority of streambanks will provide cover for fish and safe denning areas for wildlife. Most pools, runs, and riffles will be adequately covered with water and provide excellent feeding and nursery habitat for fishes. Riparian vegetation will have plenty of water. Fish migration is no problem in any riffle areas. Water temperatures are not expected to become limiting in any reach of the stream. Invertebrate life forms should be varied and abundant."

Tennant's recommended flows are generally applicable for both cold and warm water streams. However, it is suggested that the recommended flow regimens be altered to fit different hydrologic cycles or to coincide with vital periods of the life cycle of fishes.

Filipek and others <27> have developed a new method, termed the "Arkansas method", which utilizes some of Tennant's basic principles. This new method was developed due to limitations in the application of the Montana method to Arkansas streams. The Arkansas method divides the water year into three seasons based on the physical and biological processes that occur in the stream. The three physical/biological seasons as well as the flow recommended for fisheries during each season are described in Table 3-7. The instream flow requirements, as determined by the Arkansas method, are those that apply to fish populations only and

TABLE 3-7
DESCRIPTION OF PHYSICAL/BIOLOGICAL SEASONS IN THE ARKANSAS METHOD OF INSTREAM FLOW QUANTIFICATION

TIME OF YEAR	NOVEMBER THRU MARCH	APRIL THRU JUNE	JULY THRU OCTOBER
FLOW RECOMMENDED	SIXTY PERCENT OF THE MEAN MONTHLY FLOW	SEVENTY PERCENT OF THE MEAN MONTHLY FLOW	FIFTY PERCENT OF THE MEAN MONTHLY FLOW OR THE MEDIAN MONTHLY FLOW, WHICHEVER IS GREATER
PHYSICAL/BIOLOGICAL PROCESSES INVOLVED	CLEAN AND RECHARGE	SPAWNING	PRODUCTION
NORMAL CONDITIONS	-HIGH AVERAGE MONTHLY FLOWS. -LOW WATER TEMPERATURES. -HIGH DISSOLVED OXYGEN CONTENT. FLUSHING OF ACCUMULATED SEDIMENT AND CLEANING OUT OF SEPTIC WASTES. SPAWNING AREAS CLEANED AND REBUILT BY GRAVEL AND OTHER SUBSTRATE BROUGHT DOWNRIVER BY HIGH FLOWS. RECHARGE OF GROUNDWATER (AQUIFERS).	-HIGH AVERAGE MONTHLY FLOWS. -INCREASING (PREFERRED) WATER TEMPERATURES. -HIGH DISSOLVED OXYGEN CONTENT. HIGH FLOWS AND INCREASING WATER TEMPERATURES SPUR SPAWNING RESPONSE IN FISH TO SPAWN: 1) IN CHANNEL 2) IN OVERBANK AREA OR 3) UPRIVER AFTER MIGRATION. FEEDING ALSO ACTIVATED BY HIGH SPRING FLOWS.	-LOW AVERAGE MONTHLY FLOWS. -HIGH WATER TEMPERATURES. -LOW DISSOLVED OXYGEN CONTENT COMMON. HIGH WATER TEMPERATURES INCREASE PRIMARY, SECONDARY AND TERTIARY PRODUCTION. LOW FLOWS CONCENTRATE PREDATORS (FISH) WITH PREY (INVERTEBRATES, FORAGE FISH).
LIMITING FACTORS	REDUCED FLOWS AT THIS TIME OF YEAR CAUSE: DECREASE IN BENTHIC PRODUCTION DUE TO ACCUMULATED SEDIMENT ON SUBSTRATE. DECREASE IN FISH SPAWNING HABITAT DUE TO REDUCED FLUSHING. DECREASE IN AQUIFER RECHARGE.	REDUCED FLOWS AT THIS TIME OF YEAR CAUSE: DECREASE IN SPAWNING EGG AND FRY SURVIVAL AND OVERALL REPRODUCTIVE SUCCESS OF IMPORTANT SPORT AND NON-GAME FISH. WEAK YEAR CLASSES OF IMPORTANT SPORT, COMMERCIAL, NON-GAME AND THREATENED FISH SPECIES.	REDUCED FLOWS AT THIS TIME OF YEAR CAUSE: WATER TEMPERATURES TO INCREASE, DECREASING SURVIVAL OF CERTAIN FISH SPECIES. DECREASE IN WETTED SUBSTRATE AND THEREFORE DECREASE IN ALGAE, MACROINVERTEBRATES. DECREASE IN DISSOLVED OXYGEN DUE TO HIGHER WATER TEMPERATURES; FISHKILLS. INCREASE CONCENTRATION OF POLLUTANTS AND SEDIMENT IN WATER. ADDITIONAL DECREASE IN GROUNDWATER TABLE.

SOURCE: FILIPEK AND OTHERS, 1985 (27)

represent the point at which fisheries begin to be impacted. The method assumes that when instream flows meet the needs for fisheries, instream requirements for other wildlife forms are probably also satisfied.

Filipek and others <28> applied the Arkansas method to streamflow data from several gaging stations in the Upper Ouachita Basin. The instream flow requirements were computed as a percent of the mean monthly discharge required for each month of the year. However, analysis of the mean monthly flows used in the computations indicated that the entire period of available streamflow data was used to determine instream flow requirements at the sites. Due to the effects of the reservoirs in the basin on the streamflow of the Ouachita, Caddo, and Little Missouri Rivers, mean monthly discharges (previously summarized in Table 3-2) that represent current streamflow conditions were used instead of the entire period of record to determine instream flow requirements at the sites. The Arkansas method was then applied to these mean monthly discharges to determine the instream flow requirements for fish and wildlife at selected streamflow gaging stations in the Upper Ouachita Basin with the results compiled in Table 3-8. The flows required to satisfy instream needs for fish and wildlife on an annual basis were also determined for the gaging stations in the basin and are shown in Table 3-8. The annual instream flow requirements for fish and wildlife were computed by averaging the monthly instream flow requirements for the year.

Instream flow requirements for fish and wildlife are not available for many locations in the basin due to the limited number of gaging stations in the Upper Ouachita Basin. If instream flow requirements for fish and wildlife are needed at ungaged locations on streams and additional information about the basin is unavailable, the following procedure may be used. Mean monthly flows from the gaging station closest to, or most representative of, the point in interest can be adjusted based on a ratio of the drainage areas. The Arkansas method may then be applied to these estimated mean monthly flows to determine the instream flow requirements at the point in question. Because there are relatively few gaging stations with historic record in the Upper Ouachita Basin, this method does enable estimation of mean monthly discharges and instream flow requirements for fish and wildlife at other points of interest. However, a representative gaging station used to estimate mean monthly discharge at an ungaged site must be carefully selected due to the variability of streamflow

TABLE 3-8
MONTHLY AND ANNUAL INSTREAM FLOW REQUIREMENTS FOR FISH AND WILDLIFE
AT SELECTED GAGING STATIONS IN THE UPPER OUACHITA BASIN

	MONTHLY AND ANNUAL INSTREAM FLOW REQUIREMENTS FOR FISH AND WILDLIFE (CFS)												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
07356000 - OUACHITA RIVER NR. MOUNT IDA	174	373	579	517	689	847	809	799	352	126	49.2	108	452
07356500 - SOUTH FORK OUACHITA RIVER AT MOUNT IDA	14.2	41.8	54.4	77.4	93.6	110	113	117	26.7	19.0	7.10	14.9	57.4
07357501 - OUACHITA RIVER AT BLAKELY MOUNTAIN DAM NR. HOT SPRINGS	782	872	1081	1088	1039	867	1289	1338	1157	596	713	689	959
07359500 - OUACHITA RIVER NR. MALVERN	908	1555	1946	1667	1696	1712	2381	2306	1436	702	698	720	1477
07359800 - CADDO RIVER NR. ALPINE	73.0	241	354	439	547	530	652	653	158	79.5	46.2	63.5	320
07359910 - CADDO RIVER AT DEGRAY REGULATING DAM NR. ARKADELPHIA	244	722	1018	484	472	841	764	970	858	315	208	214	592
07360000 - OUACHITA RIVER AT ARKADELPHIA	1110	3134	3967	2581	2489	3352	4181	4056	3240	1061	684	774	2552
07360501 - LITTLE MISSOURI RIVER AT NARROWS DAM NR. MURFREESBORO	130	209	271	220	229	274	307	449	310	226	218	167	251
07360800 - MUDDY FORK CREEK NR. MURFREESBORO	33.4	75.0	81.0	158	188	188	265	290	59.6	25.4	6.00	35.4	117
07361000 - LITTLE MISSOURI RIVER NR. MURFREESBORO	152	284	357	334	403	487	643	718	422	247	240	198	374
07361500 - ANTOINE RIVER AT ANTOINE	54.0	161	221	181	253	308	342	321	146	48.2	22.6	24.6	174
07361600 - LITTLE MISSOURI RIVER NR. BOUGHTON	232	728	904	981	1309	1459	1929	1821	897	332	246	264	925
07362000 - OUACHITA RIVER AT CAMDEN	1692	3748	5741	5026	6408	6906	8750	9093	4264	1590	1376	1498	4674

conditions and to the regulation of streams in the Upper Ouachita Basin. For example, instream flow requirements determined at three locations on the Little Missouri River (Table 3-8) downstream of Lake Greeson should not be used to estimate instream flow requirements for a location on the Little Missouri River upstream of the reservoir.

According to a report submitted to the Arkansas Soil and Water Conservation Commission by Filipek and others <28>, the recommended instream requirements as determined by the Arkansas method are designed "to maintain existing fisheries, many of which are at optimal levels". Therefore, to protect stream fisheries and to satisfy water needs for fish and wildlife in the Upper Ouachita Basin, the instream flow requirements, as previously described for streams in this basin, represent an amount of water that is unavailable for interbasin transfer.

Navigation Requirements

The U.S. Army Corps of Engineers operates and maintains the Ouachita River-Black River navigation project in Arkansas and Louisiana. According to information from the Vicksburg District of the Corps of Engineers (written communication, 1987 - See Appendix A), a minimum release of 100 cfs from Lake Ouachita is maintained for the navigation project. Therefore, 100 cfs of water should be maintained in the Ouachita River between Lake Ouachita and Camden for navigation requirements. There are no instream flow requirements for navigation on the other streams in the Upper Ouachita Basin.

Interstate Compact Requirements

The Upper Ouachita Basin is included in Reach IV of the Red River Compact. This compact is an agreement among the states of Arkansas, Oklahoma, Texas, and Louisiana. The purpose of the compact is to promote comity among these participating states by cooperating in the equitable apportionment and development of the water in specific river basins as provided by the interstate compact agreements. The following information is from sections of the Red River Compact which is defined in "Arkansas Water Law" <11>.

ARTICLE VII

APPORTIONMENT OF WATER--REACH IV ARKANSAS AND LOUISIANA

Subdivision of Reach IV and allocation of water therein.

Reach IV of the Red River is divided into topographic subbasins, and the water therein allocated as follows:

SECTION 7.01. Subbasin 1--Intrastate streams--Arkansas, reads in part as follows:

(a) This subbasin includes those streams and their tributaries above last downstream major damsites originating in Arkansas and crossing the Arkansas-Louisiana state boundary before flowing into the Red River in Louisiana. The last downstream major damsites in the Upper Ouachita Basin are as follows:

Site	Stream	Ac-ft	Location: Latitude	Location: Longitude
Lake Catherine	Ouachita River	19,000	34°26.6'N	93°01.6'W
DeGray Lake	Caddo River	1,377,000	34°13.2'N	93°06.6'W
Lake Greeson	Little Missouri River	600,000	34°08.9'N	93°42.9'W

(b) Arkansas is apportioned the waters of this subbasin and shall have unrestricted use thereof.

SECTION 7.02. Subbasin 2--Interstate Streams--Arkansas and Louisiana.

(a) This subbasin shall consist of Reach IV less subbasin 1 as defined in Section 7.01 (a) above.

(b) The State of Arkansas shall have free and unrestricted use of the water of this reach subject to the limitation that Arkansas shall allow a quantity of water equal to forty (40) percent of the weekly runoff originating below or flowing from the last downstream major damsites to flow into Louisiana. Where there are no designated last downstream damsites, Arkansas shall allow a quantity of water equal to forty (40) percent of the total weekly runoff originating above the state boundary to flow into Louisiana. Use of water in this subbasin is subject to low flow provisions of subparagraph 7.03 (b).

SECTION 7.03. Special Provisions, reads in part as follows:

(a) Arkansas may use the beds and banks of segments of Reach IV for the purpose of conveying its share of water to designated downstream diversions.

(b) The State of Arkansas does not guarantee to maintain a minimum low flow for Louisiana in Reach IV. However, when the use of water in Arkansas reduces the flow of the Ouachita River at the Arkansas-Louisiana state boundary to 780 cfs, the state of Arkansas pledges to take affirmative steps to regulate the diversions of runoff originating or flowing into Reach IV in such a manner as to permit an equitable apportionment of the runoff as set out herein to flow into the State of Louisiana.

According to the provisions outlined in the Red River Compact for Reach IV, the following streams are considered to be interstate streams and are subject to interstate compact requirements: (1) the Little Missouri River and its tributaries downstream of Lake Greeson; (2) the Caddo River and its tributaries downstream of DeGray Reservoir; and (3) the Ouachita River and its tributaries downstream of Lake Catherine. To comply with Section 7.02 (b) of the Compact, Arkansas shall allow forty percent of the total weekly runoff from these interstate streams to flow into Louisiana. The Engineering Advisory Committee to the Red River Compact Commission is in the process of determining each state's responsibilities for compliance with the compact. Although the compact compliance requirements have not been identified for Reach IV of the Red River Basin, requirements have been designated for Reach II, Subbasin 5. It is believed that similar procedures will be proposed for Reach IV.

At the present time, the amount of water required to satisfy interstate compact requirements can not be quantified for several reasons. The first reason is that compact compliance is based on a percentage of the total runoff in a basin. Runoff, as defined in the compact, includes flow in the streams and water that has been diverted from the streams for other uses. The amount of water that is diverted from streams is not accurately quantified, therefore, the amount of runoff in the basins is unknown. The second reason the interstate compact requirements can not be quantified is because the requirements are based on the previous week's streamflow and diversions. Therefore, the compact requirements change from week to week, depending on the runoff available in a basin the previous week. Using average weekly discharge for the period of record would give an idea of the weekly discharges that could be expected at a particular location. However, the compact requirements can not be determined using these data since the requirements are based on a percentage of the actual weekly runoff for a basin.

Aquifer Recharge Requirements

Recharge to the major aquifers in the Upper Ouachita Basin is primarily from precipitation and percolation in the outcrop area. Seepage from Quaternary alluvial deposits may also be a significant source of recharge to underlying, deeper aquifers in the basin <34, 41>. Some recharge to Quaternary deposits occurs locally along streams during high stages in the spring due to lateral movement of flow from the stream to the aquifers. However, the contribution to ground water from the streams during high stages probably is small and generally is temporary <14>. The water is stored during times of floods on the streams and is released soon after the floods recede <64>.

The instream flows that are required to recharge the aquifers in the basin are currently unknown because there is insufficient information available to define and quantify the stream-aquifer relationships. However, streams in the Upper Ouachita Basin that have very low indices of low flow are generally not incised sufficiently deep to be in contact with the water-yielding deposits <64> and, therefore, aquifer recharge requirements for these streams are not applicable.

Streams in the basin that exhibit sustained baseflow during dry-weather conditions are evidence that formations in these drainage basins are recharged above capacity and are discharging to streams to maintain equilibrium with annual recharge. The baseflow of these streams is sustained by rejected groundwater that is naturally discharged from the formations. Therefore, in these basins, there also would be no aquifer recharge requirements. However, if ground water levels were drawn down below the level of the streambed, the aquifer recharge requirements would then need to be considered.

Riparian Use Requirements

Section 2 of Act 1051 of 1985 requires the Arkansas Soil and Water Conservation Commission to determine surface water needs of public water supplies, industry, and agriculture. In 1984, reported surface-water use for irrigation, industry, and public water supply totaled approximately 35,600 acre-feet of water in the Upper Ouachita Basin, as determined from Arkansas Soil and Water Conservation Commission's records of registered diversions. Of the total amount of water diverted for these needs, 8,100 acre-feet were used for municipal supply, 11,000 acre-feet were used for irrigation, and 16,500 acre-feet were used for industry. These figures represent current riparian needs in the Upper Ouachita Basin.

The amount of water diverted from each of the major streams in the Upper Ouachita Basin was not determined for this report. The purpose of defining and quantifying instream flow requirements for streams in the basin was to determine the amount of water available for other uses, such as interbasin transfer. Since the water diverted for the uses mentioned above has already been removed from the streams and is not available, it was not included in the computations for total surface-water yield and excess streamflow of the basin.

Riparian water use requirements may vary considerably from year to year based on changing needs. Projected riparian water needs are accounted for in the water-use projections for irrigation, industry, and public water supplies.

Aesthetic Requirements

Instream flow requirements, as previously defined, include water that is necessary to maintain the existing in-place uses of water in or along a stream channel. Recreational activities, such as fishing, hunting, and canoeing, in the Upper Ouachita Basin represent another use of water in the streams in addition to those uses previously addressed. Instream flow requirements established for fish and wildlife (50, 60, or 70 percent of the appropriate mean monthly discharge) should be adequate to maintain fishing and hunting activities in the basin. Canoeing in the Upper Ouachita Basin, particularly on the Little Missouri River upstream of Lake Greeson, is dependent upon the natural variability of streamflow. Diversion of water from streams for other uses would affect the streamflow variability. However, during the principal canoeing season in the spring, instream flow requirements for fish and wildlife (60 or 70 percent of the appropriate mean monthly discharge) should be adequate to maintain streamflow at a level which would support canoeing activities on selected streams in the basin.

The Little Missouri River has been designated a scenic river by Act 689 of 1985 from the upper end of Lake Greeson upstream to the headwaters south of Big Fork. Designation of a scenic river is for the purpose of protection of natural and scenic beauty, water quality, and fish and wildlife of aquatic systems. There are no provisions in Act 689 for prohibiting existing and future water withdrawals from designated scenic rivers. However, instream flow requirements which have been established for water quality and fish and wildlife should also protect the natural character of the streams in the basin.

Current Available Streamflow

Determination of the current available streamflow in the Upper Ouachita Basin is necessary so that excess streamflow (that amount of water available for interbasin transfer) can be quantified. The flows required to satisfy the instream needs previously identified were compared with average annual discharges for streams to determine the amount of streamflow that is currently available from streams and rivers in the basin. The information in Table 3-9 was compiled by stream to provide a generalized summary of the current water available on an average annual basis for selected streams in the basin. It should be noted that, for the purpose of this compilation, the instream flow requirements for the interstate compact were computed as 40 percent of the average annual discharge. The actual interstate compact requirements, however, may be significantly different than those listed in the table since the actual requirements are determined from the previous week's streamflow and diversions.

The instream flow requirements for the different categories are not additive. The highest instream need represents the amount of water required to satisfy all the existing instream needs at the selected locations. The instream needs for fish and wildlife were the governing instream flow requirements for all streams listed in Table 3-9. Therefore, to determine the amount of water that is currently available at these locations, the flows required for fish and wildlife were subtracted from the average annual discharges. The water currently available for other uses, on an average annual basis, ranged from 34.4 cfs for the South Fork of the Ouachita River at Mount Ida to 2824 cfs for the Ouachita River at Camden. These results may, however, be somewhat misleading. Due to the streamflow variability in the basin, most of the water is available during the winter and spring months with considerably less water available during the low-flow months of the year.

TABLE 3-9

STREAMFLOW AT SELECTED LOCATIONS IN THE UPPER OUACHITA BASIN
THAT IS CURRENTLY AVAILABLE FOR OTHER USES

		AVERAGE ANNUAL DISCHARGE (CFS)	INSTREAM FLOW REQUIREMENTS (CFS)				CURRENT AVAILABLE STREAMFLOW (CFS)
			WATER QUALITY	*FISH AND WILDLIFE	NAVIGATION	INTERSTATE COMPACTS	
07356500	SOUTH FORK OUACHITA RIVER AT MOUNT IDA	91.8	0.1	57.4	--	--	34.4
07359910	CADDO RIVER AT DEGRAY REGULATING DAM NR. ARKADELPHIA	964	130	592	--	386	372
07360800	MUDDY FORK CREEK NR. MURFREESBORO	185	NO FLOW	117	--	74.0	68.0
07361500	ANTOINE RIVER AT ANTOINE	277	NO FLOW	174	--	111	103
07361600	LITTLE MISSOURI RIVER NR. BOUGHTON	1474	28	925	--	590	549
07362000	OUACHITA RIVER AT CAMDEN	7498	576	4674	100	2999	2824

*GOVERNING INSTREAM FLOW REQUIREMENT WHICH REPRESENTS THE AMOUNT OF WATER REQUIRED TO SATISFY EXISTING NEEDS AT SELECTED LOCATIONS

To illustrate the effect that streamflow variability can have on the determination of available streamflow, the streamflow that is currently available on a monthly basis was determined for the Little Missouri River near Boughton (Table 3-10). The governing fish and wildlife instream requirements were subtracted from the mean monthly discharges to determine the streamflow available on a monthly basis. The Little Missouri River near Boughton has 549 cfs of water available for other uses on an average annual basis. However, on a mean monthly basis, the available water ranges from 231 cfs in October to 972 cfs in March. The data in Table 3-10 show that the majority of the current available streamflow of the Little Missouri River near Boughton occurs during the period of December through May.

The current available streamflows computed in Tables 3-9 and 3-10 do not represent the amount of water that is available for interbasin transfer. Before interbasin transfer of water can be considered, the projected water needs of the basin must be addressed. The previous determinations of current available streamflow do not account for the projected water needs of the basin because data identifying the projected water needs for individual streams in the basin are not currently available. However, the projected water needs of the entire basin have been estimated and are accounted for in the excess streamflow section of the report for the determination of the total amount of water in the Upper Ouachita Basin that is available for interbasin transfer.

Minimum Streamflow

Section 2 of Act 1051 of 1985 requires the Arkansas Soil and Water Conservation Commission to establish minimum streamflows. Minimum streamflow is defined as the lowest daily mean discharge that will satisfy minimum instream flow requirements. A minimum streamflow is established to protect instream needs, particularly during low-flow conditions which may occur naturally or during periods of significant use from the stream. The minimum streamflow also represents a critical low flow condition below which some minimum instream need will not be met. The minimum streamflow is not a target level or a flow that can be maintained for an extended period of time without serious environmental consequences. Therefore, the minimum streamflow also represents the discharge at which all withdrawals from the stream will cease. Because of the critical low flow conditions which may exist at the minimum streamflow level, allocation of water based on the

TABLE 3-10
STREAMFLOW AT LITTLE MISSOURI RIVER NEAR BOUGHTON
THAT IS CURRENTLY AVAILABLE ON A MONTHLY BASIS FOR OTHER USES

	MEAN MONTHLY DISCHARGE (CFS)	INSTREAM FLOW REQUIREMENTS (CFS) WATER QUALITY	*FISH AND WILDLIFE	INTERSTATE COMPACTS	CURRENT AVAILABLE STREAMFLOW (CFS)
OCTOBER	463	28	232	185	231
NOVEMBER	1214	28	728	486	486
DECEMBER	1506	28	904	602	602
JANUARY	1635	28	981	654	654
FEBRUARY	2182	28	1309	873	873
MARCH	2431	28	1459	972	972
APRIL	2756	28	1929	1102	827
MAY	2601	28	1821	1040	780
JUNE	1281	28	897	512	384
JULY	664	28	332	266	332
AUGUST	492	28	246	197	246
SEPTEMBER	528	28	264	211	264

*GOVERNING INSTREAM FLOW REQUIREMENT WHICH REPRESENTS THE AMOUNT OF WATER REQUIRED TO SATISFY EXISTING NEEDS.

establishment of water-use priorities should be in effect long before this point is reached. Allocation of water should help to maintain streamflow above the established minimum discharge.

Minimum streamflows for streams in the Upper Ouachita Basin were determined based on the instream flow requirements as previously described in this report with the exception of fish and wildlife requirements. The instream flow requirements for fish and wildlife were re-evaluated to determine instream needs that represent minimum conditions. This was necessary because, as previously stated in the Instream Flow Requirements section of this report, recommended instream flow requirements for fish and wildlife using the Arkansas Method (Arkansas Game and Fish Commission) would maintain existing fisheries. These recommended flows are viewed as representing desirable conditions and not minimum instream flow needs.

To determine minimum instream flow requirements for fish and wildlife, the following procedure was used. As previously stated in the Instream Flow Requirements section, Tennant <66> concluded from his study that 10 percent of the average annual streamflow is the minimum flow required for short-term survival of most aquatic life forms. However, analysis of streamflow records for unregulated streams in the Upper Ouachita Basin showed that 10 percent of the average annual discharge was higher than the daily median discharge frequently during the summer months. High streamflows that generally occur during January through May increase the average annual discharge which causes the flow recommended by Tennant for short-term survival (10 percent of the average annual discharge) to frequently exceed streamflow during the low-flow season.

To account for the seasonal variability of streamflow in the basin, the year was divided into three seasons as identified in the Arkansas Method <27>. The seasons are based on physical processes that occur in the stream and the critical life stages of the fish and other aquatic organisms inhabiting the stream. The minimum instream flow requirements for fish and wildlife were established by taking 10 percent of the average seasonal flows.

In addition to requirements for fish and wildlife, instream flow requirements for water quality, navigation, interstate compacts, and aesthetics were also considered in the determination of minimum streamflows. Since the instream flow requirements are not additive, the highest instream need for each season was used to establish the minimum streamflow for each season. Minimum streamflows were established at gaging station locations and are presented in Table 3-11.

TABLE 3-11
MINIMUM STREAMFLOWS BY SEASON IN THE UPPER OUACHITA BASIN [1/]

LOCATION NUMBER	LOCATION NAME	NOV - MAR (CFS)	APR - JUN (CFS)	JUL - OCT (CFS)
07356000	OUACHITA RIVER NR. MOUNT IDA	100	93.4	22.8
07356500	SOUTH FORK OUACHITA RIVER AT MOUNT IDA	12.6	12.2	2.8
07357501	OUACHITA RIVER AT BLAKELY MOUNTAIN DAM	165	180	137
07359500	OUACHITA RIVER NR. MALVERN	286	292	256 [2/]
07359800	CADDO RIVER NR. ALPINE	70.3	69.6	13.1
07359910	CADDO RIVER AT DEGRAY REGULATING DAM	130 [2/]	130 [2/]	130 [2/]
07360000	OUACHITA RIVER AT ARKADELPHIA	517	546	181
07360501	LITTLE MISSOURI RIVER AT NARROWS DAM	40.1	50.7	35.6
07360800	MUDDY FORK CREEK NR. MURFREESBORO	23.0	29.3	5.0
07361000	LITTLE MISSOURI RIVER NR. MURFREESBORO	62.2	84.9	41.2
07361500	ANTOINE RIVER AT ANTOINE	37.5	38.5	7.5
07361600	LITTLE MISSOURI RIVER NR. BOUGHTON	179	221	53.7
07362000	OUACHITA RIVER AT CAMDEN	928	1050	576 [2/]

1/ FISH AND WILDLIFE IS THE GOVERNING INSTREAM REQUIREMENT UNLESS OTHERWISE NOTED.
2/ WATER QUALITY ($7Q_{10}$) IS THE GOVERNING INSTREAM REQUIREMENT.

The instream flows required to satisfy the interstate compact were not quantified for the reasons previously explained in the Instream Flow Requirements section. Therefore, the minimum streamflows in the Upper Ouachita Basin are those flows that appear in Table 3-11 or 40 percent of the weekly runoff, whichever is greater. Preliminary investigation of historic streamflow data indicated that the instream flows required for interstate compact compliance may be the governing instream flow requirement throughout much of the year. Tributaries located upstream from the major impoundments in the basin are not, however, influenced by the interstate compact requirement.

The seasonal minimum streamflow is shown for selected locations in Figures 3-6, 3-7, and 3-8, along with the median and miminum daily discharges for the period of record. Due to the streamflow variability of the Antoine River at Antoine, the minimum streamflow shown in Figure 3-6 is higher than the median daily discharge during late summer and lower than the minimum daily discharge during late winter and early spring. In contrast, the minimum streamflow for the Ouachita River near Malvern (Figure 3-7) approximates the minimum daily discharge during fall, winter, and early spring. The effects of regulation on daily discharges are clearly shown in Figure 3-8 for the Little Missouri River immediately downstream of Narrows Dam (Lake Greeson). The minimum streamflow at this site occurs between the median daily discharge and the estimated minimum daily discharge. The percentage of time that the minimum streamflows at these locations have been exceeded by discharges from the period of record are shown in Table 3-12.

The establishment of minimum streamflows will have varying effects on different water users in the basin. Riparian users will, for example, be affected by the establishment of minimum streamflows. Industrial and agricultural riparian users must either conserve water or construct storage reservoirs in anticipation of times when the flow of the stream falls below the minimum levels. Instream water uses will also be affected by the establishment of minimum streamflows. Although some level of flow protection will be beneficial to fish and wildlife, minimum streamflows are clearly not desirable conditions.

FIGURE 3-6

MINIMUM STREAMFLOW

ANTOINE RIVER AT ANTOINE

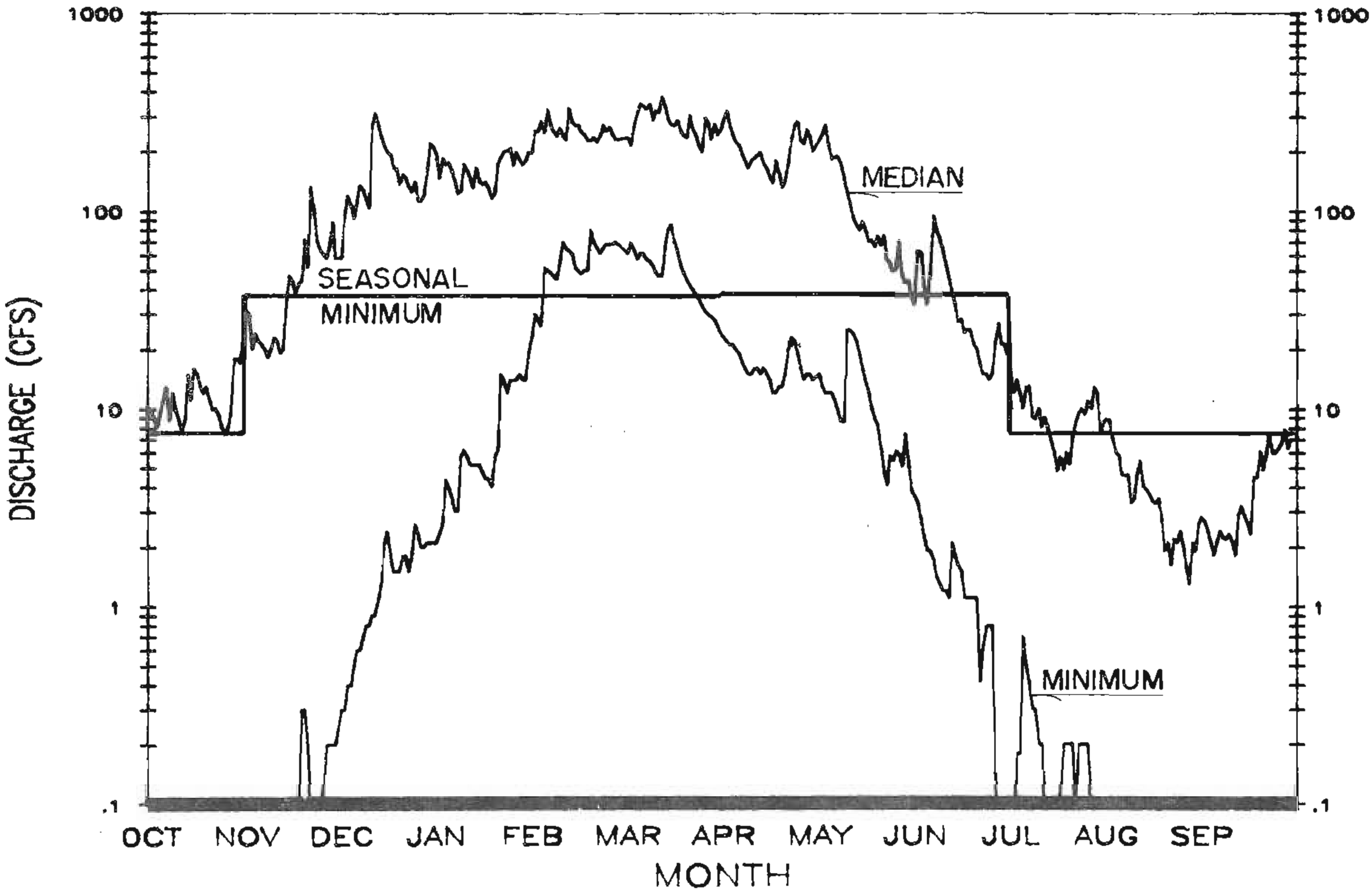


FIGURE 3-7
MINIMUM STREAMFLOW
OUACHITA RIVER NEAR MALVERN

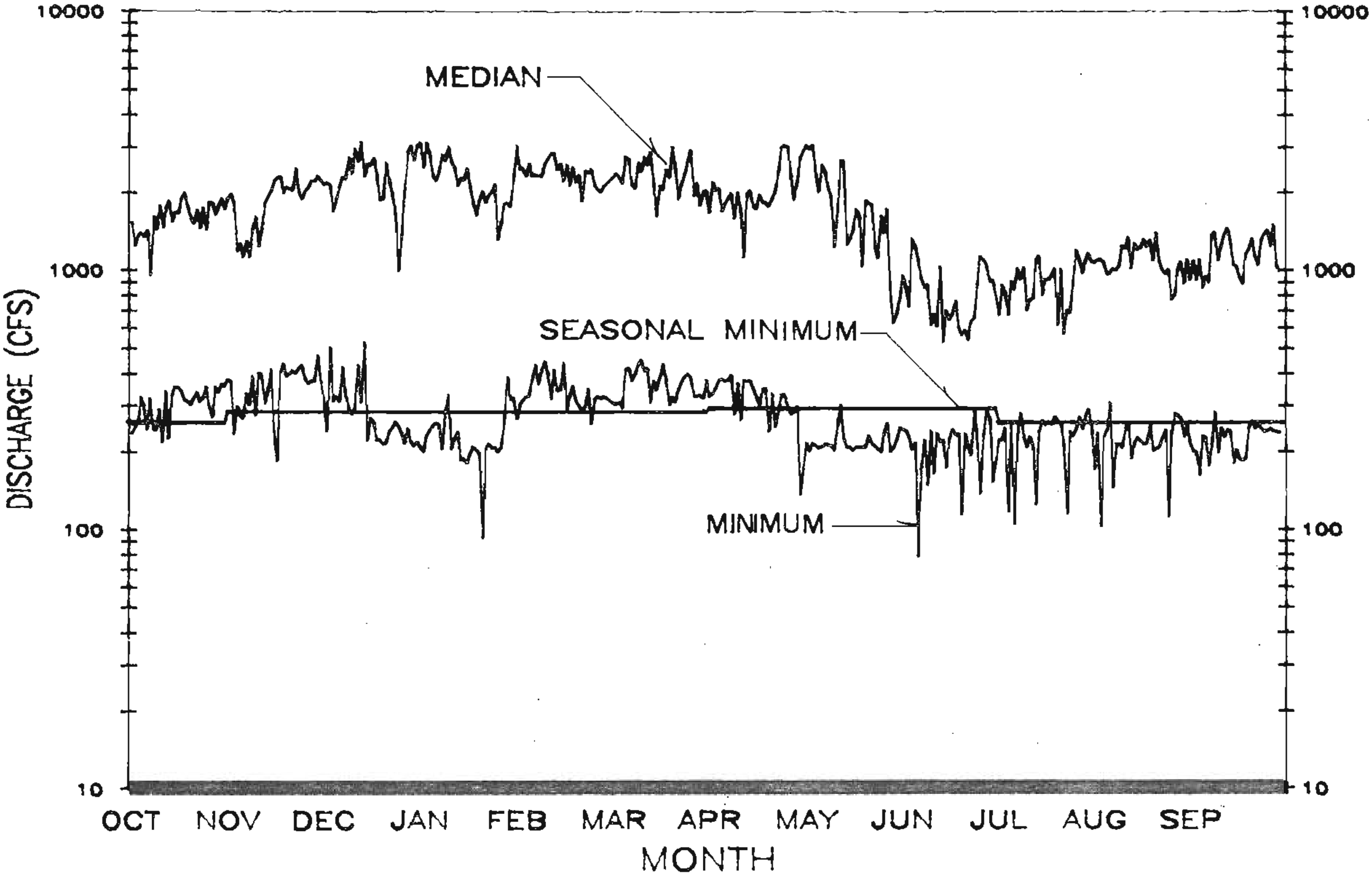


FIGURE 3-8

MINIMUM STREAMFLOW

LITTLE MISSOURI RIVER, NARROWS DAM

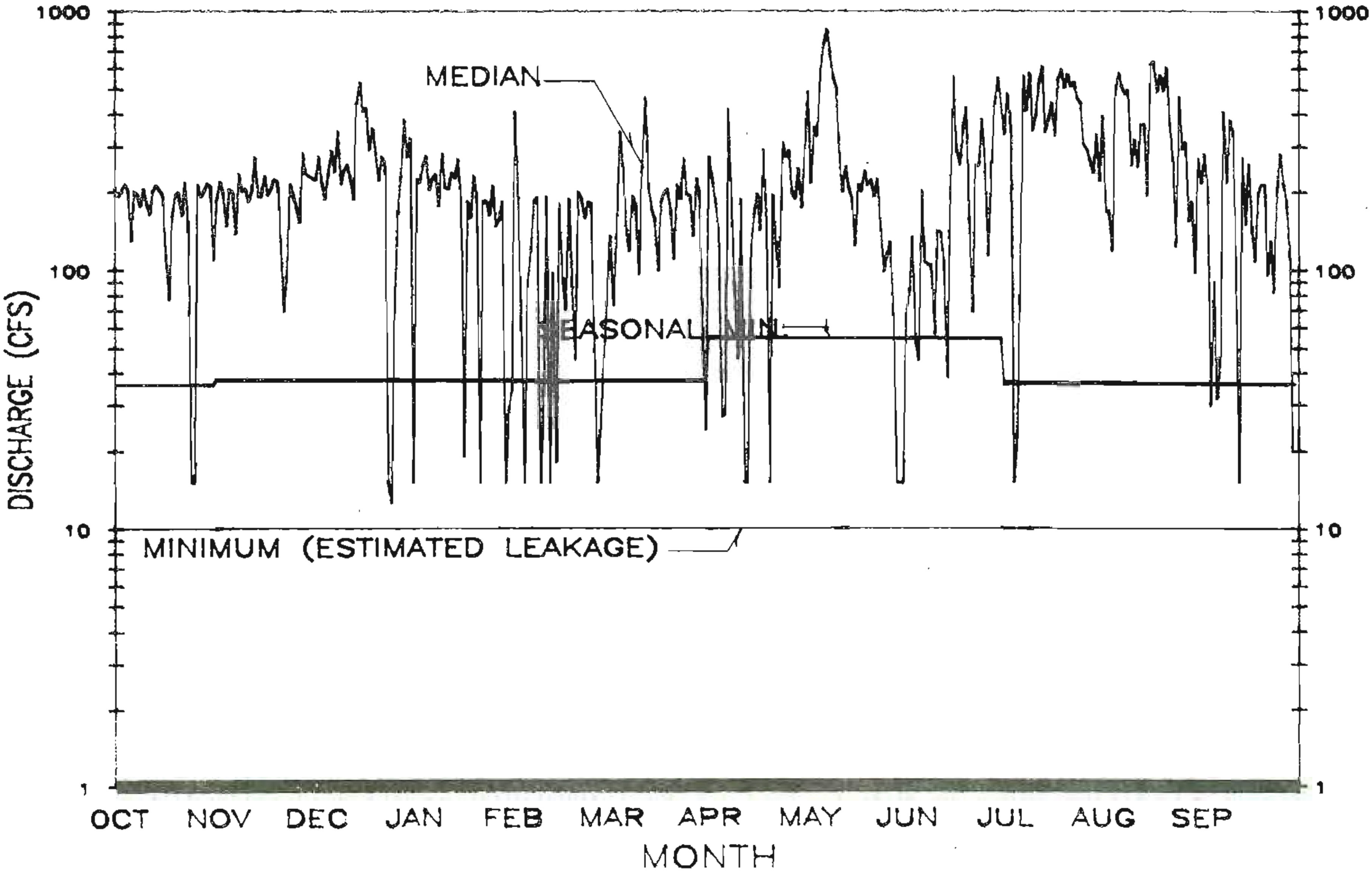


TABLE 3-12

SEASONAL EXCEEDANCE VALUES FOR MINIMUM STREAMFLOWS AT SELECTED SITES

LOCATION		SEASON		
NUMBER	NAME	NOV-MAR	APR-JUN	JUL-OCT
07359500	OUACHITA RIVER NR. MALVERN	>95%	94%	>95%
07360501	LITTLE MISSOURI RIVER AT NARROWS DAM	62%	60%	64%
07361500	ANTOINE RIVER AT ANTOINE	82%	71%	46%

Safe Yield

Section 2 of Act 1051 of 1985 requires the Arkansas Soil and Water Conservation Commission to define the safe yield of streams and rivers in Arkansas. The safe yield of a stream or river is defined as the amount of water that is available on a dependable basis which could be used as a surface-water supply.

Seasonal and annual variability of streamflow affect the dependability of water available for development. Therefore, as previously described, flow-duration curves were developed to analyze the variability of streamflow in the Upper Ouachita Basin for streams at gaging station locations (Table 3-3). To quantify the safe yield of streams in the basin, the amount of water available on a dependable basis was designated as the discharge which has been equaled or exceeded 95 percent of the time for the available period of record. This flow represents the discharge which can be expected at selected stream locations on a dependable basis; however, not all of this flow is actually available for use. Minimum streamflows, which have been established for streams and rivers in the Upper Ouachita Basin and were previously defined in this report, represent discharge that is not available for use. Therefore, the safe yield of a stream or river is the discharge which can be expected 95 percent of the time minus the discharge necessary to maintain the minimum flow in the stream during the low-flow season (July-October).

The safe yield of streams at selected gaging stations is summarized in Table 3-13. The designation of safe yield for some streams is not applicable since the minimum streamflow is greater than the 95 percent flow. This indicates that, at times during the year, water is not available in some streams for other uses and some type of streamflow storage would be required at these locations to provide a sustained yield.

Potential For Development

Although streams in the Upper Ouachita Basin have small safe yields, development of surface water storage impoundments could significantly increase dependable yields from streams in the basin. The seasonal variability in streamflow could be compensated for by storing water during high-flow periods and releasing it during low-flow periods.

The potential development for streams in the basin is presented in Table 3-14. Article VII of the Red River Compact requires that "Arkansas shall allow a quantity of water equal to 40 percent of the weekly runoff originating below or flowing from the last downstream major damsites" to flow into

TABLE 3-13
SAFE YIELD OF STREAMS AT SELECTED GAGING STATIONS

LOCATION NUMBER	LOCATION NAME	FLOW (CFS) WHICH WAS EQUALLED OR EXCEEDED 95% OF THE TIME	MINIMUM STREAMFLOW JUL - OCT (CFS)	SAFE YIELD (CFS)
07356000	OUACHITA RIVER NR. MOUNT IDA	20	22.8	N/A
07356500	SOUTH FORK OUACHITA RIVER AT MOUNT IDA	2.9	2.8	0.1
* 07357501	OUACHITA RIVER AT BLAKELY MOUNTAIN DAM	20	126	N/A
* 07359500	OUACHITA RIVER NR. MALVERN	308	256	52
07359800	CADDO RIVER NR. ALPINE	29	13.1	15.9
* 07359910	CADDO RIVER AT DEGRAY REGULATING DAM	141	130	11.0
* 07360000	OUACHITA RIVER AT ARKADELPHIA	500	181	319
* 07360501	LITTLE MISSOURI RIVER AT NARROWS DAM	10	35.6	N/A
07360800	MUDDY FORK CREEK NR. MURFREESBORO	0.0	5.0	N/A
* 07361000	LITTLE MISSOURI RIVER NR. MURFREESBORO	18	41.2	N/A
07361500	ANTOINE RIVER AT ANTOINE	0.5	7.5	N/A
* 07361600	LITTLE MISSOURI RIVER NR. BOUGHTON	63	53.7	9.3
* 07362000	OUACHITA RIVER AT CAMDEN	875	576	299

TABLE 3-14
POTENTIAL DEVELOPMENT FOR STREAMS AT SELECTED LOCATIONS

LOCATION NUMBER	LOCATION NAME	(1) MEAN ANNUAL DISCHARGE (CFS)	POTENTIAL DEVELOPMENT (2) 0.60X(1) (CFS)	POTENTIAL DEVELOPMENT (3) 0.6463X(2) (MGD)
07356500	SOUTH FORK OUACHITA RIVER AT MOUNT IDA	91.8	55.1	35.6
07359910	CADDO RIVER AT DEGRAY REGULATING DAM	964	578	374
07360800	MUDDY FORK CREEK NR. MURFREESBORO	185	111	71.7
07361500	ANTOINE RIVER AT ANTOINE	277	166	107
07361600	LITTLE MISSOURI RIVER NR. BOUGHTON	1474	884	572
07362000	OUACHITA RIVER AT CAMDEN 1/	7498	4500	2910

1/ CAN BE CONSIDERED AS A BASIN TOTAL

Louisiana. In order to determine the potential development, a quantity of water equal to 40 percent of the mean annual discharge is estimated to be necessary to satisfy interstate compact requirements and other instream needs. Therefore, the remaining 60 percent of the mean annual discharge is potentially available for development.

The potential development of the Ouachita River at Camden is approximately 2910 MGD. This indicates that a large volume of water may be developed.

Large impoundments presently exist in the Upper Ouachita Basin; however, the major use of these impoundments is for flood control and power production (See Impoundments). Lake DeGray is the only reservoir with water supply as an authorized purpose.

This basin has, in general, been developed close to the maximum. <68> There are, however, several suitable sites for impoundments as shown in Table 3-15. The total volume of these potential sites (391,000 Acre-Feet) is less than half of the storage in Lake Ouachita at the conservation pool elevation (865,000 Acre-feet).

Surface Water Use

The study area had a total water use of 53.3 MGD in 1980. Surface sources supplied 40.28 MGD, or 75% of the total 1980 use. (See Figure 3-9 and Table 3-16). A large percentage of the surface water used in the basin was from the Ouachita River.

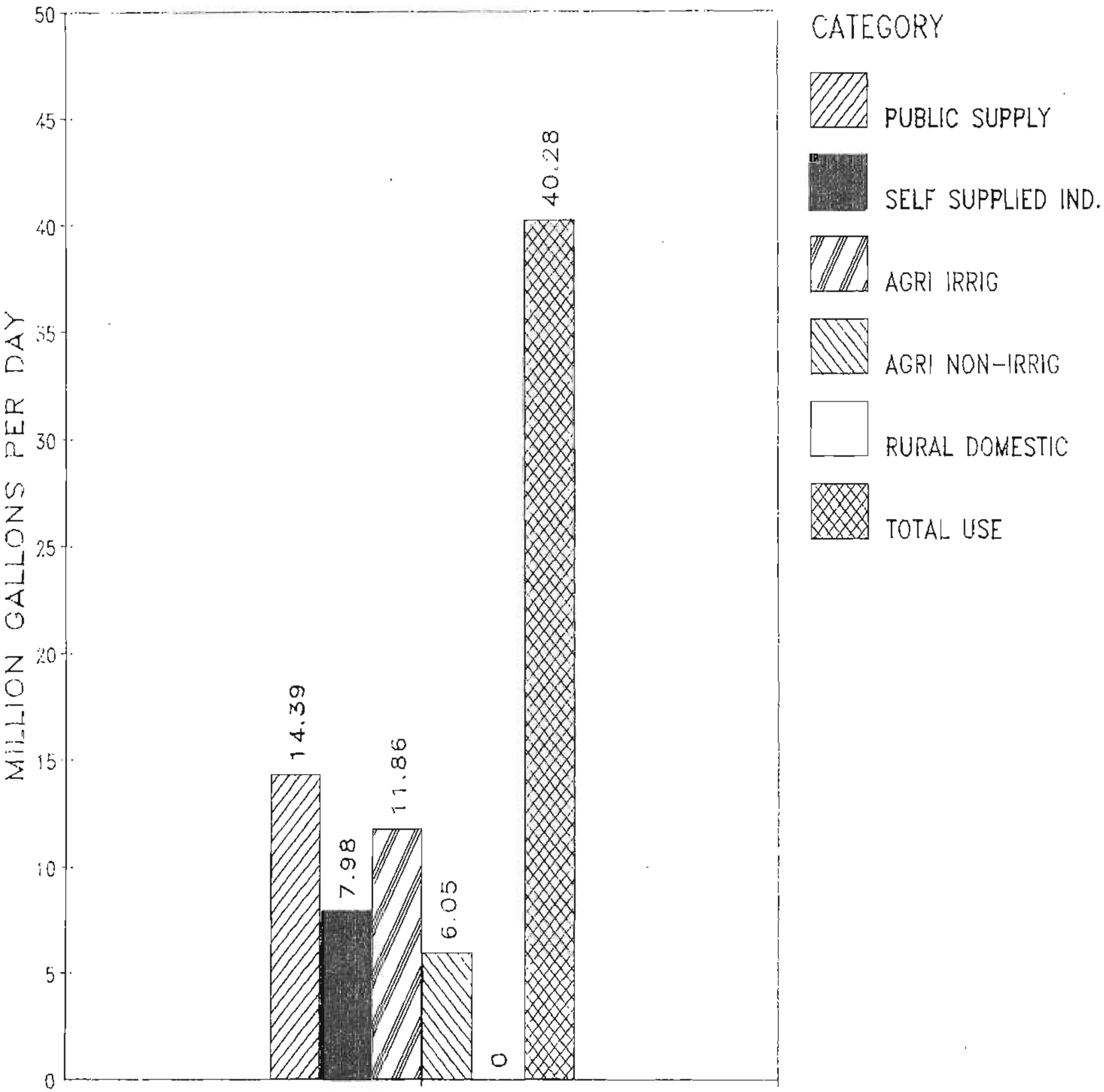
TABLE 3-15

POTENTIAL IMPOUNDMENT LOCATIONS

STREAM	MAXIMUM CAPACITY (ACRE-FEET)
IRONS FORK	49,000
FIDDLERS CREEK	42,000
MAZARN CREEK	26,000
ANTOINE RIVER	183,000
LITTLE MISSOURI RIVER	91,000
TOTAL	391,000

SOURCE: UNIVERSITY OF ARKANSAS <68>

figure 3-9
STUDY AREA WATER USE FROM SURFACE SOURCES 1980



SOURCE: Holland and Ludwig <40>

TABLE 3-16

STUDY AREA WATER USE

FROM SURFACE SOURCES

1980

CATEGORY	1980 SURFACE USE[1]/	% OF TOTAL USE
PUBLIC SUPPLY	14.39	87.9
RURAL DOMESTIC	0	0
SELF SUPPLIED INDUSTRY	7.98	84.5
AGRI. NON-IRRIGATION	6.05	67.4
AGRI. IRRIGATION	11.86	84.8
TOTAL	40.28	75.6

1/SOURCE: HOLLAND AND LUDWIG <40>

There were 41 public supply systems in the study area in 1985. <3> Surface water supplied 17 of the systems. The Cities of Hot Springs, Malvern, and Arkadelphia were the largest systems supplied. Combined maximum demand of the three systems is 22.5 MGD. <3> Assuming that the average daily use is about half the maximum demand, then the three systems use about 11 MGD or 76% of the study area surface use. Seven other systems buy water from the three cities. The Ouachita River supplies the larger systems. The Caddo River and Little Missouri River are also used as sources by other surface water systems. Streamflow in the basin generally is adequate to meet the public water supply demand.

Self supplied industries used 7.98 MGD of surface water in 1980. This represents 85% of the total self supplied industrial use of 9.44 MGD. There were seven registered diversions by industries in the 1980 diversion records. Two industries listing the Ouachita River as a source accounted for 59% of the reported diversions. Another 24% of the diversions came from Lake Catherine. Since 1980, the two industries using the Ouachita River have closed. Because of the closings, self supplied industrial use will be significantly lower until the plants are reopened.

Agricultural uses for non-irrigation purposes (livestock and fish farming) used 6.05 MGD from surface sources. Use was determined by using Statistical Reporting Service data and applying a use rate to each category. <40> A large portion of livestock use is assumed to be from farm ponds.

Surface water was diverted from streams in the basin for irrigating a part of the 20,400 acres of irrigated cropland. (See Table 2-4) Study area use from surface sources amounted to 11.86 MGD or 85% of total irrigation use. Irrigated cropland is located primarily in the floodplains of the Ouachita, Caddo, Antoine, and Little Missouri Rivers.

Water use for rural domestic needs was assumed to be zero for 1980. <40> There are diversion reports of household water use from Lake Greeson and Lake Hamilton, however, these uses are small enough to be insignificant compared to other water use amounts.

Excess Streamflow

Excess streamflow, defined in Section 5 of Act 1051 of 1985, is twenty-five percent of that amount of water available on an average annual basis above the amount required to satisfy the existing and projected water needs of the basin. The amount of water available on an average annual basis for the streams and rivers in the Upper Ouachita Basin is represented by the quantity of streamflow at the Ouachita River at Camden gaging station which is the outflow point for all water from the basin. Based on U.S. Geological Survey streamflow data at this gaging station, the surface-water yield from the basin is approximately 5.4 million acre-feet of water on an average annual basis.

To determine the excess streamflow in the basin, the surface-water yield of 5.4 million acre-feet must be adjusted to account for the water needed to satisfy existing water needs for instream flow requirements. Since the instream flow requirements are not additive, the highest instream need represents the amount of water required to satisfy all the existing instream needs. The instream flow requirements for fish and wildlife were previously identified in the Current Available Streamflow section of the report as the governing instream need for all streams investigated in the basin. Therefore, from Table 3-9, 4674 cfs or approximately 3.4 million acre-feet of water is necessary to maintain instream flow requirements on an average annual basis.

Projected surface-water needs of the basin must also be satisfied prior to the determination of water that is available for other uses. The surface-water needs in the Upper Ouachita Basin were projected to the year 2030 (Figure 1-9), resulting in an estimate of approximately 0.5 million acre-feet of water necessary for future surface-water needs. However, the projected increase of surface water use to the year 2030 takes into account the possible transfer of approximately 0.2 million acre-feet of water per year from DeGray Reservoir to Little Rock to supplement the municipal water supply. Since this represents an interbasin transfer of water and not water that is necessary for use within the basin, 0.2 million acre-feet was subtracted from the total projected use of 0.5 million acre-feet resulting in a projected surface-water need of 0.3 million acre-feet of water for use within the basin.

The available surface water in the Upper Ouachita Basin was calculated by subtracting the flow necessary to satisfy instream flow requirements (3.4 million acre-feet) and projected surface-water needs of the basin (0.3 million acre-feet) from the 5.4 million acre-feet of water in the basin resulting in 1.7 million acre-feet of available water. According to Act 1051 of 1985, twenty-five percent of the 1.7 million acre-feet of available water, or 425,000 acre-feet, is excess surface water in the Upper Ouachita Basin which is available on an average annual basis for other uses, such as interbasin transfer. The 425,000 acre-feet of excess surface water in the basin is approximately equal to one-half the amount of water stored in Lake Ouachita. However, due to streamflow variability in the basin, the majority of the excess surface water is available during the high-flow period of January through May.

Streamflow Water Quality

An inventory of the water quality for streams in the Upper Ouachita Basin has been developed from information furnished by the Arkansas Department of Pollution Control and Ecology (ADPC&E) and the U.S. Geological Survey (USGS). Water quality of streams in the basin is generally good. <6> Concentrations of most constituents are within expected ranges, and therefore, streams in the basin support most beneficial uses.

The streams in this basin are generally suitable for municipal, industrial, agricultural, and recreational uses as shown in Table 3-17. The Little Missouri River above Lake Greeson and the entire reach of the Caddo River have been designated as areas of extraordinary recreational and aesthetic value. The Little Missouri River immediately below Lake Greeson supports trout fisheries, and several streams in the basin support coolwater fisheries. <5>

Water Quality Summary

Water-quality data collection sites used for this report include five sites on the Ouachita River, two sites on the Little Missouri River, and one site on the Caddo River. Locations of the water-quality data collection sites are shown in Figure 3-10, and the station numbers and periods of record are listed in Table 3-18. A period of five years (1980-84) was used to inventory the water-quality data for all constituents except alkalinity.

Maximum, minimum, and median pH is shown for the selected sites in Figure 3-11. Median values ranged from 6.9 to 7.4. The highest median value occurred on the Caddo River near Amity. This site also had the largest variation in pH ranging from 3.2 to 8.2.

Statistical data for alkalinity are shown in Figure 3-12. Alkalinity may be defined as the capacity to react with and neutralize acid. The alkalinity in almost all natural waters is produced by the dissolved carbon dioxide species, bicarbonate and carbonate. Except for waters having a high pH (greater than about 9.5) and some other waters having unusual chemical characteristics, the alkalinity of natural waters can be assigned entirely to dissolved bicarbonate and carbonate without serious error. Most commonly, alkalinity is reported in terms of an equivalent amount of calcium carbonate. Low alkalinity indicates that the water is sensitive to acidification. <36>

Since analyses for alkalinity have not been made since 1980, a period of record of 1975-80 was selected for data evaluation. Median values for alkalinity were less than 25 mg/L at all sites inventoried except one (Caddo River near Amity) in which the median alkalinity was 36 mg/L. Median values on the Ouachita River ranged from 24 mg/L near Mount Ida to 16 mg/L at Camden. Median values of 16 mg/L and 18 mg/L occurred on the Little Missouri River near Langley and Boughton, respectively.

USE CLASSIFICATION OF SELECTED STREAMS

STREAM \ BENEFICIAL USES	WARMWATER FISHERIES	COOLWATER FISHERIES	TROUT FISHERIES	EXT. RECREATIONAL AND AESTHETIC VALUE	OUTSTANDING NATURAL RESOURCE WATER	PRIMARY CONTACT RECREATION	SECONDARY CONTACT RECREATION	PUBLIC WATER SUPPLY	INDUSTRIAL WATER SUPPLY	AGRICULTURAL WATER SUPPLY
OUACHITA RIVER (ABOVE LAKE OUACHITA)		●				●	●	●	●	●
IRONS FORK	●					●	●	●	●	●
MUDDY CREEK	●					●	●	●	●	●
NORTH FORK	●					●	●	●	●	●
BLAKLEY CREEK	●					●	●	●	●	●
TWIN CREEK	●					●	●	●	●	●
LAKE OUACHITA	●					●	●	●	●	●
GLAZYPEAU CREEK		●				●	●	●	●	●
HALLMANS CREEK	●					●	●	●	●	●
MAZARN CREEK		●				●	●	●	●	●
LITTLE MARZAN CREEK	●					●	●	●	●	●
LAKE HAMILTON	●					●	●	●	●	●
GULPHA CREEK	●					●	●	●	●	●
LAKE CATHERINE	●					●	●	●	●	●
OUACHITA RIVER (REMMEL DAM TO STATE LINE)										
COVE CREEK	●					●	●	●	●	●
PRAIRIE BAYOU	●					●	●	●	●	●
DEROCHE CREEK	●					●	●	●	●	●
L'EAU FRAIS	●					●	●	●	●	●
DECIPER CREEK	●					●	●	●	●	●
CYPRESS CREEK	●					●	●	●	●	●
FRENCH CREEK	●					●	●	●	●	●
TULIP CREEK	●					●	●	●	●	●
BAYOU FREEO	●					●	●	●	●	●

table 8-17

USE CLASSIFICATION OF SELECTED STREAMS (con't)

STREAM	WARMWATER FISHERIES	COOLWATER FISHERIES	TROUT FISHERIES	EXT. RECREATIONAL AND AESTHETIC VALUE	OUTSTANDING NATURAL RESOURCE WATER	PRIMARY CONTACT RECREATION	SECONDARY CONTACT RECREATION	PUBLIC WATER SUPPLY	INDUSTRIAL WATER SUPPLY	AGRICULTURAL WATER SUPPLY
CADDO RIVER (ABOVE DEGRAY)		●		●		●	●	●	●	●
SOUTH FORK CADDO RIVER		●		●		●	●	●	●	●
DEGRAY LAKE	●			●		●	●	●	●	●
CADDO RIVER (DEGRAY DAM TO MOUTH)										
LITTLE MISSOURI RIVER (ABOVE LAKE GREESON)		●		●		●	●	●	●	●
HURRICANE CREEK	●					●	●	●	●	●
LAKE GREESON	●					●	●	●	●	●
LITTLE MISSOURI RIVER (GREESON DAM TO MUDDY FORK)			●			●	●	●	●	●
MUDDY FORK	●					●	●	●	●	●
LITTLE MISSOURI RIVER (MUDDY FORK TO MOUTH)	●					●	●	●	●	●
PRAIRIE CREEK	●					●	●	●	●	●
VAUGHN CREEK	●					●	●	●	●	●
SALINE CREEK	●					●	●	●	●	●
HICKORY CREEK	●					●	●	●	●	●
OZAN CREEK	●					●	●	●	●	●
ANTOINE RIVER	●					●	●	●	●	●
TERRE ROUGE CREEK	●					●	●	●	●	●
CANEY CREEK	●					●	●	●	●	●
WHITE OAK CREEK	●					●	●	●	●	●
TERRE NOIR CREEK	●					●	●	●	●	●

SOURCE: Arkansas Department of Pollution Control and Ecology. ⟨5⟩

table 3-17

figure 3- 10

WATER-QUALITY DATA COLLECTION SITES

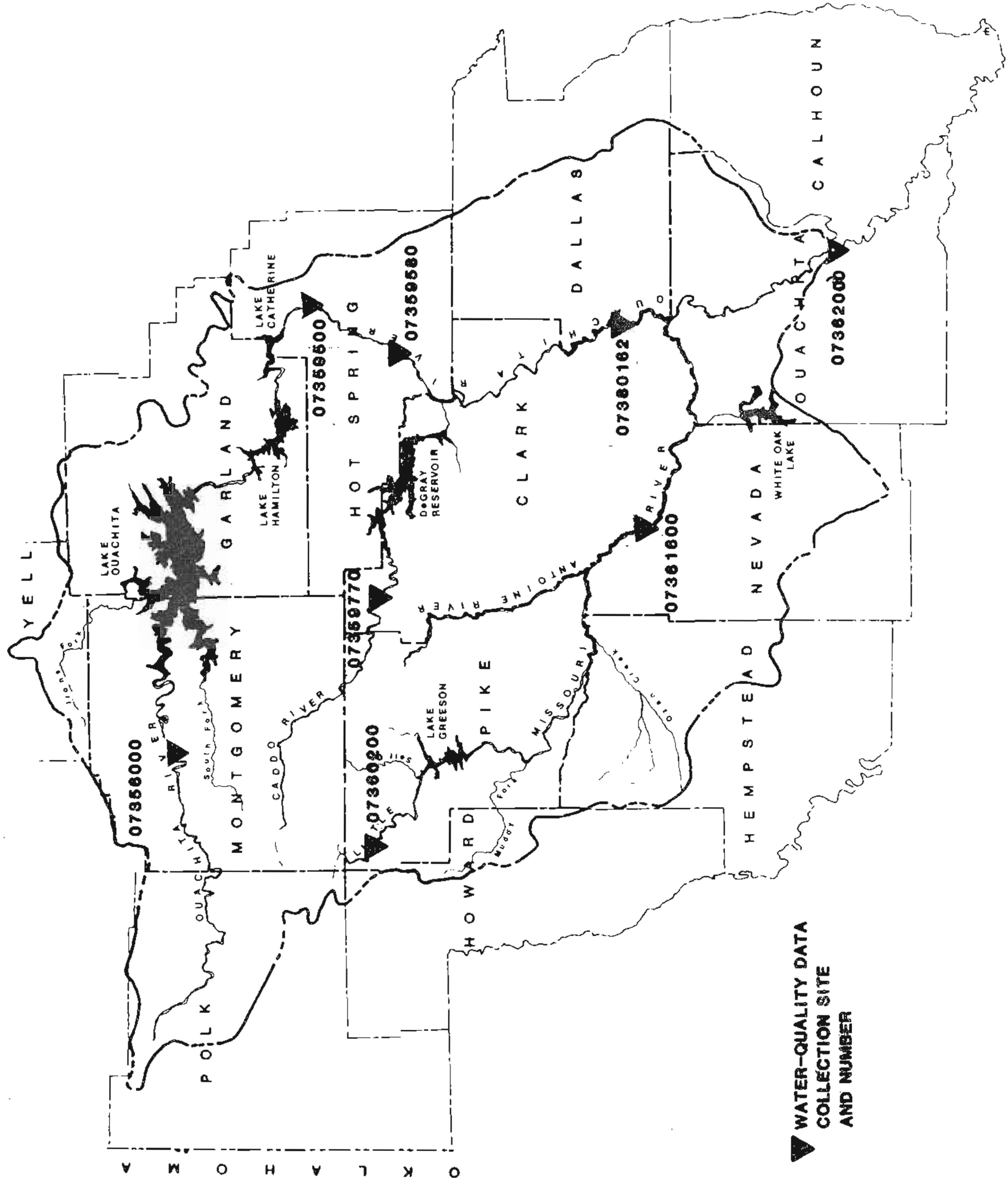


TABLE 3-18
SUMMARY OF SELECTED WATER-QUALITY DATA COLLECTION SITES IN THE UPPER OUACHITA BASIN

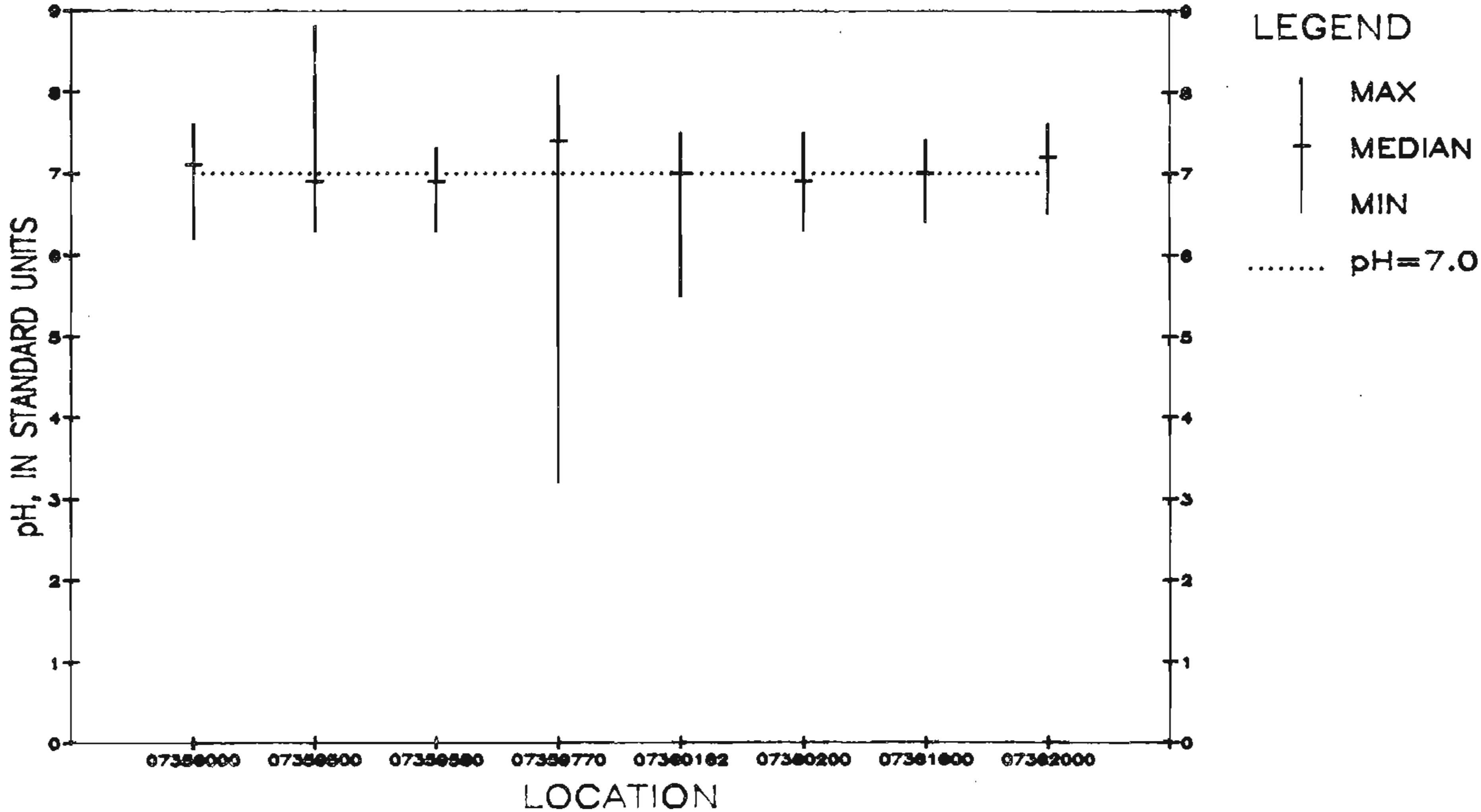
LOCATION	USGS STATION NUMBER	ADPC&E STATION NUMBER	PERIOD OF RECORD
OUACHITA RIVER NR. MOUNT IDA	07356000	OUA21	1950-52;APR 1974-84 1/
OUACHITA RIVER NR. MALVERN	07359500	OUA06	1947-50;1971-84 3/
OUACHITA RIVER NR. DONALDSON	07359580	OUA30	APR 1974-84 1/
CADDO RIVER NR. AMITY	07359770	OUA23	APR 1972-84 1,2/
OUACHITA RIVER NR. SPARKMAN	07360162	OUA29	APR 1974-83 1/
LITTLE MISSOURI RIVER NR. LANGLEY	07360200	OUA22	APR 1974-84 1/
LITTLE MISSOURI RIVER NR. BOUGHTON	07361600	OUA35	1948-55;1973-84 1/
OUACHITA RIVER AT CAMDEN	07362000	--	1947-52;1975-84 3/

1/ RECORDS FURNISHED BY ARKANSAS DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY
2/ RECORDS FURNISHED BY CORPS OF ENGINEERS
3/ RECORDS FURNISHED BY USGS

FIGURE 3-11

MAXIMUM, MINIMUM, AND MEDIAN PH AT SELECTED SITES

PERIOD OF RECORD: 1980-84

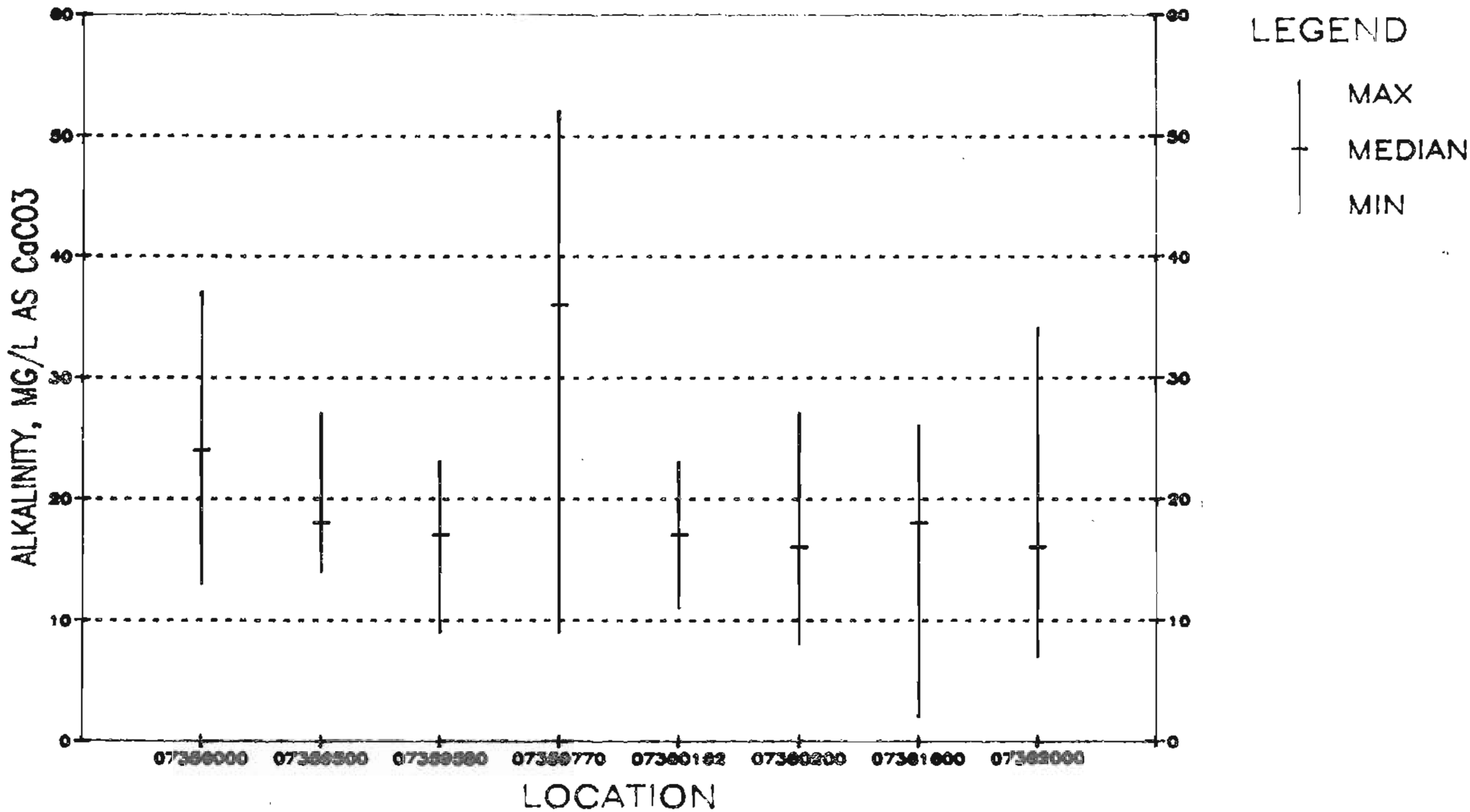


SOURCE: U.S. GEOLOGICAL SURVEY FILE DATA

FIGURE 3-12

MAXIMUM, MINIMUM, AND MEDIAN ALKALINITY CONCENTRATIONS

PERIOD OF RECORD: 1975-80



SOURCE: U.S. GEOLOGICAL SURVEY FILE DATA

Variations in turbidity at the selected sites are shown in Figure 3-13. Median values on the Ouachita River ranged from 3.4 NTU near Malvern to 12 NTU at Camden. Median values for turbidity on the Little Missouri River were 2.0 NTU near Langley and 20 NTU near Boughton. The Ouachita River and the Little Missouri River appear to be increasing in turbidity from upstream to downstream reaches.

Figures 3-14, 3-15, and 3-16 show statistical data for concentrations of nitrogen, chloride, and dissolved solids, respectively. The lowest median concentrations and the smallest range between the maximum and minimum values for these constituents occurred on the Little Missouri River near Langley. Water-quality data for other constituents are shown in Table 3-19 for the Ouachita River and Table 3-20 for the Little Missouri River and the Caddo River.

Expected Ranges in Water Quality

ADPC&E has summarized data from least-disturbed watersheds of various sizes to develop expected ranges of water quality parameters for various regions of the state. The major streams in this basin originate in the Ouachita Mountains; therefore, data from the uppermost monitoring station on each of the major streams were used for comparison with the expected ranges developed by ADPC&E for the Ouachita Region.

A comparison of water-quality data for the Little Missouri River near Langley, Caddo River near Amity, and Ouachita River near Mount Ida to expected ranges for the Ouachita Mountain region is shown in Table 3-21. Median concentrations for most constituents were within expected ranges, however, median alkalinity concentrations were less than expected on the Little Missouri River and the Ouachita River.

Concentrations of zinc routinely exceeded ADPC&E guidelines for heavy metals. <6> The guidelines ADPC&E has developed for heavy metals are based on a toxicity review. Guidelines developed represent instream concentration limits based upon the protection of either the most sensitive aquatic species or human health <6>; therefore, ADPC&E guidelines for a given constituent are at least as stringent as the drinking-water regulations (human health).

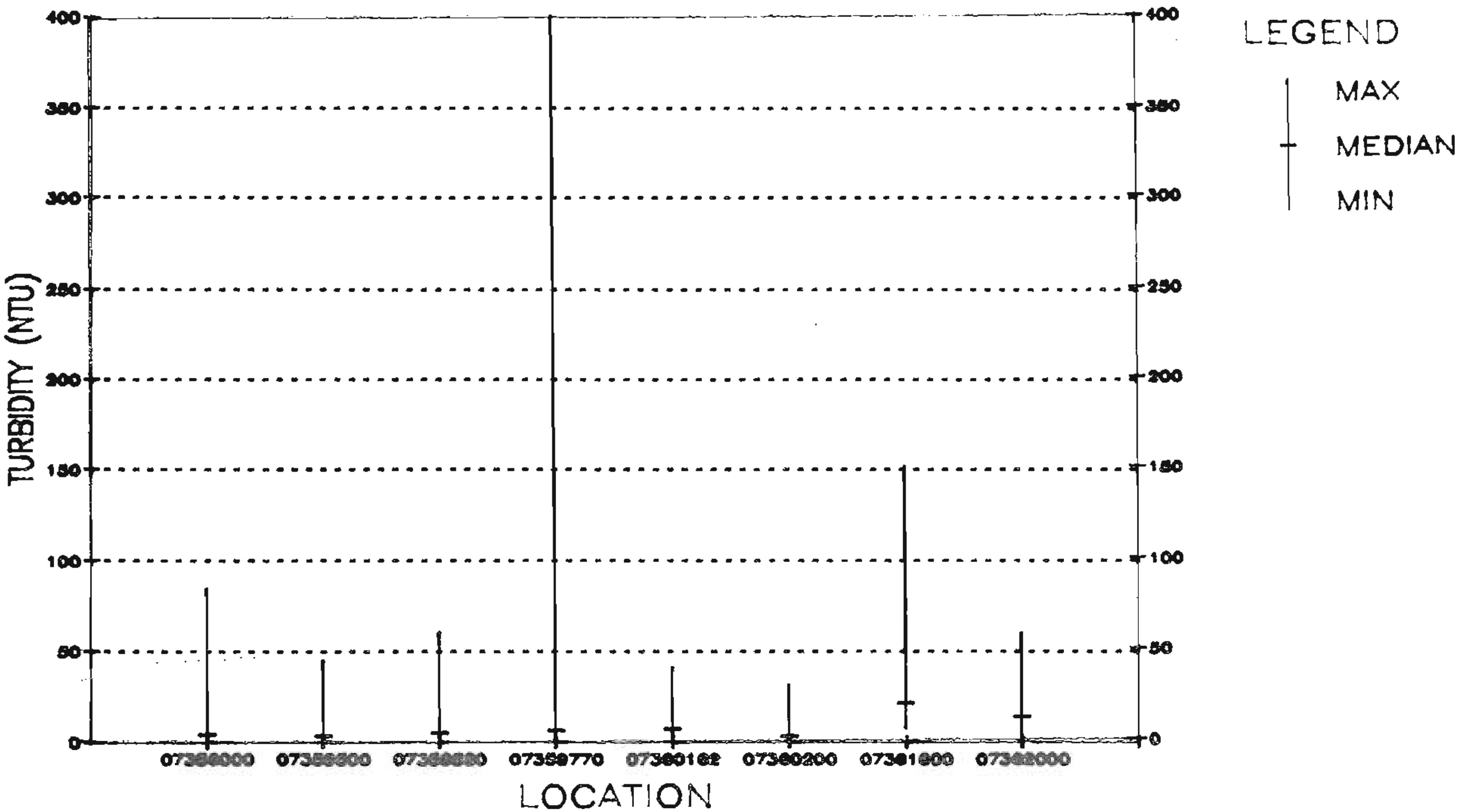
Comparison to Drinking-Water Regulations

Several of the large cities in the basin including Hot Springs, Arkadelphia, Malvern, and Camden use surface water for public supply (See Water Use). Therefore, median concentrations for constituents at the eight water-quality monitoring stations were compared to the drinking-water

FIGURE 3-13

MAXIMUM, MINIMUM, AND MEDIAN TURBIDITY AT SELECTED SITES

PERIOD OF RECORD: 1980-84

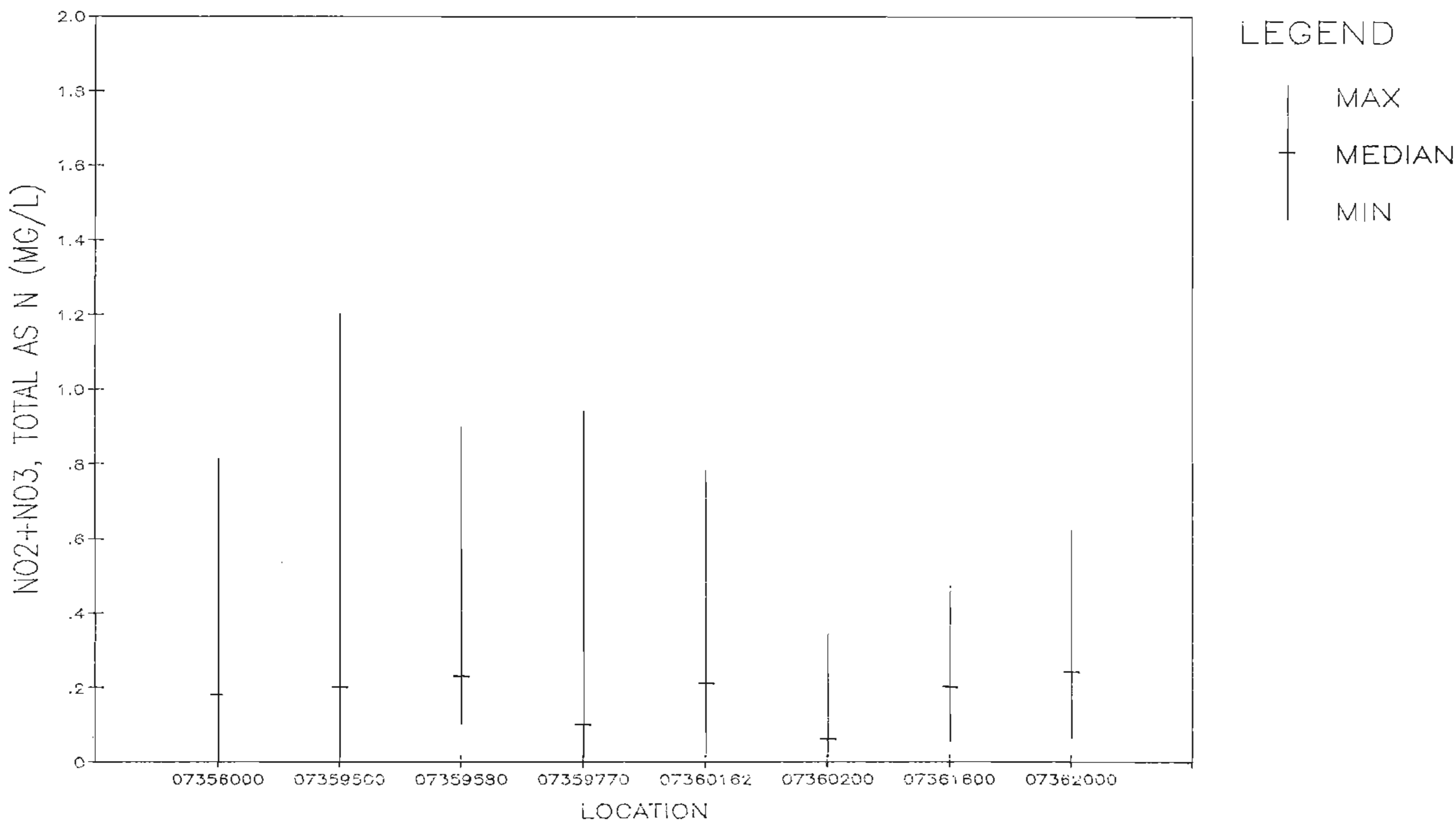


SOURCE: U.S. GEOLOGICAL SURVEY FILE DATA

figure 3-14

MAXIMUM, MINIMUM AND MEDIAN NITROGEN (NO2+NO3) CONCENTRATIONS

PERIOD OF RECORD - 1980-1984

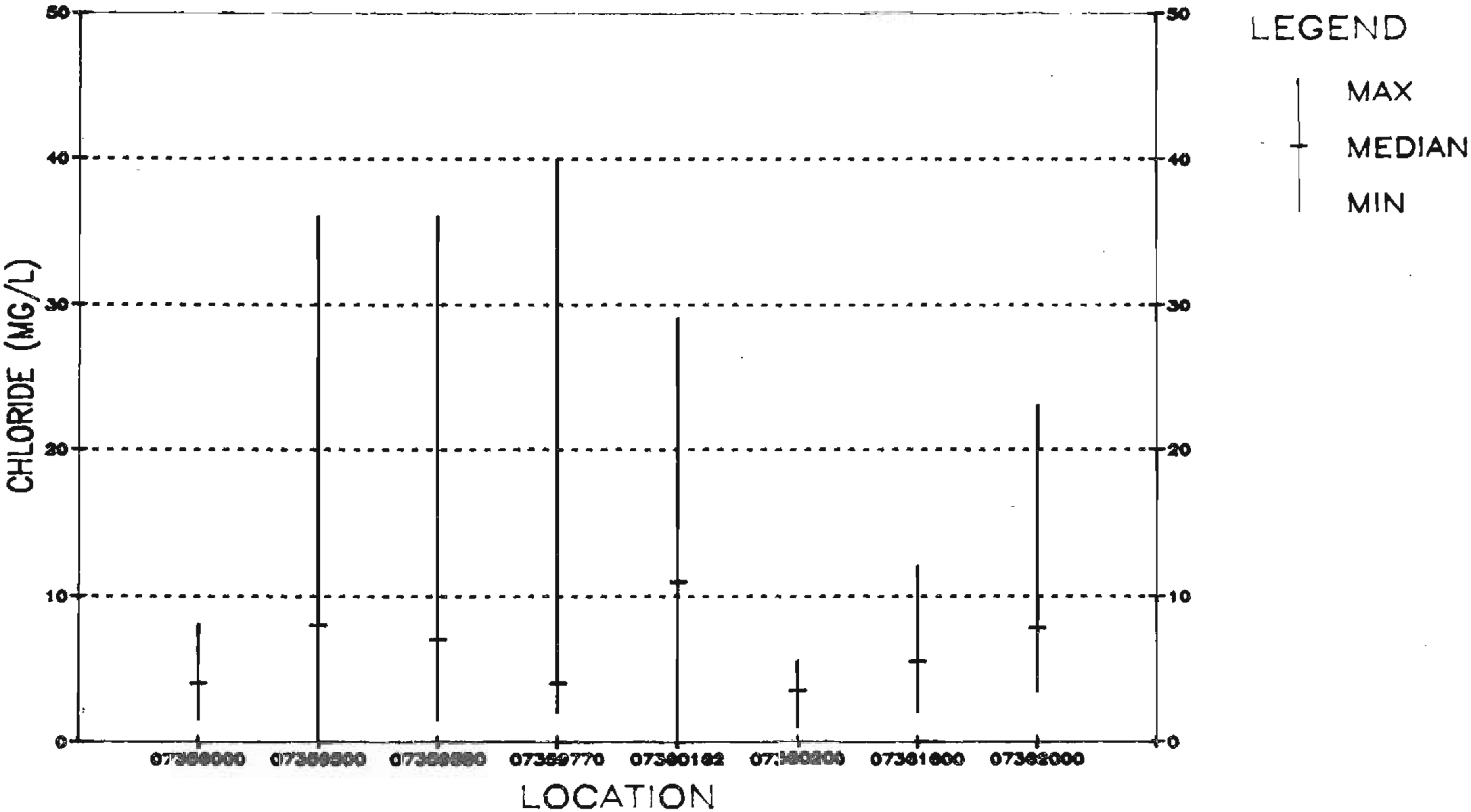


SOURCE: U.S. GEOLOGICAL SURVEY FILE DATA

FIGURE 3-15

MAXIMUM, MINIMUM, AND MEDIAN CHLORIDE CONCENTRATIONS

PERIOD OF RECORD: 1980-84

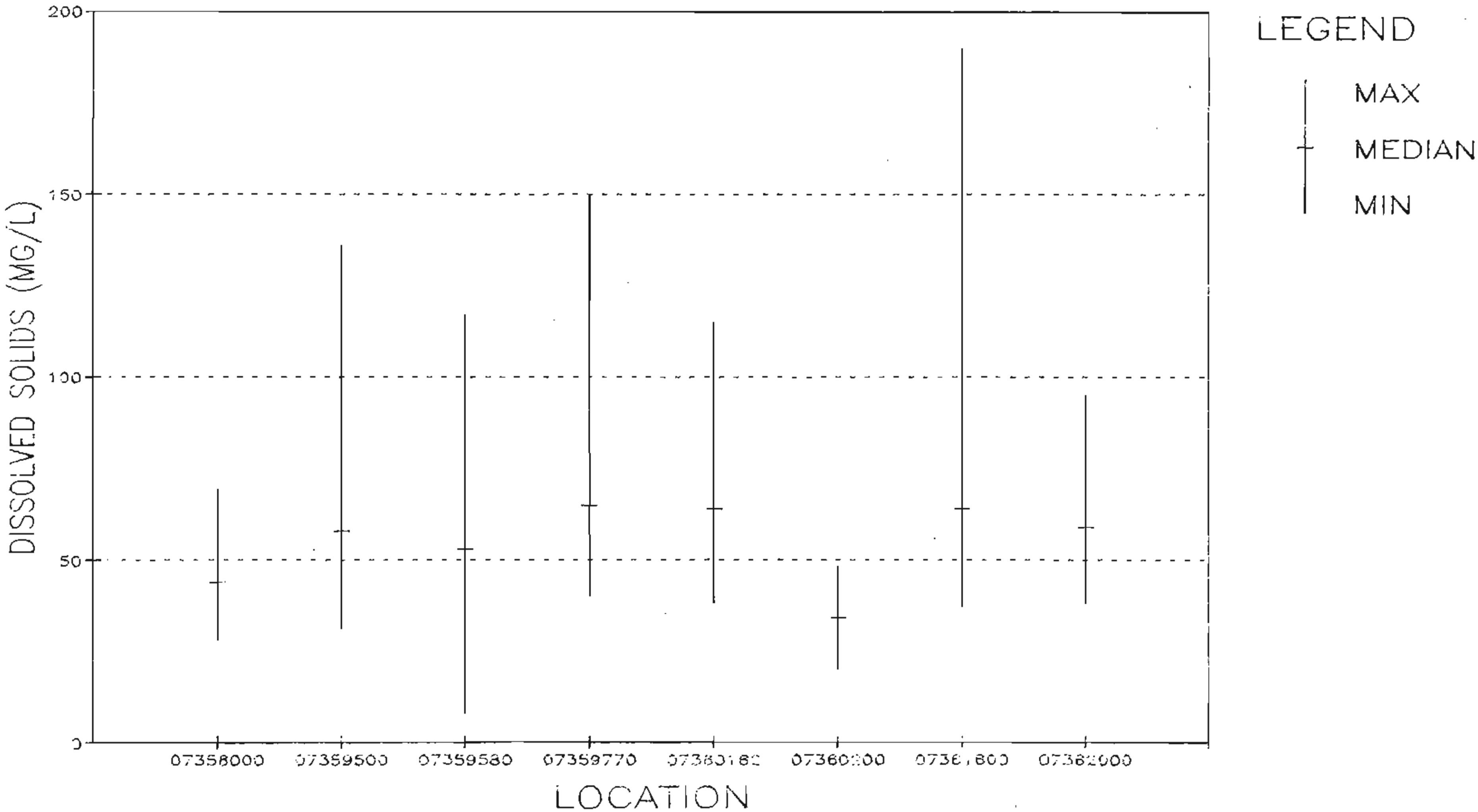


SOURCE: U.S. GEOLOGICAL SURVEY FILE DATA

FIGURE 3–16

MAXIMUM, MINIMUM, AND MEDIAN DISSOLVED SOLIDS CONCENTRATIONS

PERIOD OF RECORD: 1980–84



SOURCE: U.S. GEOLOGICAL SURVEY FILE DATA

TABLE 3-19
WATER QUALITY DATA AT SELECTED SITES ON THE OUACHITA RIVER
PERIOD OF RECORD: 1980-84

PARAMETER	07356000 - NR. MOUNT IDA			07359500 - NR. MALVERN			07359580 - NR. DONALDSON			07360162 - NR. SPARKMAN			07362000 - AT CAMDEN		
	NUMBER OF SAMPLES	RANGE	MEDIAN	NUMBER OF SAMPLES	RANGE	MEDIAN	NUMBER OF SAMPLES	RANGE	MEDIAN	NUMBER OF SAMPLES	RANGE	MEDIAN	NUMBER OF SAMPLES	RANGE	MEDIAN
SPECIFIC CONDUCTANCE, UMHOS	22	37-134	58	21	71-408	112	11	74-201	112	9	47-311	108	39	59-174	93
TEMPERATURE, DEG. C	47	0.0-30.0	17.0	56	4.0-31.0	16.5	53	4.0-31.0	18.0	47	7.0-30.0	20.0	47	1.0-30.0	18.0
DISSOLVED OXYGEN, mg/L	47	6.5-14.1	9.4	56	4.8-13.6	9.6	54	5.8-12.9	8.8	46	4.4-11.6	8.8	38	5.7-12.7	8.6
BOD, mg/L	43	0.4-4.0	1.4	51	0.3-11	2.8	49	0.6-6.9	2.5	44	0.5-4.8	1.3	(-)	(-)	(-)
SULFATE, mg/L	45	<1.0-10	4.0	54	<1.0-41	8.0	52	<1.0-36	7.0	39	1.0-26	7.0	39	<5.0-18	9.4
FECAL COLIFORM/100 ml	42	<10-1400	40	55	<10-1100	16	54	<4-1000	28	46	<13->600	24	38	<3-940	22
HARDNESS, mg/L	31	4-40	22	32	12-69	31	30	16-71	29	31	18-61	28	38	19-35	23
SUSPENDED SOLIDS, mg/L	46	<1-64	4	55	<1-32	5	44	<1-17	6	43	1-46	13	(-)	(-)	(-)
NITROGEN, TOTAL AS N, mg/L	16	0.19-2.1	0.72	20	0.33-2.7	0.92	49	0.10-0.90	0.23	45	0.02-0.77	0.21	25	0.06-0.62	0.24
NITROGEN, AMMONIA, TOTAL AS N, mg/L	45	<0.01-0.09	0.030	56	0.000-1.4	0.060	53	<0.010-2.00	0.050	43	0.010-0.370	0.050	12	0.000-0.13	0.060
PHOSPHORUS, TOTAL AS P, mg/L	42	<0.01-0.18	0.030	53	<0.010-0.400	0.040	51	0.010-0.200	0.040	43	<0.01-0.16	0.040	39	0.010-0.10	0.050
ARSENIC, TOTAL, ug/L	26	<5-16	<5	30	<5-15	<5	22	<5-7	<5	26	<5-13	<5	12	0-1	1
CADMIUM, TOTAL, ug/L	45	<2-4	<2	55	<10-59	<10	45	<10-<10	<10	36	<10-<10	<10	13	<1-6	1
CHROMIUM, TOTAL, ug/L	47	<1-37	1	49	<1-58	2	45	<5-11	<5	35	<5-9	<5	13	0-30	10
COPPER, TOTAL, ug/L	46	<10-19	<10	56	<20-<20	<20	46	<20-27	<20	38	<20-37	<20	13	2-17	6
LEAD, TOTAL, ug/L	23	<1-11	<1	29	<10-<10	<10	24	<10-<10	<10	14	<10-30	<10	13	1-15	5
ZINC, TOTAL, ug/L	40	<6-150	6	49	<10-300	70	41	<10-430	44	34	<3-80	21	12	0-70	20
SELENIUM, TOTAL, ug/L	25	<10-<10	<10	27	<10-19	<10	20	<10-<10	<10	23	<10-<10	<10	13	<1-1	<1
IRON, TOTAL, ug/L	(-)	(-)	(-)	11	40-330	160	(-)	(-)	(-)	(-)	(-)	(-)	13	450-1800	940
MANGANESE, TOTAL, ug/L	(-)	(-)	(-)	11	27-160	77	(-)	(-)	(-)	(-)	(-)	(-)	13	50-250	100

SOURCE: US GEOLOGICAL SURVEY (101)

TABLE 3-20
WATER QUALITY DATA AT SELECTED SITES
PERIOD OF RECORD: 1980-84

PARAMETER	07359770 - CADDO RIVER NR. AMITY			07360200 - L. MISSOURI RIVER NR. LANGLEY			07361600 - L. MISSOURI RIVER NR. BOUGHTON		
	NUMBER OF SAMPLES	RANGE	MEDIAN	NUMBER OF SAMPLES	RANGE	MEDIAN	NUMBER OF SAMPLES	RANGE	MEDIAN
SPECIFIC CONDUCTANCE, UMHOS	11	63-127	107	(-)	(-)	(-)	10	55-261	88
TEMPERATURE, DEG. C	57	3.0-37.0	19.0	34	2.0-30.0	17.0	60	2.0-28.0	15.5
DISSOLVED OXYGEN, mg/L	57	7.6-14.1	9.8	34	6.8-14.3	10.0	55	6.6-12.9	9.1
BOD, mg/L	50	0.6-73	2.0	32	0.3-2.8	0.9	54	0.5-4.1	1.4
SULFATE, mg/L	55	<1.0-14	6.0	34	<1.0-6.0	3.0	56	<1.0-30	8.0
FECAL COLIFORM/100 ml	56	10-2900	20	34	<10-230	32	58	<4-1400	60
HARDNESS, mg/L	32	3-69	37	17	4-40	14	32	16-54	31
SUSPENDED SOLIDS, mg/L	57	<1-506	5	35	<1-26	2	59	2-154	12
NITROGEN, TOTAL AS N, mg/L	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
NITROGEN, AMMONIA, TOTAL AS N, mg/L	55	<0.01-0.28	0.040	33	<0.01-0.14	0.020	56	0.01-0.28	0.060
PHOSPHORUS, TOTAL AS P, mg/L	53	<0.01-0.32	0.030	31	<0.01-0.06	0.010	52	0.01-1.90	0.050
ARSENIC, TOTAL, ug/L	24	<5-14	<5	11	<5-7	<5	26	<5-11	<5
CADMIUM, TOTAL , ug/L	49	<10-<10	<10	33	<2-<2	<2	51	<10-<10	<10
CHROMIUM, TOTAL, ug/L	49	<5-19	<5	35	<1-23	<1	48	<5-15	<5
COPPER, TOTAL, ug/L	50	<20-91	<20	34	<10-26	<10	40	<20-50	21
LEAD, TOTAL, ug/L	28	<10-<10	<10	24	<1-7	<1	19	<10-56	31
ZINC, TOTAL, ug/L	44	<10-710	48	29	<6-50	<6	41	<10-200	66
SELENIUM, TOTAL, ug/L	22	<10-14	<10	11	<10-<10	<10	23	<10-<10	<10

SOURCE: U.S. GEOLOGICAL SURVEY <101>

TABLE 3-21

COMPARISON OF WATER QUALITY PARAMETERS AT SELECTED LOCATIONS
TO EXPECTED RANGES FOR THE OUACHITA MOUNTAIN REGION

	EXPECTED RANGE [1]		MEDIAN VALUES [2]		
CONSTITUENT	LOW-FLOW CONDITIONS	SPRING CONDITIONS	07360200 LITTLE MISSOURI R. NR. LANGLEY	07359770 CADDO R. NR. AMITY	07356000 OUACHITA R. NR. MOUNT IDA
pH	6.5-7.5	HIGHER FLOW IS SLIGHTLY MORE ACIDIC	6.9	7.4	7.1
TURBIDITY, NTU	3.0	NO CHANGE	2.0	5.8	4.6
TSS, mg/L	3.0	NO CHANGE	2.0	5.0	4.0
TDS, mg/L	55	SLIGHTLY LESS	34	65.0	44
BOD, mg/L	<1.0	NO CHANGE	0.9	4.0	1.4
T. PHOS., mg/L	<0.5	NO CHANGE	0.01	0.03	0.03
NH_3, mg/L	<0.05	NO CHANGE	0.02	0.04	0.03
Cl, mg/L	<5.0	NO CHANGE	3.5	4.0	4.0
SO_4, mg/L	<10.0	SLIGHTLY HIGHER	3.0	6.0	4.0
COND., umho	100	LOWER	(-)	107	58
ALKA., mg/L	40	LOWER	16 [3]	36 [3]	24 [3]
T. HARD., mg/L	35	LOWER	14	37	22
F. COLI./100ml	<100	LOWER	32	20	40

PARAMETER	ADPC&E GUIDELINES FOR HEAVY METALS	MEDIAN VALUES		
ARSENIC, ug/L	50	<5	<5	<5
CADMIUM, ug/L	0.4	<2	<10	<2
CHROMIUM,ug/L	50	<1	<5	1
COPPER, ug/L	5	<10	<20	<10
LEAD, ug/L	10	<1	<10	<1
SELENIUM, ug/L	10	<10	<10	<10
ZINC, ug/L	6.5	<6	48	6

[1]/ EXPECTED RANGES REPRESENT A SUMMARY OF DATA COMPILED BY ADPC&E FROM LEAST DISTURBED WATERSHEDS.

[2]/ THESE VALUES REPRESENT MEDIAN CONCENTRATIONS FROM SELECTED SITES IN THE OUACHITA MOUNTAIN REGION. SAMPLES WERE COLLECTED FROM 1980 THROUGH 1984 UNLESS OTHERWISE NOTED.

[3]/ PERIOD OF RECORD: LANGLEY 1975-79, AMITY 1975-80, MOUNT IDA 1975-79.

regulations in Table 3-22. Turbidity and fecal coliform bacteria were the only constituents in which the primary regulations were exceeded. Median values for fecal coliform bacteria from all sites exceeded the 1 colony/100 ml limit. The Caddo River near Amity, the lower reaches of the Ouachita River, and both sites on the Little Missouri River exceeded maximum limits for turbidity.

Secondary regulations which were exceeded by median values at the selected sites include iron and manganese. Data for these two constituents were only available at two sites, Ouachita River near Malvern and Ouachita River at Camden. Median values for manganese exceeded the maximum recommended level at both sites, and median values for iron exceeded the maximum recommended level at Camden.

Pesticides

Water-quality samples collected by USGS and ADPC&E at several streamflow sites in the Upper Ouachita Basin during the period of 1975-84 have been analyzed for the presence of pesticides. Concentrations of pesticides in water samples were all below the detection limits for the following seven sites in the Basin: Ouachita River near Mount Ida, Ouachita River near Malvern, Ouachita River near Donaldson, Caddo River near Amity, Ouachita River near Sparkman, Little Missouri River near Langley, and Little Missouri River near Boughton.

Surface-water samples and bottom material samples collected during the period of 1976-82 at Ouachita River at Camden were also analyzed for the presence of pesticides. Pesticide concentrations were below detection limits in the water samples, however, four bottom material samples contained concentrations of some pesticides which were slightly above the detection limits.

TABLE 3-22
COMPARISON OF WATER QUALITY PARAMETERS AT SELECTED SITES
TO NATIONAL DRINKING-WATER REGULATIONS

CONSTITUENT [1]	MAXIMUM CONCENTRATION	MEDIAN VALUES [3] 07356000 OUACHITA R. NR. MT. IDA	07359500 OUACHITA R. NR. MALVERN	07359580 OUACHITA R. NR. DONALDSON	07359770 CADDO R. NR. AMITY	07360162 OUACHITA R. NR. SPARKMAN	07360200 L. MISSOURI R. NR. LANGLEY	07361600 L. MISSOURI R. NR. BOUGHTON	07362000 OUACHITA R. AT CAMDEN
PRIMARY REGULATIONS									
ARSENIC	0.050	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.001
CADMIUM	0.010	<0.002	<0.010	<0.010	<0.010	<0.010	<0.002	<0.010	0.001
CHROMIUM	0.050	0.001	0.002	<0.005	<0.005	<0.005	<0.001	<0.005	<0.010
LEAD	0.050	<0.001	<0.010	<0.010	<0.010	<0.010	<0.001	0.031	0.005
SELENIUM	0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.001
TURBIDITY, NTU	1-5	4.6	3.4	4.8	5.8	6.7	2.0	20	12
FECAL COLIFORM, COLONIES/100 ml	1	40	16	28	20	24	32	60	22
SECONDARY REGULATIONS [2]									
CHLORIDE	250	4.0	8.0	7.0	4.0	11	59	5.5	7.8
COPPER	1.0	<0.01	<0.020	<0.020	<0.020	<0.020	<0.010	0.021	0.006
DISSOLVED SOLIDS	500	44	58	53	65	64	34	64	59
IRON	0.3	(-)	0.160	(-)	(-)	(-)	(-)	(-)	0.940
MANGANESE	0.05	(-)	0.077	(-)	(-)	(-)	(-)	(-)	0.100
pH, UNITS	6.5-8.5	7.1	6.9	6.9	7.4	7.0	6.9	7.0	7.2
SULFATE	250	4.0	8.0	7.0	6.0	7.0	3.0	8.0	9.4
ZINC	5.0	0.006	0.070	0.044	0.048	0.021	<0.006	0.066	0.020

SOURCES: U.S. ENVIRONMENTAL PROTECTION AGENCY (97), US GEOLOGICAL SURVEY (101)

1/ DATA IN mg/L UNLESS OTHERWISE NOTED

2/ SECONDARY REGULATIONS ARE RECOMMENDED IN ARKANSAS AND ARE NOT ENFORCED.

3/ PERIOD OF RECORD: 1980-84

Impoundments

There is a large volume of water in this basin that is stored in impoundments. An inventory of the lakes of Arkansas <12> was conducted by this agency as part of the revision of the 1975 State Water Plan. There are approximately 7400 lakes within the seven county study area as shown in Table 3-23, yet most of the water is impounded by three Corps of Engineers' reservoirs. Lakes Ouachita, DeGray, and Greeson have capacities of 865,000 acre-feet, 261,500 acre-feet, and 77,600 acre-feet, respectively at the permanent pool elevation. The total capacity of these three reservoirs (1,204,100 acre-feet) is more than 80 percent of the total amount of water impounded in the seven-county study area (See Table 3-24). <12>

Impoundment Water Use

Reported withdrawals from impoundments in 1980 were approximately 2600 acre-feet. This represents about 7 percent of the total 39,000 acre-feet of surface water use that was reported in 1980 (See Water Use Section). Most of the impoundment withdrawals were for industrial usage.

Major Impoundments

The major impoundments in the basin are Lake Ouachita, DeGray Lake, Lake Greeson, Lake Hamilton, Lake Catherine, and White Oak Lake as shown in Figure 3-1. The three Corps of Engineers impoundments (Ouachita, DeGray, and Greeson) are operated for a variety of purposes including flood control, power generation, recreation, conservation, and water supply. Lakes Hamilton and Catherine are privately owned and are operated for power generation and recreation. White Oak Lake is an Arkansas Game and Fish Commission Lake that is operated for recreation. Each lake is discussed individually in the following sections.

Lake Ouachita: Blakely Mountain Dam, located ten miles northwest of Hot Springs, controls more than 1,100 square miles of the Ouachita River drainage area to form Lake Ouachita. The 1,100-foot long earthfill structure stands 235 feet above the streambed, with the upstream and downstream slopes protected by riprap. The lake is operated for flood control, hydroelectric power, headwater benefits, fish and wildlife conservation, and recreational purposes. Blakely Dam was placed in operation for flood control in 1953 and power production began in August, 1955. <71>

Lake Ouachita has a storage capacity of nearly 2.77 million acre-feet of water which includes 617,000 acre-feet for flood control, 1.28 million acre-feet for power

TABLE 3-23

COUNTY SUMMARY OF LAKES IN THE STUDY AREA 1/

COUNTY	LAKES OVER 5 ACRES			LAKES UNDER 5 ACRES 2/			TOTAL		
	NUMBER	AREA (ACRES)	CAPACITY (AC-FT)	NUMBER	AREA (ACRES)	CAPACITY (AC-FT)	NUMBER	AREA (ACRES)	CAPACITY (AC-FT)
CLARK	11	239	1,842	1,307	758	2,652	1,318	997	4,494
DALLAS	11	96	841	634	322	1,452	645	418	2,293
GARLAND	12	6,671	201,343	1,430	400	532	1,442	7,071	201,875
HOT SPRING	6	2,193	36,113	947	284	994	953	2,477	37,107
MONTGOMERY	6	47	825	430	1,280	837	436	1,327	1,662
NEVADA	31	359	2,210	1,500	524	2,553	1,531	883	4,763
PIKE	10	84	468	1,050	368	1,050	1,060	452	1,518
TOTAL	87	9,689	243,642	7,298	3,936	10,070	7,385	13,625	253,712

1/ DOES NOT INCLUDE CORPS OF ENGINEERS RESERVOIRS OR ARKANSAS GAME AND FISH COMMISSION LAKES
2/ DATA ESTIMATED

SOURCE: ARKANSAS SOIL AND WATER CONSERVATION COMMISSION <12>

TABLE 3-24

SUMMARY OF LAKES

IN THE UPPER OUACHITA BASIN

OWNER/OPERATOR	NUMBER	SURFACE AREA (ACRES)	CAPACITY (AC.-FT.)
U.S. CORPS OF ENGINEERS RESERVOIRS	3	29,800[1]	1,204,100[1]
AR GAME AND FISH COMMISSION LAKES	2	2,700	21,400
ALL OTHERS:[2]			
OVER 5 ACRES	87	9,700	243,600
UNDER 5 ACRES[3]	7,298	3,900	10,100
TOTAL	7,390	46,100	1,479,200

[1]CONSERVATION POOL
[2]DATA OBTAINED FROM STUDY AREA TOTALS ON TABLE 3-23
[3]DATA ESTIMATED

SOURCE: ARKANSAS SOIL AND WATER CONSERVATION COMMISSION <12>

generation, and 865,000 acre-feet for a minimum permanent pool. (See Figure 3-17) The minimum permanent pool covers a surface area of 20,900 acres at elevation 535 mean sea level (msl). <71, 73>

The power storage capacity consists of 1.28 million acre-feet of water between elevation 535 and 578 feet msl. Theoretically, the pool would be drawn down to elevation 535 feet msl during the most critical flow period of record; however, the pool normally fluctuates between 578 and 565 feet msl. Two power generators have a capacity of 75,000 kilowatts and an average yearly output of 156 million Kilowatt-hours. Hydroelectric power which is surplus to the needs of the project is marketed by Southwestern Power Administration <71, 73>.

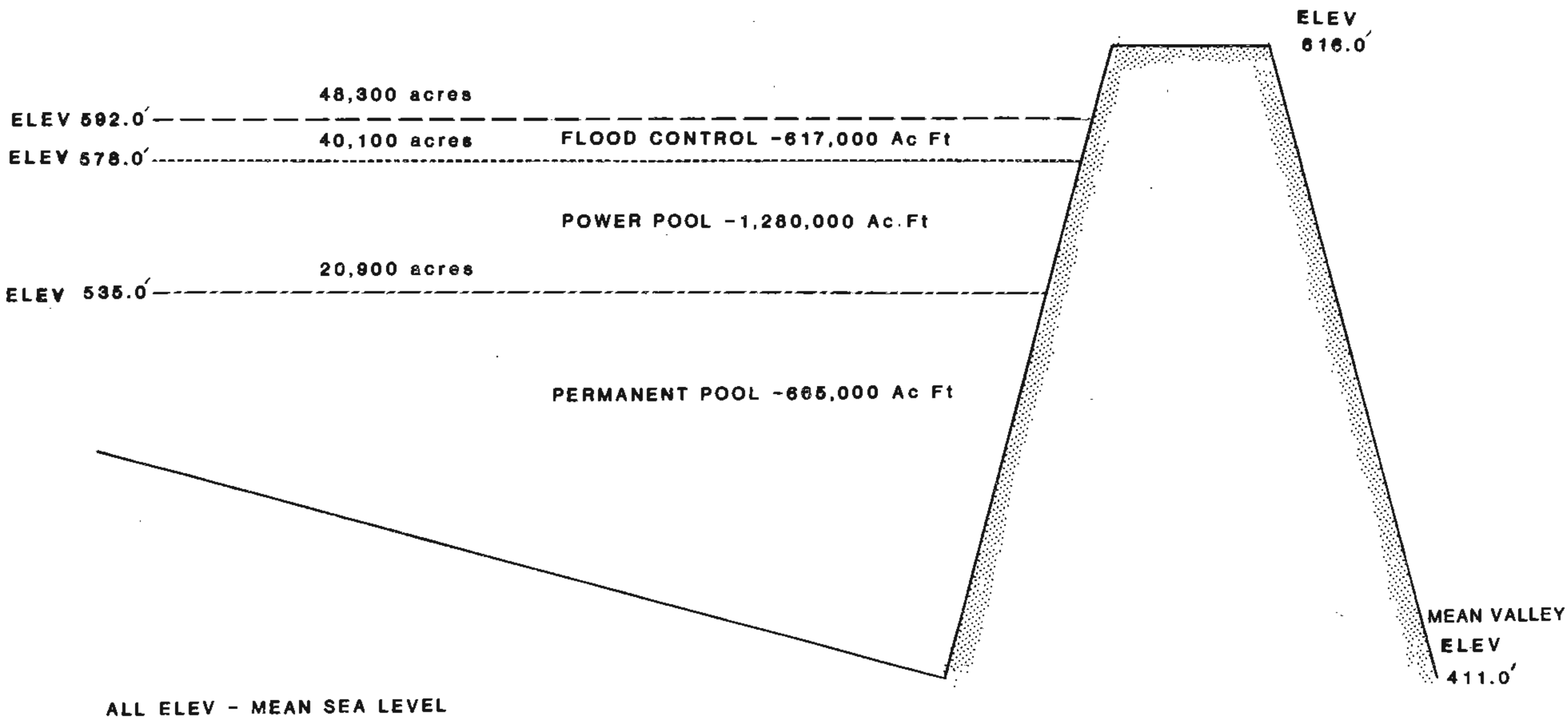
Flood control storage consists of 617,000 acre-feet of water between elevations 578 and 592 feet msl. This volume is equivalent to 10.5 inches of runoff from the drainage area above the dam. The flood control storage capacity was designed to control the dual-peak flood of 1927, assuming the power pool to be full. In actual practice, the power pool is usually down to about 565 feet msl at the beginning of the flood season. The estimated frequency of the lake level reaching 592 feet msl, the maximum pool elevation, is once in 200 years. The maximum pool elevation that has occurred since the dam has been in operation was 590.1 feet msl which occurred December 6, 1982 and was within 2 feet of the emergency spillway crest. At spillway crest elevation (592 feet msl), the lake extends up the valley for 39 miles covering a surface area of 48,300 acres with a 975 mile shore line. Operation of Blakely Mountain Dam for flood control has resulted in $13.6 million in estimated flood damage prevention through September, 1979. Downstream floods are reduced on an average of about four feet at Arkadelphia and three feet at Camden for three to six floods per year. <71, 73, 74>

Above the lake's storage capacity of 2.77 million acre-feet, a surcharge storage capacity of 993,000 acre-feet of water has been installed between elevations 592 and 610.2 feet msl to control a maximum probable storm of 19.7 inches of runoff assuming the flood control pool to be full. The emergency spillway is located in a natural saddle about 1 mile west of the dam. The maximum flow through the uncontrolled spillway would be 45,000 cfs. <73>

Originally, releases from the lake were to be limited to 3,000 cfs when the flow of the Ouachita River at Malvern, Arkansas (about 44 miles downstream) exceeded 20,000 cfs. Releases were to be increased to a maximum of 15,000 cfs when the flow did not exceed 20,000 cfs at Malvern. Later studies indicated that damage occurs in the reach of the Ouachita

figure 3-17

LAKE OUACHITA
(Blakely Mountain Dam)



SOURCE: U.S. Corps of Engineers 〈71,73〉

River from Malvern to Arkadelphia when flows at Malvern exceed 15,000 cfs and that greater flood control benefits could be obtained by restricting releases to conform to this lower flow. The operating procedure at Lake Ouachita has been changed to conform to the lower flow at Malvern. <73>

DeGray Lake: DeGray Dam is about 5.4 miles north of Arkadelphia and controls a drainage area of 453 square miles which is about 92 percent of the Caddo River watershed. The DeGray Project consists of a main dam, earth dikes along the reservoir rim, hydroelectric power generating facilities consisting of one conventional unit and one reversible pump turbine unit, a conduit for power and flood control release, and a downstream regulating dam. The dam consists of a compacted earthfill embankment 3400 feet long with upstream and downstream slopes protected by riprap. This project provides flood control, power generation, conservation of fish and wildlife resources, recreation, water quality control, and water supply. The project was completed in 1972 but flood control regulation began in 1969. Power generation started in 1971. <71, 73>

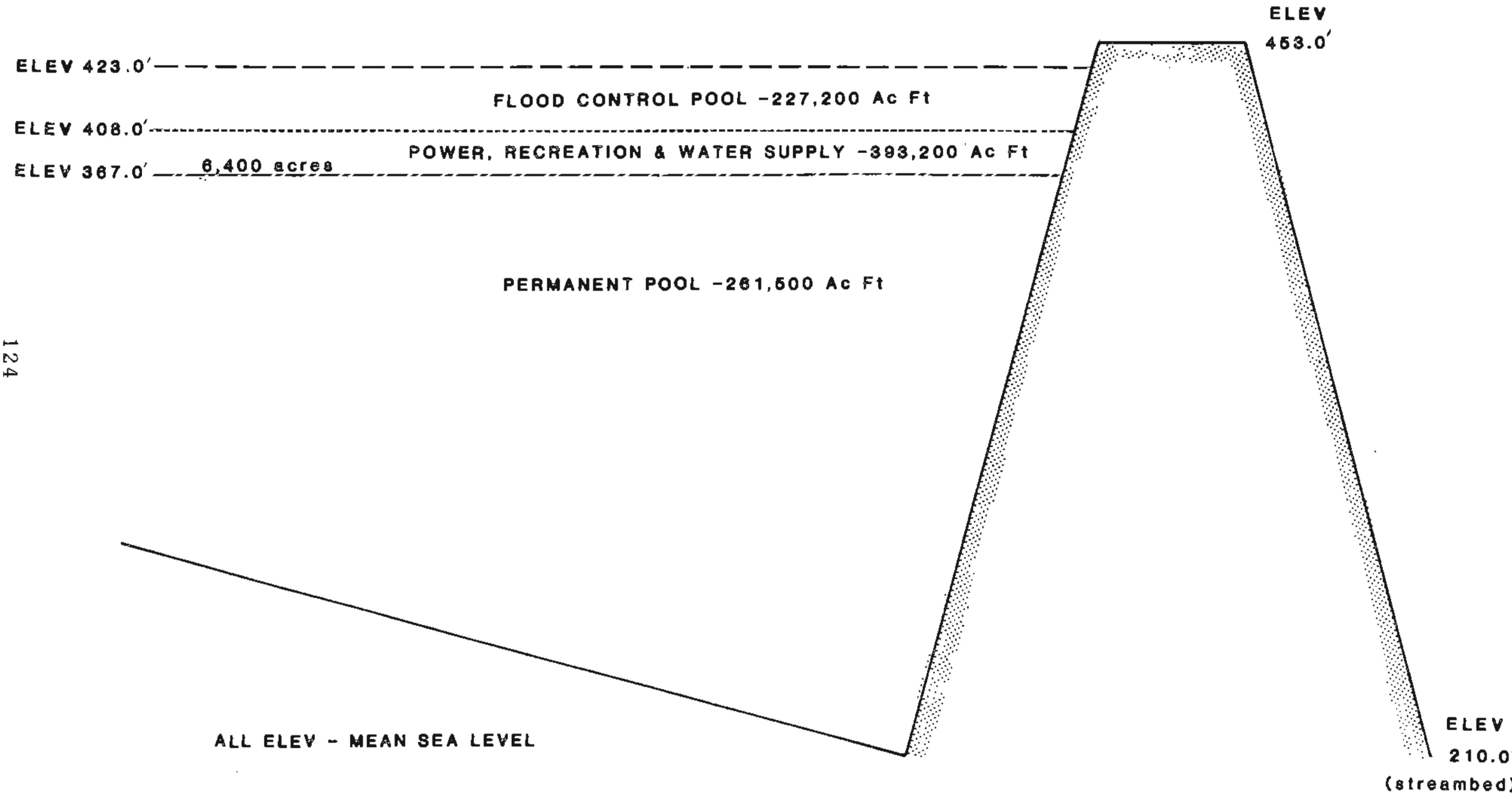
The lake has a capacity of 881,900 acre-feet of water, as shown in Figure 3-18, which includes 261,500 acre-feet for a minimum permanent pool; 393,200 acre-feet for power supply, recreation, and water supply; and 227,200 acre-feet for flood control. The minimum permanent pool covers a surface area of 6400 acres at elevation 367 feet msl. <71, 73>

The power and water supply pool consists of 393,200 acre-feet of water between elevations 367.0 feet and 408.0 feet msl. The powerhouse which is on the downstream side of the dam is operated remotely from Blakely Mountain Dam and contains one 40,000 kilowatt generator and one 28,000 kilowatt reversible unit. Provisions for a third power unit are included in the project design. Average annual power output is 88.5 million KWH. The energy generated in excess of project needs is marketed by the Southwestern Power Administration. <71, 73>

The flood control pool, which is between elevations 408.0 and 423.0 feet msl, contains 227,200 acre-feet of storage which is sufficient to control a flood with a magnitude of the dual-peak flood of April 1927. The volume of runoff controlled by the flood control pool is equivalent to 11.7 inches from the drainage area above the dam. The 227,200 acre-feet of storage in the flood control pool is equal to 9.4 inches of runoff from the drainage area. The remaining 2.3 inches of runoff would be released for power generation and limited to 2000 cfs when the flow of the Ouachita River at

figure 3-18

DeGRAY LAKE
(DeGray Dam)



SOURCE: Corps of Engineers ⟨71,73⟩

Camden exceeded 20,000 cfs. The power pool was assumed to be full at the beginning of the storm event.

The estimated frequency of reaching the emergency spillway elevation (423 feet msl), is once in 85 years. The maximum pool elevation that has occurred since the dam has been in operation was 420.2 feet msl on December 6, 1982 and was within 3 feet of the emergency spillway crest elevation. <38, 73, 74>

Above the lake's storage capacity of 881,900 acre-feet, a surcharge storage capacity of 495,100 acre-feet was designed between 423 and 447.5 feet msl to control the maximum probable storm of 26.0 inches of runoff assuming the flood control pool to be full. The emergency spillway is located in a natural saddle about 4000 feet east of the dam. The spillway is an uncontrolled, unlined, broad-crested type with a crest elevation of 423.0 feet msl. A free board of 5.5 feet places the top of the dam at 453 feet msl. <38, 73>

Water is released from the dam through a unique intake structure that can take water from three different elevations in the reservoir resulting in three different water temperatures through each entrance. The intake structure was installed in this manner so as to preserve the warm water fishery below the dam by releasing warm, high quality water from various levels within the lake. The intake gates have been at the upper release level (395.0 feet msl) since March, 1983. <38, 73>

Releases from DeGray are restricted by maximum values for flood control and minimum values for water supply. When DeGray's pool elevation exceeds 408.0 feet msl, the excess storage will normally be released by power generation as soon as possible. When the river stage at Arkadelphia exceeds 17 feet (approximately 20,000 cfs), power generation is limited to 816,000 KWH daily, one-half plant capacity, or approximately 2000 cfs. After flows have receded at Arkadelphia, the release rate from DeGray is regulated so as not to exceed a flow of 20,000 cfs at Arkadelphia or a maximum of 6,000 cfs from the dam. <38> According to information supplied by the Vicksburg District of the Corps of Engineers (written communication, 1987 - See Appendix A), the DeGray Lake project is designed to release 250 MGD for water supply downstream to the reregulating pool. Currently, 98 MGD are released for water quality water supply and a total of 152 MGD are available for release to the reregulating pool for municipal and industrial water supply uses. The sponsor for water supply within the DeGray Lake project is the Ouachita River Water District (ORWD). As the local sponsor, the ORWD has the right to contract with other entities for the sale of water for water supply.

The regulating dam, located 3 miles downstream from the main dam, consists of an earth embankment, concrete gravity spillway, and sluices. The crest of the dam is at elevation 235.0 msl and the crest of the spillway (top of the water supply and pumping pool) is at elevation 221.0 msl. The top of the water supply and pumping pool covers 430 acres and has a storage capacity of 3,000 acre-feet. <38>

The regulating dam provides storage for water supply, water quality, and pumped storage. A reversible turbine unit is available to "pump-back" power flows in excess of those required for water supply from the regulating pool back to the main lake which increases the dependable capacity of the lake for producing hydroelectric power. Water availability and fuel prices have not required the use of the pump-back facility other than for testing purposes and very limited use (230 hours from October, 1974 through September, 1982). <38, 73>

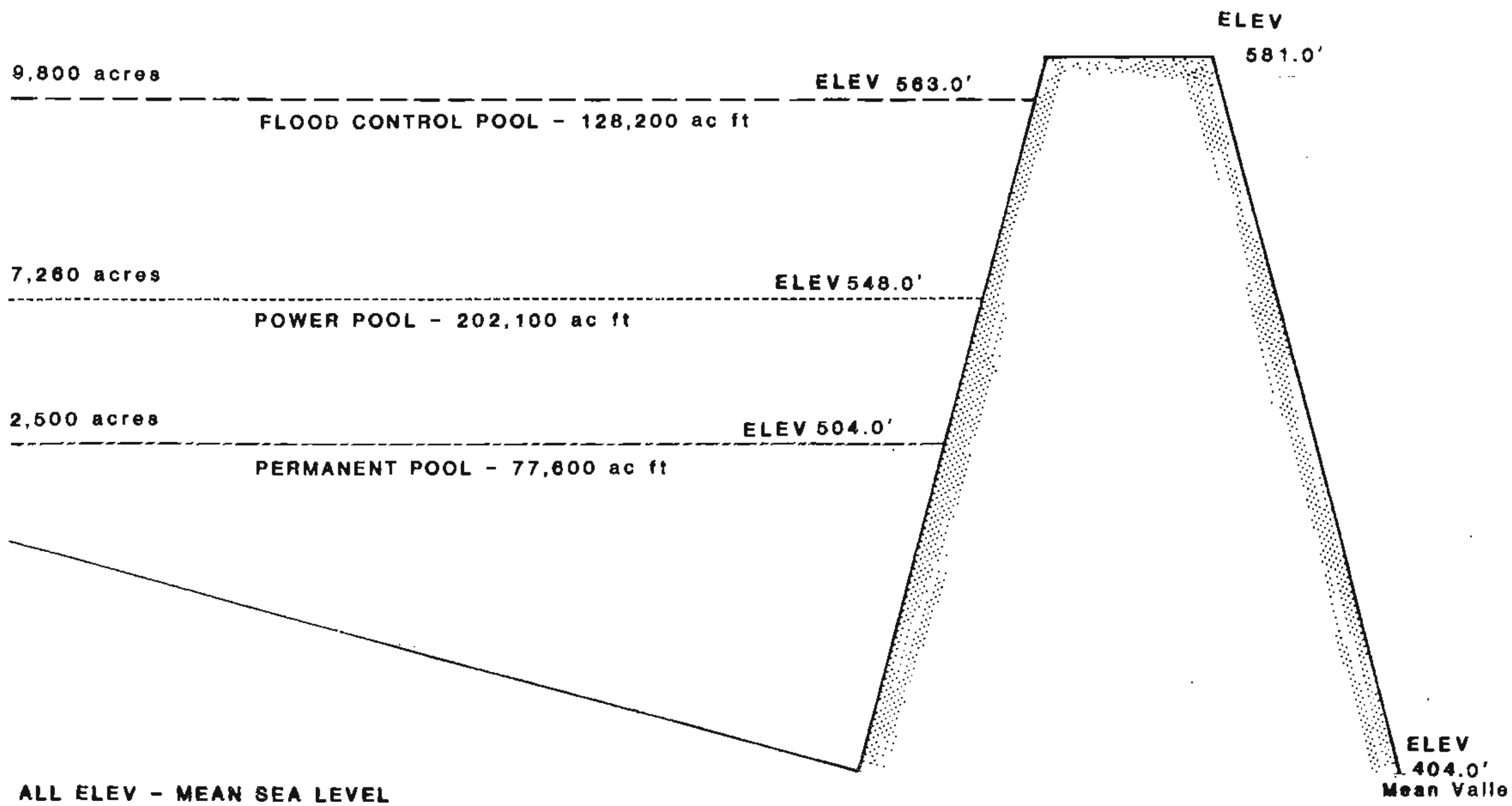
Lake Greeson: Narrows Dam is located north of Murfreesboro on the Little Missouri River in Pike County and forms Lake Greeson. The dam is a concrete gravity-type structure with two non-overflow abutment sections, two regulated outlets for flood control, and a power intake section. The 941 foot-long structure is 190 feet high and controls flow from 237 square mile of drainage area above the dam. The structure became operational in 1950 and is operated for flood control, hydroelectric power, fish and wildlife conservation, and recreation purposes. <71, 73>

Lake Greeson has a storage capacity of approximately 408,000 acre-feet, which includes a minimum permanent pool of 77,600 acre-feet, a power generation pool of about 202,100 acre-feet, and 128,200 acre-feet for flood control. (See Figure 3-19). The minimum permanent pool covers a surface area of 2500 acres at 504 feet msl. <71, 73>

The power storage consists of 202,100 acre-feet of water between elevation 504 and 548 feet msl. Theoretically, the pool would be lowered to an elevation of 504 feet msl during the most critical flow periods; however, the pool normally fluctuates between 548 and 530 feet msl. Three power generators have a capacity of 8,500 kilowatts each. Two of the three units were installed during the initial construction of the project and began power production in 1950. The third unit was installed in 1970. The power plant is operated remotely from the power plant at Blakely Mountain Dam. Average annual power output is 30.4 million KWH. Hydroelectric power which is surplus to the needs of the project is marketed by Southwestern Power Administration. <71, 73>

figure 3-19

LAKE GREESON
(Narrows Dam)



SOURCE: Corps of Engineers ⟨71,73⟩

Flood control storage consists of 128,200 acre-feet of water between 548 and 563 feet msl. This volume is equivalent to 10.1 inches of runoff from the drainage area above the dam. The flood control storage capacity was designed to control the maximum flood of record assuming the power pool to be full. In practice, the power pool is usually down to about 530 feet msl at the beginning of the flood season. The estimated frequency of reaching the emergency spillway elevation of 563 feet msl is once in 50 years. When filled to the emergency spillway crest elevation, the lake extends up the Little Missouri River Valley for a distance of more than 13 miles with a surface area of 9800 acres and a 155 mile shoreline. Lake Greeson reduces flood peaks on the Little Missouri River by one to three feet and on the Ouachita River at Camden by about one foot. The dam, combined with channel improvements, has prevented an estimated $4.1 million in basin flood damages through September, 1979. <71, 73>

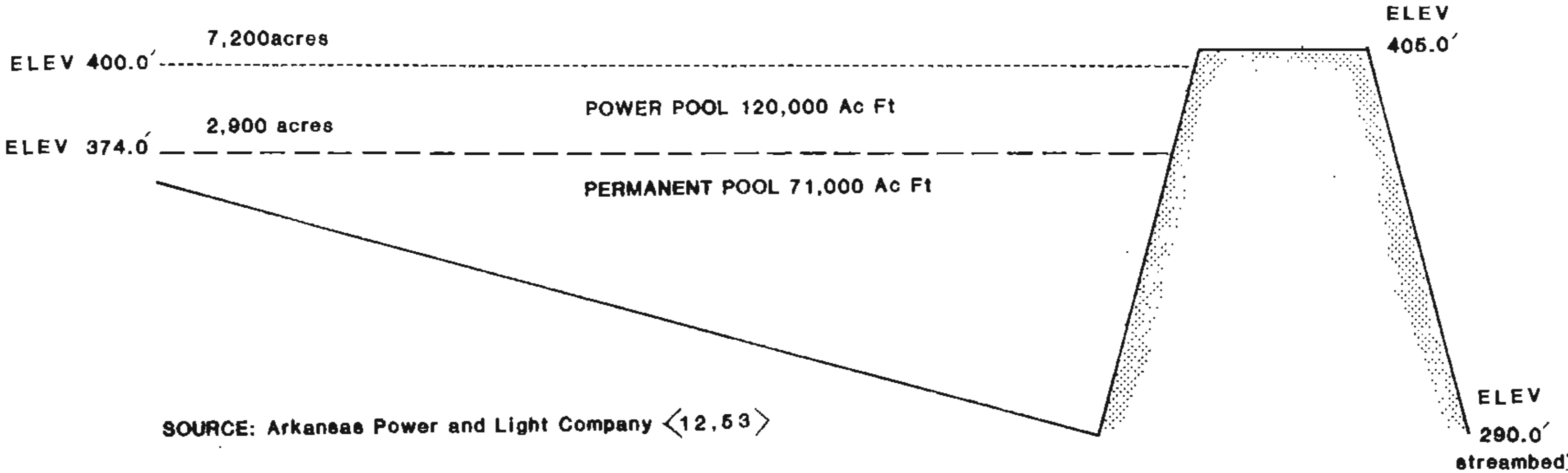
Above the lake's storage capacity of 408,000 acre-feet, a surcharge storage capacity of 192,700 acre-feet of water between 563 and 580.2 feet msl is designed to control the maximum probable storm of 23.0 inches of runoff assuming the flood control pool to be full. A record pool elevation of 564.6 feet msl was recorded in May, 1968 which was 1.6 feet above the emergency spillway crest. Flow through the spillway, which is located in the center section of the dam, at the time of the crest was 900 cfs. A freeboard of 0.8 foot places the top of the dam at 581 feet msl. <71, 73>

Releases from the dam are restricted when river stage downstream at Boughton, Arkansas (about 60 miles downstream) approaches bank-full conditions. The restricted discharge from the reservoir is equivalent to one generator operating continuously, but peaking is permitted up to the capacity of two units as long as the daily release does not exceed 900 cfs. <73>

Lake Hamilton: Carpenter Dam is about 19 miles downstream from Blakely Mountain Dam on the Ouachita River and forms Lake Hamilton. The concrete gravity dam controls a drainage area of 1420 square miles; however, about 1100 square miles of the drainage area are controlled by Lake Ouachita which provides flood storage for downstream areas. The dam was put in operation in 1932 for power generation and recreation. As shown in Figure 3-20, storage capacity of the lake is approximately 191,000 acre-feet which includes 71,000 acre-feet for a minimum permanent pool and 120,000 acre-feet for power storage. Lake Hamilton covers about 7,200 acres at the top of the power pool (elevation 400 feet msl) and is about 18.5 miles long. <12, 53, 72>

figure 3- 20

LAKE HAMILTON
(Carpenter Dam)

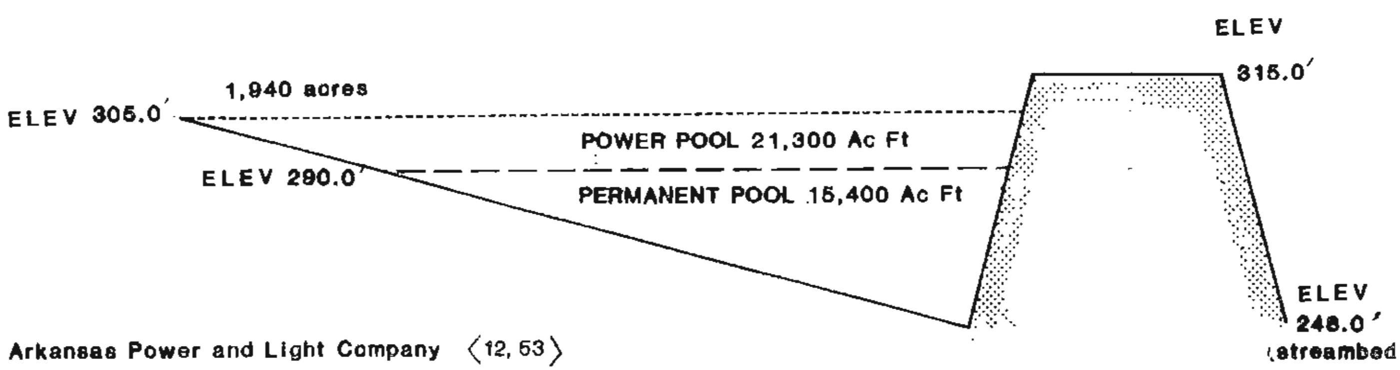


SOURCE: Arkansas Power and Light Company ⟨12,53⟩

ALL ELEV - MEAN SEA LEVEL

figure 3- 21

LAKE CATHERINE
(Remmel Dam)



SOURCE: Arkansas Power and Light Company ⟨12, 53⟩

The powerhouse at Carpenter Dam is built into the dam and has two vertical hydraulic turbine generators with a total rating of 56,000 kilowatts. Average annual power generation is 92 million KWH. <53>

The shores of Lake Hamilton have become highly developed over the past years, and as a result a pool elevation of 399 to 400 feet msl is generally maintained. Either Lake Hamilton or Lake Catherine is lowered each winter for management of lake fisheries and to allow property owners to construct and maintain recreation facilities. Lake Hamilton was lowered to about elevation 395 feet msl in November of 1985 and was allowed to fill back up to the top of the power pool (400 feet msl) in the spring of 1986. The lake will be drawn down again in November of 1987. <53>

Lake Catherine: Remmel Dam is about 12 miles downstream from Carpenter Dam on the Ouachita River and forms Lake Catherine. The reinforced concrete slab and buttress dam controls a drainage area of about 1,540 square miles; however, about 1,100 square miles of the drainage area are controlled by Lake Ouachita which provides the flood storage for downstream areas. Remmel Dam was put into operation in 1924 for power generation and recreation. Storage capacity of the lake is approximately 37,000 acre-feet which includes about 15,400 acre-feet for a minimum permanent pool and about 21,300 acre-feet for power generation. (See figure 3-21). Lake Catherine covers about 1,940 acres at the top of the power pool (305 feet msl) and is approximately 11 miles long. <12, 53, 72>

The powerhouse at the dam contains three vertical hydraulic turbine generators with a total rating of 9300 kilowatts. Average annual power generation is 50 million KWH.

To operate the lake for recreational purposes, a pool elevation of about 305 feet msl is generally maintained. Either Lake Hamilton or Lake Catherine is lowered each winter for management of lake fisheries and to allow property owners to construct and maintain recreation facilities. Lake Catherine was lowered to about 300 feet msl in November of 1986 and was allowed to fill back up to the top of the power pool (305 feet msl) in the spring of 1987. The lake will be drawn down again in November of 1988. <53>

White Oak Lake: White Oak Lake is located in Ouachita County between Camden and Prescott. The lake was constructed in 1960 by damming White Oak Creek. <7> White Oak Creek flows in a northerly direction and empties into the Little Missouri River.

White Oak Lake is owned by the Arkansas Game and Fish Commission and is operated for recreational purposes. The total area covered by the lake is 2676 acres and total storage in the lake is 21,408 acre-feet. This lake is the second largest Game and Fish Commission lake.

Actually, White Oak Lake should be considered as two reservoirs since two dams form two separate bodies of water. Upper White Oak Lake, which is south of the lower lake, covers 1031 acres and has a storage capacity of 8248 acre-feet. Lower White Oak Lake covers 1645 acres and contains 13,160 acre-feet of water.

Impoundment Water Quality

The water quality of five of the major impoundments in this basin is addressed in this section. Lakes Ouachita, Hamilton, and Catherine are located in series on the Ouachita River near Hot Springs. The tailwater of Lake Ouachita is the headwater of Lake Hamilton, and the tailwater of Lake Hamilton is the headwater of Lake Catherine. Lake DeGray is located on the Caddo River and Lake Greeson is located on the Little Missouri River.

A report by Nix <56> on the water-quality conditions of Lakes DeGray, Ouachita, and Greeson includes data collected during the 1985 water year (October, 1984 through September, 1985). The three reservoirs have been monitored by Nix since 1973, under contracts with the Vicksburg District, Corps of Engineers. <56> Additional information on DeGray, Ouachita, Greeson, Hamilton, and Catherine has been provided by Nix through the Arkansas Lakes Interim Study <55>, which was also funded by the Vicksburg District. Sixteen Martek water-quality monitors were installed upstream and downstream of the five lakes. Temperature, dissolved oxygen, specific conductance, and pH measurements have been recorded at 30-minute intervals since September 1981. Vertical profiles of these constituents have also been taken at one site in each of the five reservoirs at approximately weekly intervals. <55>

Thermal stratification is one of the most important phenomena affecting reservoir water quality. When fully developed, a reservoir can be characterized by three zones. The epilimnion is the uppermost warm strata of nearly uniform temperature. The cold, deep region of the reservoir is the hypolimnion. The metalimnion is the zone between these two and is characterized by a strong temperature gradient. The plane of maximum temperature gradient within the metalimnion is known as the thermocline. <45>

Lakes DeGray, Ouachita, and Greeson: Thermal stratification patterns for DeGray, Ouachita, and Greeson were similar during the period of investigation (1985 water year). <56> Very slight stratification persisted in mid-January in Lakes DeGray, Ouachita, and Greeson, but had disappeared by mid-February. Spring stratification began to develop by mid-March which indicates that the reservoirs were in a mixed condition for only about two months. <56>

Lakes Greeson and Ouachita are considered mid-level release reservoirs since power releases are made from an elevation below the thermocline but above the bottom of the reservoir. Releases from these reservoirs are generally quite cold. Releases from DeGray are made from a multi-level inlet structure. This structure is presently set to draw water from the uppermost strata of the lake; therefore, releases from DeGray most nearly approximate natural water temperatures. <56>

The dissolved oxygen profiles for DeGray, Ouachita, and Greeson are dominated by a well oxygenated epilimnion, and a moderately oxygenated hypolimnion as shown in Figures 3-22, 3-23 , and 3-24 . However, the degree to which these conditions develop is different for each of the reservoirs. The metalimnetic dissolved oxygen minima generally progresses to anoxic conditions in Lake Greeson much earlier than in Lakes DeGray or Ouachita. <56>

The dissolved oxygen profile observed in Lake Greeson during November and December of 1984 (See Figure 3-24) was significantly different from that observed in previous years. By October, essentially anoxic conditions existed under the thermocline in Lake Greeson. The distribution of dissolved oxygen during November suggests that oxygen had been introduced to the deep hypolimnion while still maintaining the metalimnetic dissolved oxygen minima. <56> This occurrence may be related to an underflow situation which has been observed in other reservoirs. <52> Cold oxygenated water completely under flows the reservoir after a cold rain leaving the anoxic water at a higher elevation, producing the metalimnetic minima. <56>

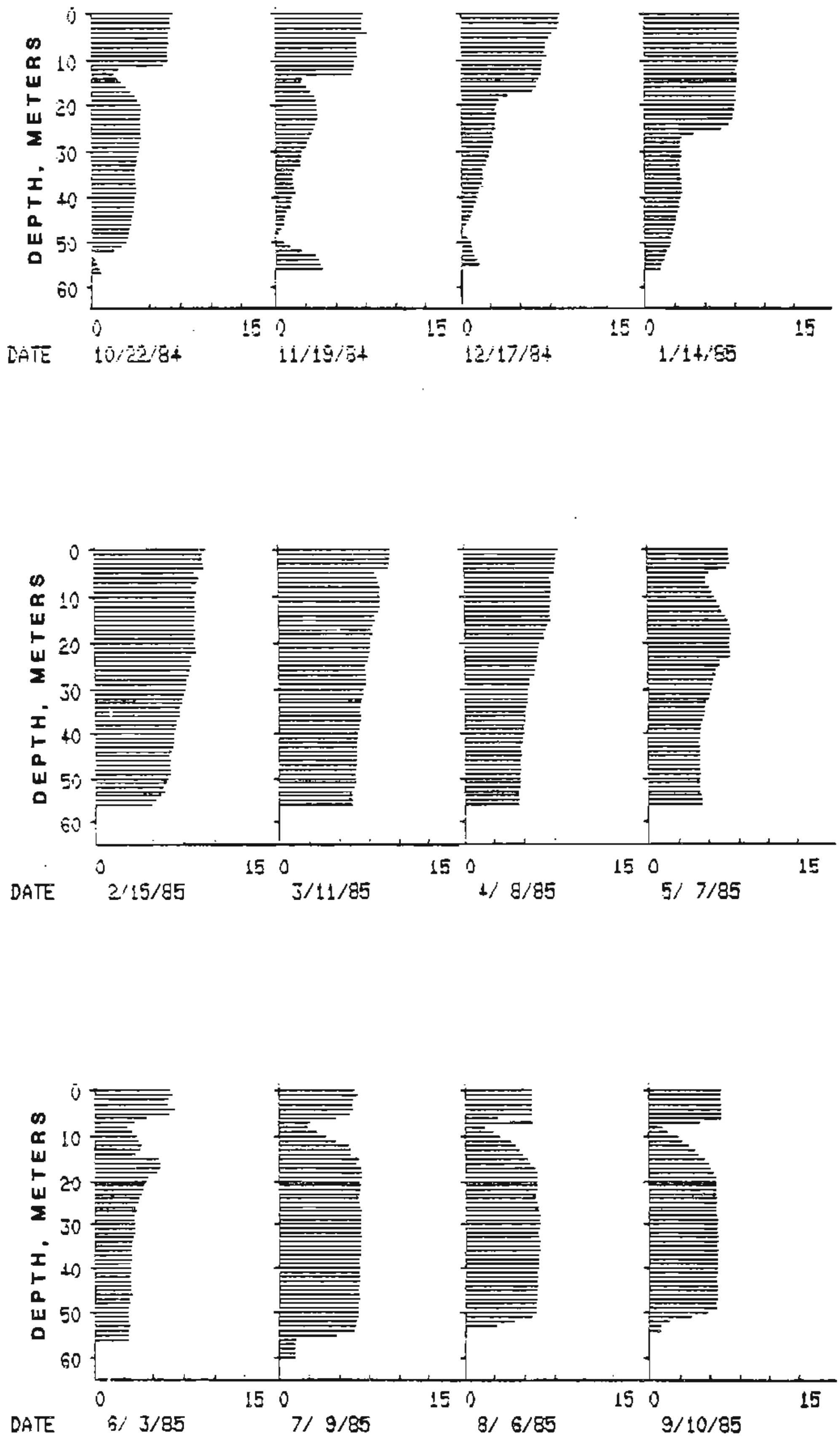
During the fall and early winter of 1984, the metalimnetic region and the deep hypolimnion of Lake Ouachita also became anoxic. In previous years, the metalimnetic dissolved oxygen minima did not develop to anoxic conditions and the hypolimnion maintained moderate levels of dissolved oxygen late into the stratified season. <56>

Profiles of specific conductance in Lakes DeGray, Ouachita, and Greeson are consistent with the development of reduced species in the anoxic zones. When the metalimnion

figure 3-22

LAKE DEGRAY

DISSOLVED OXYGEN PROFILE IN MG/L

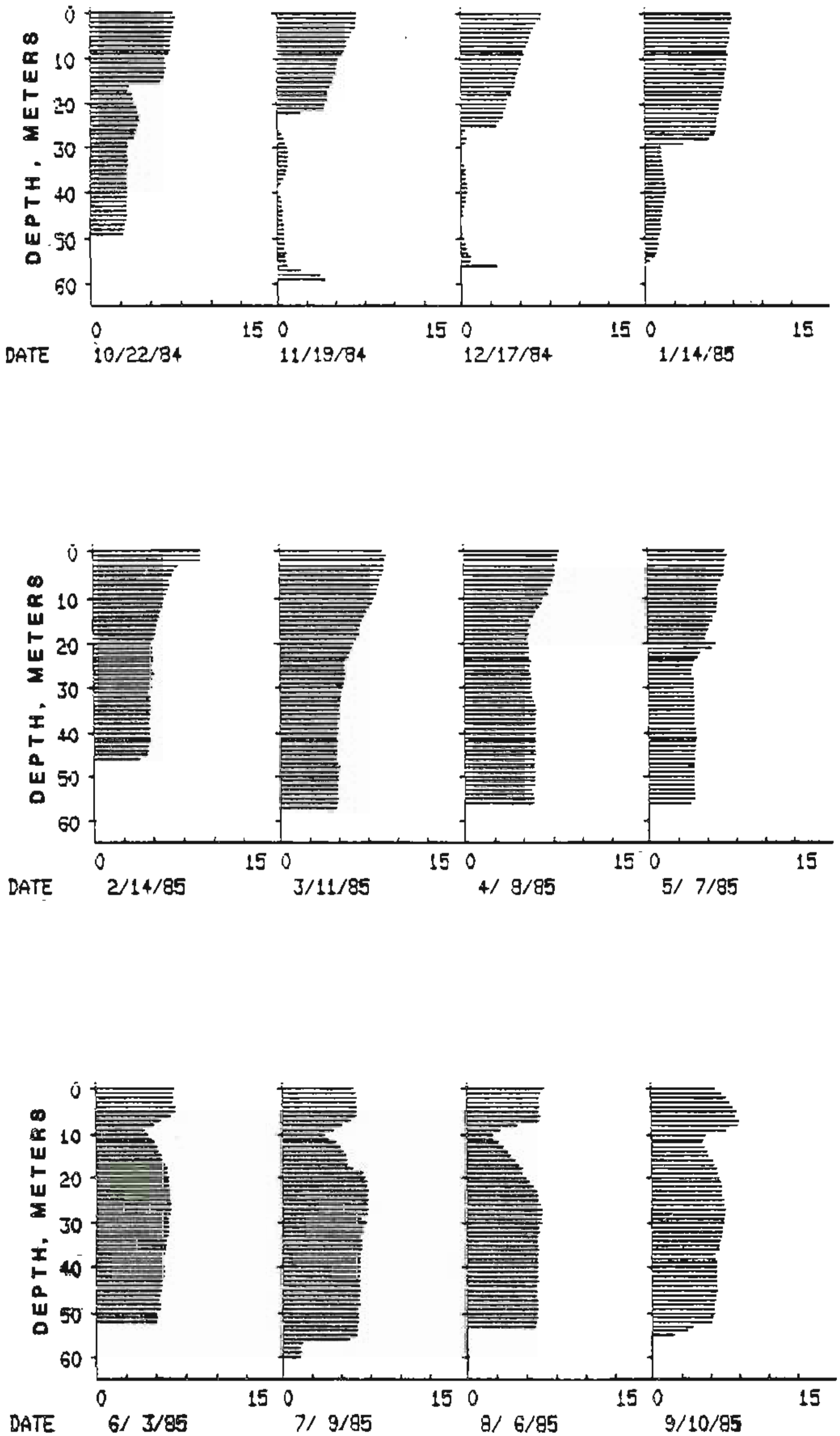


SOURCE: MODIFIED FROM NIX <56>

figure 3-23

LAKE OUACHITA

DISSOLVED OXYGEN PROFILE IN MG/L

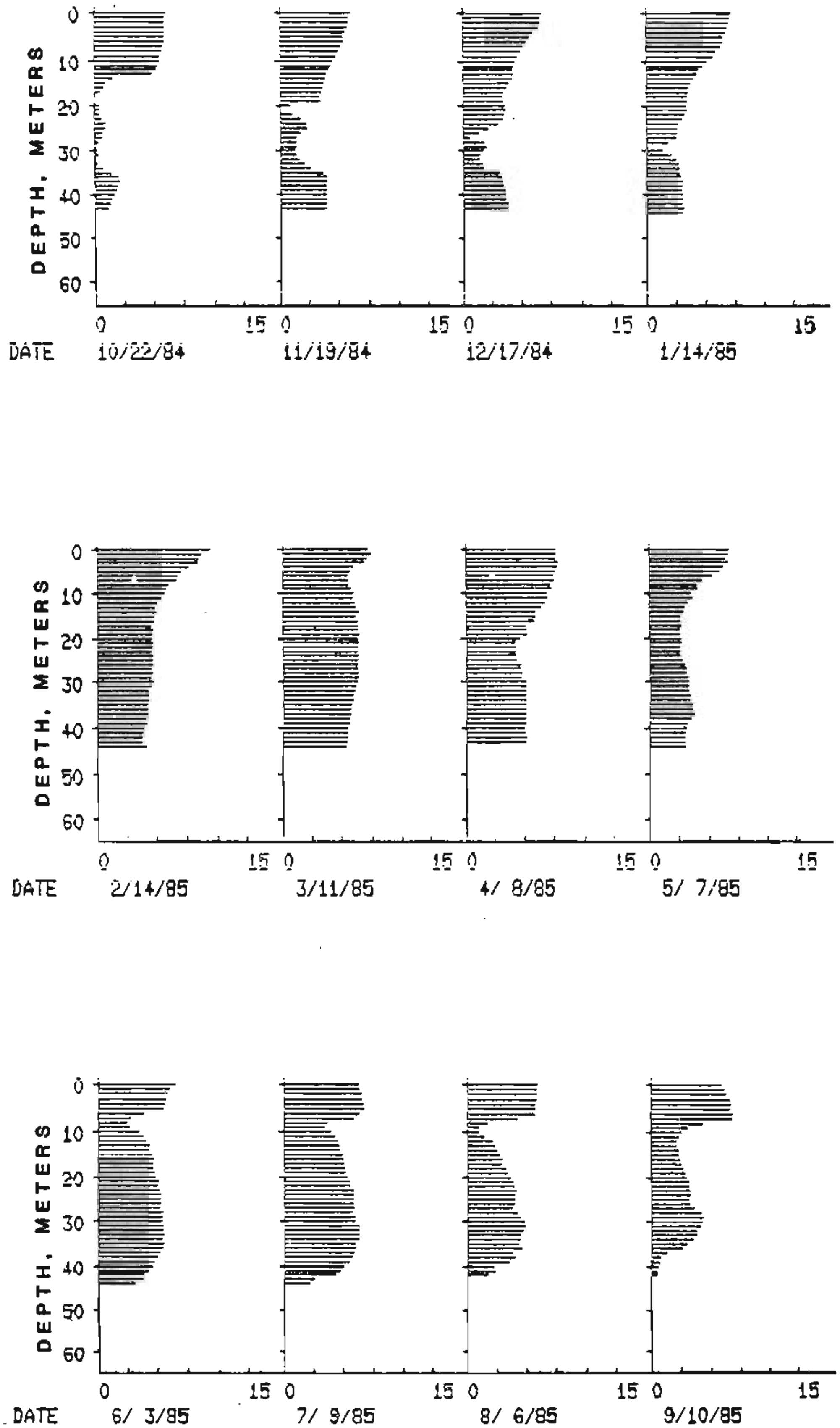


SOURCE: MODIFIED FROM NIX ⟨56⟩

figure 3-24

LAKE GREESON

DISSOLVED OXYGEN PROFILE IN MG/L



SOURCE: MODIFIED FROM NIX ⟨56⟩

becomes anoxic, specific conductance values increase, due mainly to an increase in concentrations of iron and manganese. The increased concentrations of reduced species in a portion of the water column which does not extend to the bottom muds suggests the advective transport from upstream hypolimnetic water. <56>

Samples taken from the water column at depths of 0%, 5%, 50%, and 95% of the total depth indicated that Lakes DeGray, Ouachita, and Greeson had similar water types. The reservoirs contained water which, in general, was low in most of the dissolved components. Nutrient levels were not excessive, and productivity levels, as indicated by chlorophyll concentrations, were within the range found for most reservoirs in Arkansas. As anaerobic conditions developed in the deep hypolimnion of the reservoirs, moderate increases in phosphorus and ammonia nitrogen were observed. Seasonal cycling of nitrate was observed in the reservoirs with winter peaks reaching 0.2 mg/L and summer lows below the detection limit of 0.02 mg/L. <56>

There are some differences in the waters of Lakes DeGray, Ouachita, and Greeson. DeGray seems to be the most nutrient rich (phosphorus and nitrogen), but Greeson appears to have higher concentrations of phytoplanton and chlorophyll. Turbidity is also slightly higher in Lake Greeson. <56>

The low nutrient concentrations observed by Nix in the deeper, more open sections of the lakes do not necessarily reflect the condition that exists in pockets or in the upstream sections of the reservoir. These data should not be interpreted as being representative of the entire reservoir. Nutrient problems in isolated pockets could very easily exist without being detected at the open water stations. <56>

According to a report by the Corps of Engineers' Waterway Experiment Station <75>, sediments are deposited in DeGray Lake in a unique manner. Although reservoirs are expected to exhibit a gradient of decreasing sediment particle size from the headwaters to the dam, median particle size in DeGray Lake increases from the headwaters to the dam. Actually, an abrupt change in median particle size occurs approximately 8 miles above the dam at a very narrow, constricted portion of the lake. The smaller sized sediments in the upper portion of the lake suggest the accumulation of riverborne material. Sediments in the lower portion of the lake have larger and more variable median particle sizes, are less influenced by river inputs, and are more representative of pre-impoundment soils. The presence of leaves, twigs, and other debris in several samples from the lower portion of the lake support this theory. The area of the lake above the restriction is, more or less, acting as a debris basin with most of the riverborne sediments being deposited in the upper portion of the lake. <75>

Lakes Hamilton and Catherine: The releases from Lake Ouachita affect Lake Hamilton, Lake Catherine, and the Ouachita River downstream from Lake Catherine. Water released from Lake Ouachita flows directly into the upper end of Lake Hamilton, and is about 52°F during most of the summer and fall periods. <55>

During periods of stratification, the cold releases from Lake Ouachita dive under the warm epilimnion of Lake Hamilton and move through the deeper portion of the lake. The cold discharges from Lake Hamilton do the same in Lake Catherine. Therefore, the epilimnion of the two lakes (Hamilton and Catherine), along with the water in their side pockets, do not receive the "flushing action" from the upstream releases. The lack of this "flushing action" results in Lake Hamilton and Lake Catherine being somewhat atypical when compared to the other lakes in the basin because the "unflushed" epilimnion remains nutrient rich or polluted. <55>

Federal Projects

USDA - Soil Conservation Service

The Watershed Protection and Flood Prevention Act (Public Law 83-566) of 1954 authorized the Secretary of Agriculture to cooperate with states and local agencies in the planning and carrying out of works of improvement for soil and water conservation. Both technical and financial assistance is provided under the P.L. 83-566 program to local organizations representing people living in small watersheds. Eligible purposes are projects that (1) prevent damage from erosion, floodwater, and sediment; (2) further the conservation, development, utilization, and disposal of water; or (3) conserve and properly use land. <91>

The Upper Ouachita Basin has been divided into 52 watersheds. Seven of these watersheds have been authorized to be planned as projects as shown in Table 3-25 and Figure 3-25. Currently, three watersheds are under construction, one watershed is authorized for operations, and three watersheds have had planning authorized. Brushy Creek, Terre Noire Creek, and Terre Rouge Creek Watersheds had planning authorized but were suspended or terminated due to lack of interest by local sponsors and/or lack of economic feasibility. <86>

TABLE 3-25

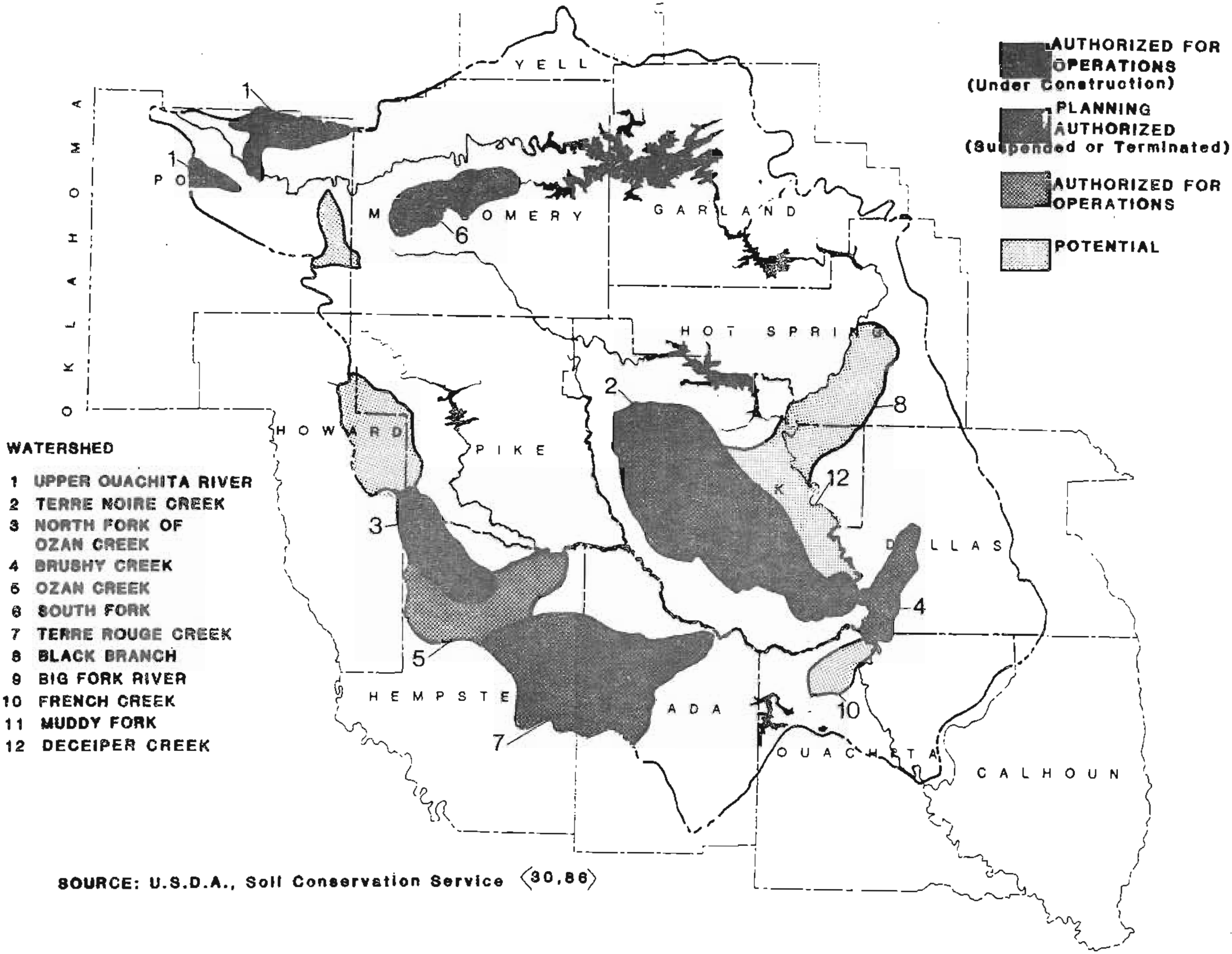
STATUS OF USDA (SCS) WATERSHED PROJECTS

NAME	STATUS
UPPER OUACHITA RIVER	AUTHORIZED FOR OPERATIONS - UNDER CONSTRUCTION
TERRE NOIRE CREEK	PLANNING AUTHORIZED - SUSPENDED OR TERMINATED
NORTH FORK OF OZAN CREEK	AUTHORIZED FOR OPERATIONS - UNDER CONSTRUCTION
BRUSHY CREEK	PLANNING AUTHORIZED - SUSPENDED OR TERMINATED
OZAN CREEKS	AUTHORIZED FOR OPERATIONS
SOUTH FORK	AUTHORIZED FOR OPERATIONS - UNDER CONSTRUCTION
TERRE ROUGE CREEK	AUTHORIZED FOR OPERATIONS - SUSPENDED OR TERMINATED

SOURCE: USDA, SOIL CONSERVATION SERVICE <86>

figure 3-25

STATUS OF USDA(SCS) WATERSHED PROJECTS



SOURCE: U.S.D.A., Soil Conservation Service ⟨30,86⟩

The Upper Ouachita River Watershed is authorized for operations and is under construction. This project includes land treatment and structural measures for watershed protection, flood prevention, municipal and industrial water supply, and recreation. Land treatment measures are planned for approximately 700 acres of cropland, 7400 acres of pastureland, and 1000 acres of forest land. Structural measures consist of two multiple purpose structures. Structure Number 1, which is located on Irons Fork and has been constructed <37>, provides municipal and industrial water for the City of Mena and flood protection for crop and pasture lands. Structure Number 2, located on Ward Creek, will provide urban flood prevention for the City of Mena and recreation for the public including recreational facilities. Damages in Mena from flooding on Ward Creek will be virtually eliminated when land treatment measures and Structure Number 2 are installed. When the entire project is completed, the area flooded from the 100-year storm will be reduced from 1200 acres to 100 acres. <79>

The South Fork Watershed is authorized for operations and is under construction. This project includes land treatment and structural measures for watershed protection, flood prevention, and municipal and industrial water supply. Land treatment measures have been planned for 400 acres of cropland, 2000 acres of pastureland, and 2900 acres of forest land. Structural measures of this project include two single-purpose floodwater structures and one multiple purpose structure for flood prevention and municipal and industrial water supply. Structure Number 3, a single purpose floodwater retarding structure on North Fork, has been constructed. <37> The multiple purpose structure (site 2) will be located on Big Cedar Creek and will provide municipal and industrial water to Mount Ida while reducing downstream flooding. When this project is completed, flooding will be reduced on the entire 1606 acre flood plain. The flood plain represents the area that would be inundated by a flood having a recurrence interval of 100 years. The average annual area flooded will be reduced 62 percent, from 1434 acres to 539 acres. This project will eliminate flooding in Mount Ida from storms of less than a 12-year frequency. <80>

The North Fork of Ozan Creek Watershed is authorized for operations and is under construction. This project includes land treatment and structural measures for watershed protection and flood prevention. Land treatment measures have been planned for 5400 acres of cropland, 3000 acres of pastureland, and 1400 acres of forest land. Structural measures consist of 8 floodwater retarding structures and selective snagging in the stream channel. The original plan included 64,000 feet of channel enlargement, but due to environmental considerations, channel capacity will be increased only by selective snagging. Sites 1, 2, 3, 4, and 5 have been completed. Upon completion of this project, 4315 acres of flood plain land will be benefited. <58, 78>

Ozan Creeks Watershed is authorized for operations. This project will include land treatment and structural measures for watershed protection and flood prevention. Land treatment measures are planned for 9000 acres of cropland, 22,000 acres of pastureland, and 6100 acres of forest land. Structural measures will consist of 22 floodwater retarding structures and approximately 250 acres of land stabilization measures. This project will reduce flood damages on the 11,426 acres of flood plain. The average annual area flooded will be reduced by 25 percent, from 25,358 acres to 19,124 acres. <81>

In addition to the seven authorized watersheds, other watersheds have the potential to be PL83-566 projects for the purposes of flood control, drainage, and/or irrigation water supply. Potential for flood control exists on the Big Fork River, French Creek, and Muddy Fork watersheds (See Water Quantity Recommendations). Potential for watershed protection projects exists on Pine Creek (within Terre Rouge Watershed) and Deceiper Creek Watershed (See Water Quality Recommendations).

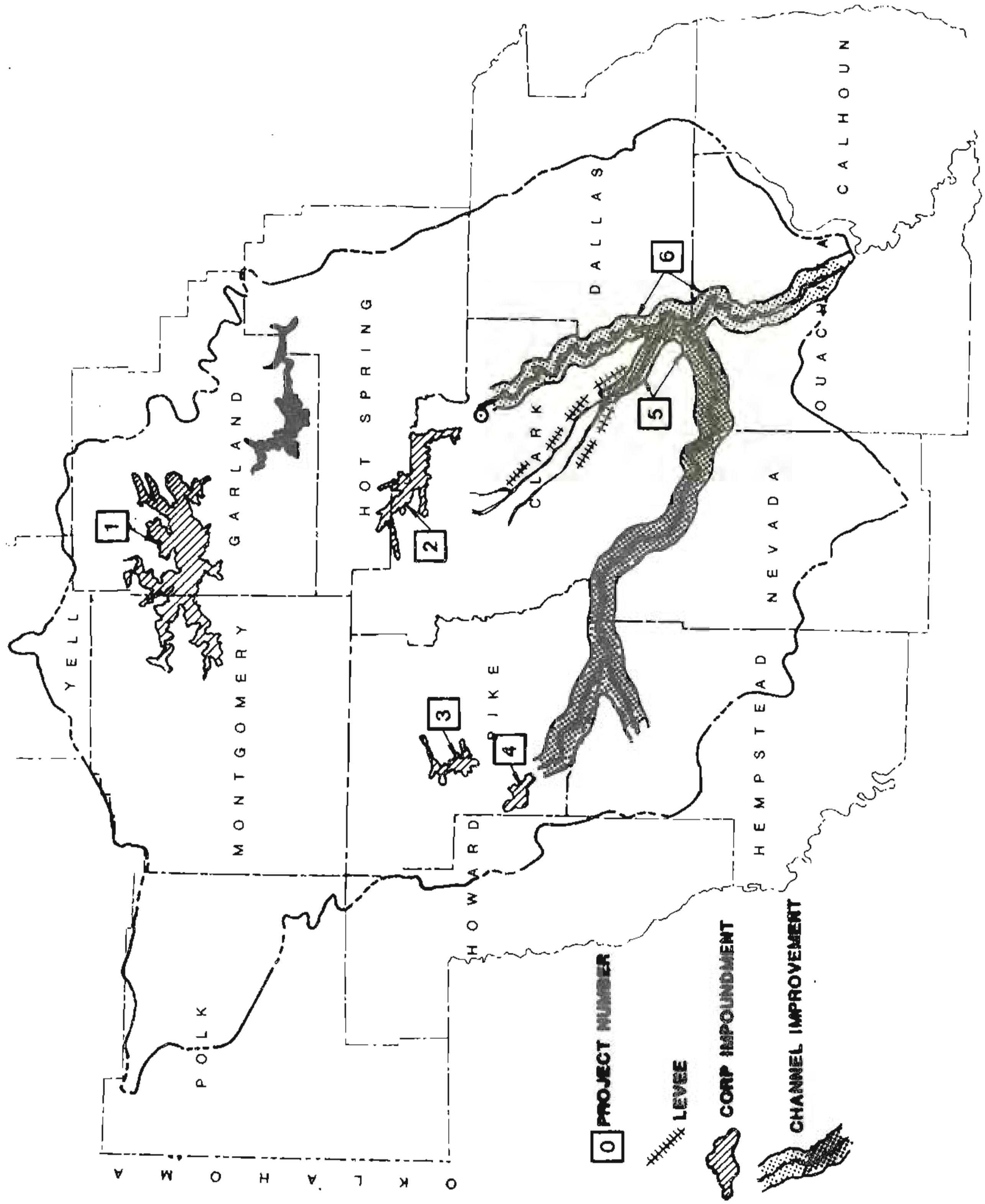
Corps of Engineers Projects

Reservoirs have been constructed and stream channel capacities have been increased by works of the Corps in the Upper Ouachita Basin. The major projects of the Corps in this basin are shown in Figure 3-26 and the status of each project is listed in Table 3-26. The numbers preceding the project names in the table correspond to those in Figure 3-26.

The Corps of Engineers has constructed Lake Ouachita, DeGray, and Greeson in the Upper Ouachita Basin. Lake Ouachita was authorized by the Flood Control Act of 1944, Public Law 78-534. Lake Greeson was authorized by the Flood Control Act of 1941, Public Law 77-228, which was amended by the Public Law 78-534. Degray Lake was authorized by the U.S. Congress in the Rivers and Harbors Act of 1950. <73>

figure 3- 20

MAJOR PROJECTS OF THE CORPS OF ENGINEERS



SOURCE: U.S. Army Corps of Engineers ⟨71⟩

TABLE 3-26

MAJOR PROJECTS OF THE CORPS OF ENGINEERS

NUMBER[1]/	PROJECT NAME	STATUS
1	BLAKELY MOUNTAIN DAM (LAKE OUACHITA)	COMPLETED
2	DEGRAY DAM (DEGRAY LAKE)	COMPLETED
3	NARROWS DAM (LAKE GREESON)	COMPLETED
4	MURFREESBORO DAM (MURFREESBORO LAKE)	DEAUTHORIZED
5	LITTLE MISSOURI RIVER, OZAN CREEK, AND TERRE NOIRE CREEK	COMPLETED
6	OUACHITA RIVER	COMPLETED

[1]/REFER TO FIGURE 3-26, MAJOR PROJECTS OF THE CORPS OF ENGINEERS

SOURCE: U.S. ARMY CORP OF ENGINEERS <71>

The original authorized purposes of Lake Greeson and Lake Ouachita are flood control and hydroelectric power production. This authority was amended in 1944 to include public recreation. Authorized purposes of DeGray Lake are flood control, hydroelectric power generation, water supply, navigation, and recreation. A secondary benefit derived from the project is pollution abatement. <73> Information on the design and operation of these lakes is presented in the Impoundments section of this report.

Congressional authorization in 1950 provided for the construction of Murfreesboro Dam (Murfreesboro Lake). The dam was to be constructed on Muddy Fork, a tributary of the Little Missouri River about four miles west of Murfreesboro. The project would provide flood control benefits and allow other improvements in the watershed to better control floods below the damsite along the Muddy Fork and the Little Missouri River. The project is in a "deauthorized" status. <71>

Congressional authorization of the overall Ouachita River and Tributaries Project provided for channel improvement on the Little Missouri River below Murfreesboro, Ozan Creek, and Terre Noire Creek. The work provides a degree of flood control and drainage to developed areas along the respective streams. Improvements on Terre Noire Creek were completed in 1948 while work on the Little Missouri River and Ozan Creek was finished in 1956. Improvements are maintained by local interests. Estimated flood damage prevention by these channel improvements on the Little Missouri River, Ozan Creek, and Terre Noire Creek through September, 1979 was almost $500,000. <71>

Development of the Ouachita River for navigation was first authorized over 100 years ago (1871) and consisted of channel clearing and snagging from Arkadelphia to the mouth. The original project was modified in 1950 to increase the channel to a nine-foot navigation depth extending up to Camden on the Ouachita River. <71> Most of the project is located outside this basin; however, the segment of the navigation project from Camden to the basin boundary (approximately 5 miles southeast of Camden) is within the Upper Ouachita Basin.

SURFACE-WATER RESOURCE PROBLEMS

To insure future productivity and economic growth, adequate water supplies must be available. The overriding policy of the Arkansas Soil and Water Conservation Commission in the area of water management is to insure Arkansans with sufficient water quantity of a quality satisfactory for the intended beneficial use. This basin is a highly productive region with a diverse economic base that includes agriculture, forestry, mining, recreation, and tourism. Without adequate quantities of water with acceptable quality, production from economic activities in the basin could be significantly impacted.

A series of public meetings were held within each conservation district to determine the public perception of and concerns with problems associated with soil, water, and related resources. These meetings fulfilled the requirements of the Soil and Water Resources Conservation Act (RCA) passed by Congress in 1977. This Act directed the Secretary of Agriculture to conduct a continuing appraisal of the status and condition of our soil, water and related resources. The purpose of RCA is to insure that programs administered by the Secretary of Agriculture for the conservation of soil, water and related resources respond to the nation's long term needs. Broad based participation in the RCA effort by groups, organizations, and the general public is a primary objective of the Act and is necessary to ensure that programs respond to the public needs. Included in the following list are those concerns and problems voiced by the public and various state and federal agencies. The categories of expressed concern within the basin were as follows: <60>

Flooding	Food and Fiber Production
Soil Erosion	Land Use
Water Supply	Solid Waste Disposal
Forestry	

The potential exists for a dramatic increase in water use in this basin. Significant increases in water used for public supply and irrigation may cause water use to increase to as much as 450 MGD in the future. Problems with water quantities in the basin include the following: (1) use of water stored in major impoundments, (2) availability of surface water for public supplies and irrigation, and (3) flooding. Water quality problems include problems from concentrated land use practices, municipal and industrial discharges, low buffering capacities, and problems from the tailwaters of the major reservoirs. Also addressed in this section are problems associated with the determination of instream flow requirements.

Surface-Water Quantity Problems

Availability

Streamflow in the Upper Ouachita Basin is adequate, on an average annual basis, to satisfy existing water needs in the basin. In fact, as previously determined in the excess streamflow section of the report, 425,000 acre-feet of water in the basin, which is approximately equal to one-half the amount of water stored in Lake Ouachita, is excess surface water which is available on an average annual basis for other uses. However, the determination of streamflow availability based on average annual streamflow can be very misleading. This is illustrated by an example of the streamflow variability for the Antoine River at Antoine. Computations of current available streamflow for the Antoine River at Antoine (current available streamflow section) show that 103 cfs of water is available for other uses on an average annual basis. However, on a mean monthly basis, the available water ranges from 22.7 cfs in August to 206 cfs in March. In addition, approximately twenty percent of the time, daily mean streamflow of the Antoine River has been 5.0 cfs or less for the period of record (1955-85) at the gaging station. Due to the variability of flow of the Antoine River and of other streams in the basin, the majority of streamflow is available during the winter and spring months of the year with considerably less water available during the summer and fall months when water use demands are generally highest. Therefore, planning efforts should be focused on the low-flow periods when streamflow availability can be a problem.

Streamflow variability of unregulated streams can, at times, cause problems in the amount of water available for use from the streams. Availability of streamflow can also be a problem downstream of the reservoirs in the basin. Generally, regulation of streamflow by reservoirs in the basin has reduced streamflow variability by increasing the base flows and decreasing the peak flows of streams downstream of the reservoirs. Therefore, reservoir regulation does, at times, increase the amount of flow available from streams during periods of significant water use. However, low-flow problems can occur in streams where flows are regulated, especially those areas downstream of hydroelectric power facilities.

This problem is illustrated in Figure 3-27 which shows the daily mean discharge for the Ouachita River at Blakely Mountain Dam downstream of Lake Ouachita for the 1981 water year. Blakely Mountain Dam is operated for purposes such as flood control and hydropower generation. Due to the pattern of water releases from the dam for these purposes, streamflow of the Ouachita River immediately downstream of Lake Ouachita is extremely variable on a daily basis as shown in Figure 3-27. In fact, streamflow of the Ouachita River at this location during the 1981 water year was often only 20 cfs. The problem of frequent low-flow conditions immediately downstream of reservoirs was also illustrated for the Little Missouri River downstream of Narrows Dam in Figure 3-8 in the Minimum Streamflow section of the report. The previous examples illustrate that the pattern of water releases from reservoirs in the basin can cause low-flow problems immediately downstream of the reservoirs which may affect instream and off-stream uses of the water.

In addition to the problems that may exist at times due to streamflow variability, there is also a problem with the accessibility of surface water for use. According to Arkansas Water Law <11>, <u>only</u> riparian landowners can use the flow from streams and rivers that are adjacent to their property. Therefore, even though flow may be present in a stream, it is not accessible to the majority of landowners who may need the water.

<u>Reallocation of Reservoir Storage</u>

Corps of Engineers reservoirs in this basin have a combined storage of nearly 3.8 million acre-feet. <71> This storage is divided into different authorized purposes such as power generation, flood control, water supply, and recreation. However, each lake is not authorized for all purposes. For instance, of the three major reservoirs (DeGray, Ouachita, and Greeson), only Lake DeGray has an authorized purpose for water supply and recreation. A reallocation of authorized storage of water in the major reservoirs of the basin may be needed for water supply, recreation pool levels, or downstream needs such as riparian use, water quality, or fish and wildlife needs.

Prior to construction of the various reservoirs, a certain base or average flow occurred in the stream impounded. This water was available to riparian users, for dilution of contaminants, and to the fisheries of the stream.

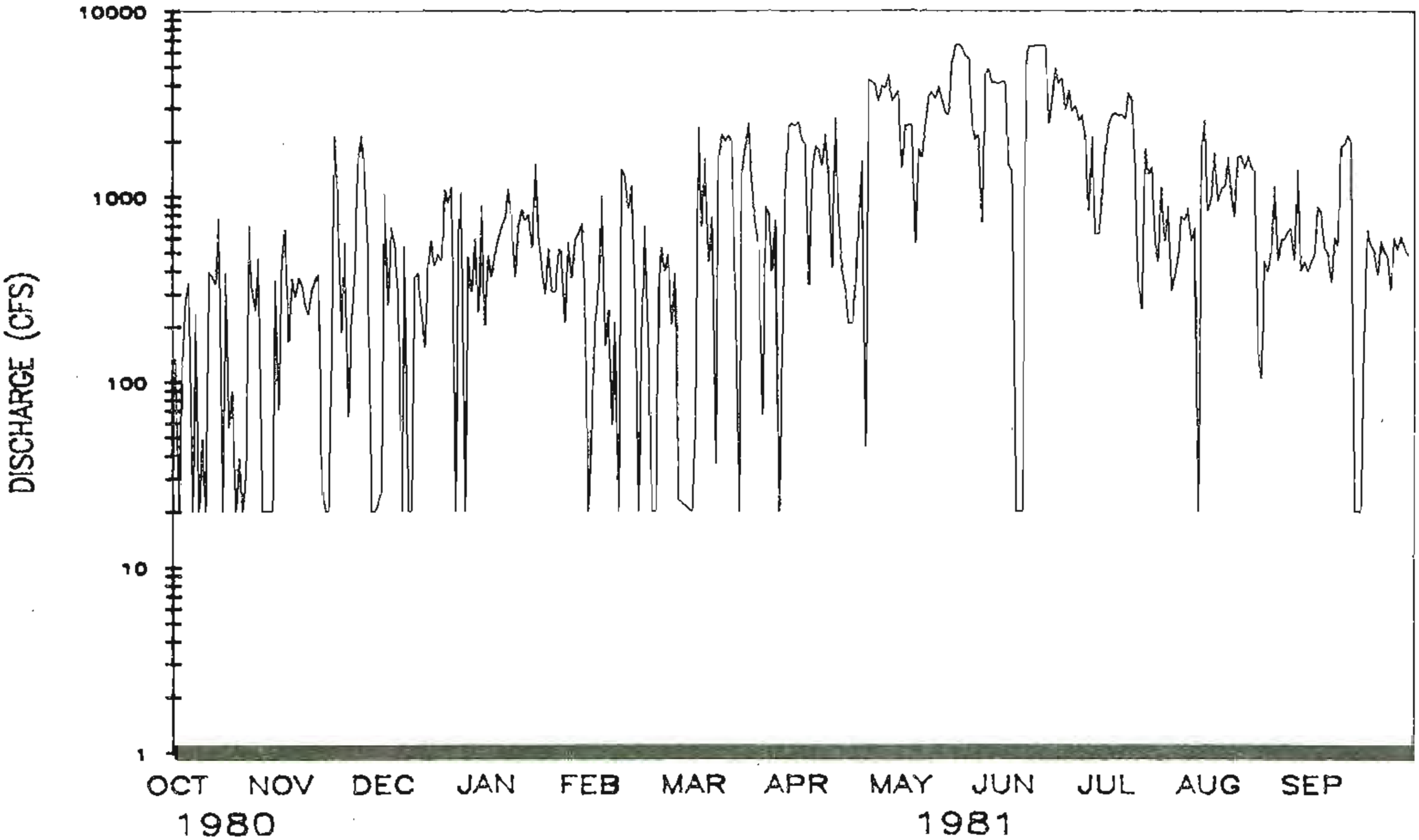
Construction of dams with hydropower generation capabilities has impacted fisheries. Temperature changes caused by deep water releases necessitated the introduction of

FIGURE 3-27

DAILY DISCHARGE VALUES

OUACHITA RIVER AT BLAKELY MTN. DAM

WATER YEAR 1981



cold water species as a mitigatory measure. However, project operation procedures are adversely impacting the cold water species. During the summer, flows are occasionally reduced to only leakage from the dam. Summer temperatures and low streamflows cause water temperatures to rise dangerously close to levels fatal to coldwater species. A reallocation of storage for release as a base flow is needed to sustain a minimal flow higher than current leakage flows.

Other aspects of project operation impact recreational use of the lake. Hydroelectric generation during dry periods lowers lake levels. Lowered lake levels can: cause dangerous boating conditions, inconvenience dock operators, limit access to public launch ramps, and create unaesthetic shoreline conditions. Although recreation was not an authorized storage purpose for many Corps of Engineer lakes, it is possible that benefits to local economies from recreation could surpass the benefits of hydropower generation.

Many cities are approaching the maximum potential of their water supply. Others are switching from questionable groundwater sources. However, few suitable reservoir sites remain. Cost of development increases as special interest groups oppose impoundments or require certain design features. Permitting, environmental impact statements, and other governmental requirements increase project cost. As these and other factors accumulate, purchase of storage for a water supply source from an existing Corps lake may become a feasible alternative.

Because the cost of the reallocation is determined by the highest of benefits foregone; replacement cost; or the updated cost of storage in the project; reallocation may be cost prohibitive. In most cases, the updated cost is highest. "In the updating method, the construction cost of the project will be updated from the midpoint of the physical construction period to the beginning of the fiscal year in which the contract for the reallocation storage is approved by use of the Engineering News Record Construction Index." <70> This cost is to be repaid at the current water supply rate within the physical life of the project, not to exceed 50 years.

The Interstate Conference on Water Policy (ICWP) is a national association of state and regional water officials concerned with all aspects of water resources. Each year a statement of policy outlining water-related concerns of the ICWP is published. One such policy statement is as follows:

"The Water Supply Act of 1958 provides a policy for non-Federal payment of water supply costs at Federal reservoirs, both for participants at the time of project construction and for those who purchased reallocated storage at a later time.

The payment required has been based on a simple principle: new water supply participants should pay for reallocated water supplies what they would have paid if they had been water supply participants when the project was built."

"In recent years, the Federal government has developed a new policy on payment for reallocated water supplies. The U.S. Army Corps of Engineers now states that its policy is to charge the highest of the following: benefits or revenues foregone, replacement costs, or updated cost of storage in the Federal project."

"Under this new policy, the Federal government has in several cases sought repayment of "updated costs" of storage in the Federal project. This means that after reallocation of project purposes, the total original construction cost has then been distributed among the new mix of project purposes. The share of the original cost reallocated to water supply has then been increased to present cost levels by using the construction cost index in the Engineering News Record. Non-Federal participants are asked to pay this inflated cost, plus interest at the rate in effect at the time of reallocation, as opposed to the interest rate at the time of project construction."

"This new Federal policy has been established by agency initiatives, rather than by Congressional action, and has not been applied consistently across the nation. During the period since 1977, the new cost recovery policy has been applied in some cases, but not in others." <44>

The Arkansas Soil and Water Conservation Commission is in support of the ICWP position.

Flooding Problems

There are approximately 585,000 acres located within the 100-year flood plain in this basin. Land use within the flood plain consists of an estimated 50,000 acres of cropland, 76,000 acres of pastureland, 457,000 acres of forest land, and 2,000 acres of other land uses. <85>

Damages from floods vary in different topographic regions of the basin. Most flood damage in the Ouachita Mountains is caused by the high velocity of water which deposits gravel and rocks on flood plains, washes out roads, and destroys fences and buildings. Loss due to inundation is limited to crop damage in the narrow flood plains. <34>

Flood damages in the Coastal Plain are caused by inundation. Streams in the Coastal Plain are sluggish and large areas in the flood plains are occasionally inundated; however, peak flows along the Ouachita River have been greatly reduced by storing floodwaters in Lake Ouachita. In effect, the 1,105 square miles of drainage area above Blakely Mountain Dam does not contribute to peak flows downstream. <34>

An estimated 5,700 acres of cropland flood one time per year. An additional 13,300 cropland acres flood once every two years, and approximately 7,700 more acres of cropland flood once every five years. <82> Because of flooding and/or lack of drainage, approximately 45 percent of the cropland in the basin is classified as being "wet". <85> These "wet" cropland areas may have other significant problems but excess water is the major restriction.

An estimated 3.2 million dollars (1977 Price Base) in damages occur annually to crop, pasture, and forest lands within the flood plain. Total damages, which include damages to roads and bridges, urban areas, and other agricultural areas, are estimated to be approximately 5.0 million dollars (1977 Price Base) annually. <83> Specific problem areas that presently are not a part of a flood control project include Terre Rouge Creek, Terre Noire Creek, Brushy Creek, Black Branch (Friendship Bottoms), French Creek, Muddy Fork, and the Big Fork River. <30, 86>

Surface-Water Quality Problems

The water quality of streams and lakes of the Upper Ouachita Basin is generally good <6>, but several water-quality problems exist in the basin. The problems addressed in this section include the effects of basin-wide land use practices, municipal and industrial discharges, low buffering capacities, and the tailwaters of the major reservoirs.

Land Use Practices

Land use in the Upper Ouachita Basin is described in detail in the Land Resource Section of this report. Excessive soil erosion, which occurs mainly on cropland and forest land, and degradation of surface runoff from concentrated animal feeding operations appear to be the major water quality problems as a result of basin-wide land use practices.

Excessive Soil Erosion: Excessive soil erosion can cause water quality problems such as increased levels of turbidity, pesticides, and nutrients. Areas most severely impacted are generally those areas where there is insufficient water available for dilution. Such areas include upper reaches of streams and tributaries, and side pockets of reservoirs.

As discussed in the water quality inventory, turbidity levels appear to be increasing in the basin as streams flow from the Ouachita Mountains region into the Coastal Plain and Blackland Prairie area. A major reason for this occurrence is probably the difference in land use practices of the two regions. More than 90 percent of the cropland in the basin occurs in the Coastal Plain and Blackland Prairie regions. <85> Also, cropland covers only three percent (See Table 2-1) of the basin, but it accounts for almost 40 percent of the total sheet and rill erosion occurring in the basin as described in Chapter II. A certain amount of erosion is, however, unavoidable.

In order to identify excess erosion, tolerable levels of erosion must be defined. The soil loss tolerance value (T-value) indicates the rate of soil loss in tons per acre per year that will allow a high level of production to be sustained economically and indefinitely. Any combination of cropping and management practices that will keep soil losses at or below the T-value for a specific soil will provide satisfactory erosion control for that soil. T-values generally range from 1.0 to 5.0 tons per acre per year. <89>

The erosion that is occurring on non-federal rural land in the basin is shown in relation to "T" on Table 3-27. Most of the land is in the less than "T" category meaning that, in general, there is not a significant erosion problem. However, approximately 60,000 acres of cropland and about 30,000 acres of forest land in the basin are eroding above tolerable levels. Watershed protection may be necessary in some of these areas (See Water Quality Recommendations).

Concentrated Feeding Operations: When large concentrations of animals are located in areas where their wastes are not managed properly, the potential for high nutrient concentrations in surface runoff is great. As part of an inventory of confined animal feeding operations in 1983 <93>, the Soil Conservation Service identified a portion of the Upper Ouachita Basin as a problem area due to the number of concentrated feeding operations in the basin. The waste study area shown in Figure 2-5 includes all of Montgomery, Nevada, and Pike Counties, and a portion of Hempstead and Polk Counties.

Degradation of surface waters from concentrated feeding operations can occur in several ways. For example, nutrients may be transported by surface runoff from the concentrated confinement site, the waste application site, or the improper disposal of dead animals.

TABLE 3-27

EROSION IN RELATION TO T

NON-FEDERAL RURAL LAND

LAND USE	<T 1000 TONS	<T 1000 ACRES	<T TONS/ACRE	T-2T 1000 TONS	T-2T 1000 ACRES	T-2T TONS/ACRE	>2T 1000 TONS	>2T 1000 ACRES	>2T TONS/ACRE
CROPLAND	138.4	58.8	2.4	192.0	30.6	6.3	306.9	28.4	10.8
PASTURELAND	152.1	505.1	0.3	9.1	2.0	4.6	-	-	-
FOREST LAND	272.0	1984.2	0.1	75.3	15.7	4.8	405.6	14.8	27.4
OTHER	20.5	19.8	1.0	14.5	3.1	4.7	96.9	4.5	21.5
TOTAL	583.0	2567.9	0.2	290.9	51.4	5.7	809.4	47.7	17.0

SOURCE: USDA, SOIL CONSERVATION SERVICE <85>

As shown in Table 2-8, the highest waste application rates occurred in Polk, Pike, and Hempstead Counties. A pollution hazard exists on approximately 13 percent of the application sites and on about seven percent of the confinement locations. <90> The high concentrations of fecal coliform bacteria identified in the Water Quality Inventory section of this report may be influenced by animal wastes. Specific impacts of confined animal operations on water quality in the basin have not been documented.

Another potential problem from concentrated feeding operations results from improper disposal of dead animals. It was estimated that approximately 60 percent of the confined animal operations in the waste study area employed surface disposal methods in 1983. <90>

Municipal and Industrial Discharges

Water quality is impacted by municipal and industrial discharges in the basin. Above Lake Ouachita, the Ouachita River has high quality water, but as the river flows past Hot Springs, municipal and industrial discharges progressively lower water quality. Prairie Creek near Mena (tributary to the Ouachita River) and the South Fork of the Caddo River are being degraded as a result of municipal and industrial discharges. <6>

Low Buffering Capacity

A potential for acidification of the streams and reservoirs exists in the Upper Ouachita Basin. Median values for pH presented in the water quality inventory (Figure 3-11) were within expected ranges, but median values for alkalinity (Figure 3-12) were less than 25 mg/L for all data collection sites except one (Caddo River near Amity). Since the Ouachita Mountain region has only a modest amount of limestone, and since the sandstones and shales of the region contribute very limited amounts of dissolved components to streams, the resulting water is poorly buffered and susceptible to acidification. <56> Due to the poorly buffered surface water in the basin, acidic precipitation could have a significant effect on the streams and reservoirs in this area. According to the National Atmospheric Deposition Program <17>, the weighted mean pH of precipitation collected near Arkadelphia during 1984 was 4.6. The streams and lakes of the Upper Ouachita Basin run the risk of becoming acidified should the amount of acid introduced to the system from acidic precipitation or from other sources be increased.

Tailwater of Reservoirs

The tailwater releases from the three major reservoir systems in the basin have a definite impact on downstream water quality. At times, releases from the major reservoirs may contain low concentrations of dissolved oxygen. The cold releases from Lake Ouachita dive under the water stored in Lakes Hamilton and Catherine resulting in the two downstream reservoirs being "unflushed".

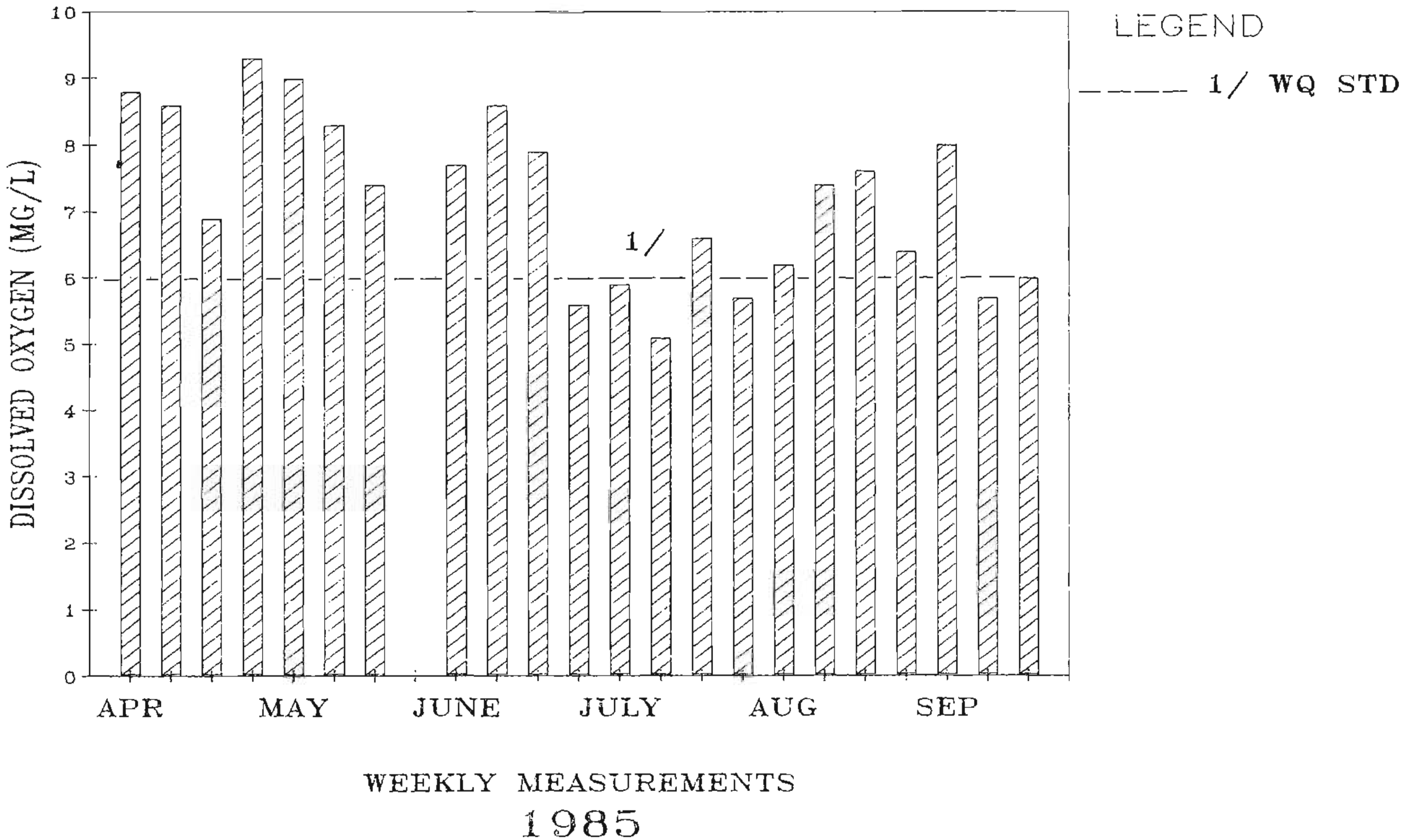
Lake Greeson: The effect that cold water releases have upon tailwater water quality are most apparent at Lake Greeson. During late summer, dissolved oxygen depletion can become critical at the elevation which water is released from the lake. <55> Dissolved oxygen concentrations for the tailwater of Lake Greeson are shown in Figure 3-28 for samples taken between April and September, 1985. Only moderate depression of dissolved oxygen was observed, however, dissolved oxygen concentrations did not meet the standard established by ADPC&E's Regulation No. 2 <5> on several occasions. During some years, the tailwater released from Lake Greeson may be anaerobic and contain moderate concentrations of iron, manganese, and hydrogen sulfide. <55>

The problem of low dissolved oxygen in the tailwater releases at Lake Greeson results because water is released from the lake at the elevation which the metalimnetic dissolved oxygen minima occurs. Dissolved oxygen depletion also occurs, as expected, in the deeper portion of the lake. Together with the metalimnetic dissolved oxygen minima, a water column is produced which in late summer has adequate dissolved oxygen at mid elevations, moderate to low dissolved oxygen below this level, and oxygen depletion as the bottom is approached. <55>

Lake DeGray: Dissolved oxygen concentrations in the tailwater released from Lake DeGray can be a problem. When the intake structure is in the upper position, dissolved oxygen concentrations in the tailwater of the lake are near saturation. However, when in the lower position, a lowering of the temperature and the dissolved oxygen concentration occurs. <55>

During periods of minimal or no release from DeGray, the dissolved oxygen concentrations in the regulating pool below the lake may decline. When the intake structure is in the lower position, the problem is magnified because water with low dissolved oxygen concentrations is being released from DeGray. During these periods, the Caddo River from the regulating dam to its confluence with the Ouachita River could be severely impacted.

figure 3-28
DISSOLVED OXYGEN CONCENTRATIONS
IN THE LITTLE MISSOURI RIVER
DOWNSTREAM FROM LAKE GREESON



SOURCE: Modified from Nix <56> 1/WQ STD FOR TROUT FISHERY

Ouachita-Hamilton-Catherine: Generally, releases from Lake Ouachita contain adequate levels of dissolved oxygen. However, significant oxygen depletion can occur in the hypolimnetic water of Lake Hamilton, especially during years when releases from Lake Ouachita are minimal. <55>

The cold water that is released from Lake Ouachita is a dominant factor in determining the characteristics of Lake Hamilton and Lake Catherine. As described in the inventory, these two downstream lakes do not receive the "flushing action" of the epiliminion because the cold water entering the reservoir dives under the epilimnion. Areas surrounding Lakes Hamilton and Catherine are highly developed, and have experienced some pollution problems in previous years. A recent study on Lake Hamilton indicates that the lake is not severely polluted, but problems may occur if the quantity of untreated discharge increases significantly. <55>

Determination of Instream Flow Requirements

The Arkansas Soil and Water Conservation Commission has been mandated by Act 1051 of 1985 to determine the instream flow requirements for water quality, fish and wildlife, navigation, interstate compacts, aquifer recharge, and other uses such as industry, agriculture, and public water supply in the State of Arkansas. When these needs are determined and future water needs are projected for the Upper Ouachita Basin, the water that is available for other uses can be determined. Three major problems that have been encountered in the process of determining instream flow requirements for streams in the Upper Ouachita Basin for the categories previously mentioned are as follows: (1) lack of sufficient and/or appropriate data; (2) inflexible methodologies; and (3) effects of reservoir regulation.

(1) Lack of sufficient and/or appropriate data

The first major problem is the lack of sufficient and/or appropriate data to quantify instream needs in the basin. For instance, streamflow data in the Upper Ouachita Basin are necessary in the determination of instream flow requirements for water quality, fish and wildlife, navigation, and the Red River interstate compact. However, information for only thirteen continuous streamflow gaging stations in the basin is currently available. Extrapolation of the gaging station data to other reaches on gaged streams such as the Little Missouri River and to other ungaged streams such as Terre Noire and

Terre Rouge Creeks may introduce significant error into the computations, particularly with the diverse geology, physiography, and streamflow characteristics present within the basin.

In addition to the insufficient streamflow data available to quantify instream needs, appropriate data are not available to determine instream flows which should be reserved in order to satisfy the interstate compact requirements. The amount of water that needs to remain in the streams for use in Louisiana is based on a percent of the total runoff in a basin. Runoff, as defined in the compact, includes flow in the streams and water that has been diverted from the streams for other uses. The amount of water that is diverted from the streams is not accurately quantified, therefore, the amount of runoff in the basins is unknown. An additional problem that exists in the determination of instream flow requirements for the interstate compact is that compact compliance requirements are based on the previous week's streamflow and diversions. Therefore, the instream flow requirements are dependent on the runoff available in a basin the previous week and may change from week to week.

Appropriate data are also not available to determine instream flow requirements for fish and wildlife. Limited data have been collected to characterize fish and wildlife habitat conditions in conjunction with streamflow conditions. This information must be available in order to determine the instream flow requirements for fish and wildlife, and is particularly important if the habitat of an endangered species must be protected. According to information provided by the Arkansas Natural Heritage Commission (personal communication, 1987 - See Appendix A), the pink mucket (Lampsilis orbiculata), which is listed by the U.S. Fish and Wildlife Service as an endangered species, has been found to exist in the Ouachita River in the Upper Ouachita Basin. Five other species that have been identified in the Upper Ouachita Basin (crystal darter, Ammocrypta asprella; Ouachita rock pocketbook, Arkansia wheeleri; Ouachita madtom, Noturus lachneri; Caddo madtom, Noturus taylori; and longnose darter, Percina nasuta) have been designated by the U.S. Fish and Wildlife Service as in need of further biological research and field study to determine if these species should be listed as threatened or endangered. Therefore, data identifying instream flow requirements for fish and wildlife in the Upper Ouachita Basin should be collected, particularly for those species which are classified as endangered or threatened.

(2) Inflexible methodologies

The second major problem in the process of determining instream flow requirements is that the methods currently used are not flexible to address the diversity of the aquatic systems or the historic instream and off-stream uses of water from the streams. For example, according to the Arkansas Method, instream flow requirements for fish and wildlife are computed as a percent of the mean monthly discharge at each of the gaging station locations in the basin. At the present time, however, there is no flexibility in the method so that the unique streamflow needs of the different fisheries in the basin are taken into account. Therefore, using the Arkansas Method, the instream needs for the trout fishery downstream of Lake Greeson are computed in the same manner as the instream flow requirements for all other fisheries in the basin.

Another example of the inflexible methods used to determine instream flow requirements is the use of the $7Q_{10}$ discharge as the flow necessary to satisfy instream needs for water quality. Several reaches of streams in the Upper Ouachita Basin, such as the Little Missouri River above Lake Greeson and the Ouachita Basin above Lake Ouachita, have been classified by the Arkansas Department of Pollution Control and Ecology as having extraordinary recreational and aesthetic value <5>. On the other hand, according to ADPC&E <6>, some stream reaches in the basin, such as the Ouachita River downstream of Hot Springs, have been impacted by industrial and municipal discharges. Yet, the $7Q_{10}$ discharge has been designated as the flow necessary to satisfy water-quality requirements for streams in the basin that contain water of excellent chemical quality as well as for those streams that have water-quality degradation problems.

In addition to the problems with the methodologies previously described, the current methods used to determine instream flow requirements do not take into consideration the variation in historic instream and off-stream uses of water for streams in the basin. For example, water needs for agricultural purposes are important in several reaches of the Ouachita River and should be considered in the establishment of instream flow requirements for all categories in the appropriate reaches of the Ouachita River. Similarly, the Little Missouri River upstream of Lake Greeson has been designated as a scenic river with extraordinary recreational and aesthetic value. Since other current and historic uses of water from this reach of the Little Missouri River are not significant, a high level of protection for the water quality and the fisheries should be considered.

(3) Effects of reservoir regulation

The third major problem in the process of instream flow quantification is determining instream needs for stream reaches that are affected by reservoir regulation. The reservoirs in the Upper Ouachita Basin are operated for purposes such as flood control and hydropower generation. Generally, regulation of streamflow by reservoirs in the basin has reduced streamflow variability by increasing the base flows and decreasing the peak flows of streams downstream of the reservoirs. However, low-flow problems occur in streams where flows are regulated by hydroelectric power facilities. The amount of water released from these facilities is highly variable on a daily basis and may result in frequent low-flow conditions downstream. Therefore, instream flow requirements must be established to protect instream uses downstream of the reservoirs taking into account the variability in the current patterns of releases from the reservoirs.

Critical Surface Water Areas

Section 2 of Act 1051 of 1985 requires the Arkansas Soil and Water Conservation Commission to define critical water areas and to delineate areas which are now critical or which will be critical within the next thirty years. A critical surface water area is defined as any area where current water use, projected water use, and (or) quality degradation have caused, or will cause, a shortage of useful water for a period of time so as to cause prolonged social, economic, or environmental problems.

No streams in the Upper Ouachita Basin are designated as critical surface water areas based on quantity problems. Shortages of water may exist, at times, on streams upstream of the major reservoirs in the basin. However, these low flows are a result of natural streamflow variability, not a result of significant water withdrawals from the streams. Shortages of water may also exist, at times, immediately downstream of the reservoirs in the basin depending upon the pattern of releases from the reservoirs, particularly those for hydropower generation. However, as previously discussed in the streamflow characteristics section of the report, the reservoirs in the basin generally contribute to an increase in low flow downstream of the reservoirs. At the present time, streamflow generally is adequate to support the water quantity needs of the basin.

It is anticipated that the quantity of water in streams in the basin will also be adequate to satisfy water demands within the next thirty years. Surface water use projections to the year 2030 indicate a significant potential increase in surface water use for the basin. However, the projected increase of surface water use takes into account the possible transfer of approximately 250 MGD of water from DeGray Reservoir to Little Rock to supplement the municipal water supply. Storage in DeGray Reservoir will be adequate to satisfy this projected demand for water from the basin. Therefore, it is projected that no areas in this basin will be critical surface water areas within the next thirty years based on quantity problems.

The water quality of streams and lakes of the Upper Ouachita Basin is generally good, but as previously discussed, water-quality problems do exist in the basin. Point-source pollution due to municipal and industrial discharges, non-point pollution due to excessive soil erosion, and low dissolved oxygen concentrations in tailwaters of some of the major reservoirs are three water-quality problems that exist in the Upper Ouachita Basin. However, no streams in the basin have been designated as critical surface water areas based on these water-quality problems since effects of these problems are generally local and they do not cause prolonged social, economic, or environmental problems.

Another water-quality problem that has been identified in the Upper Ouachita Basin is the low alkalinity (<25 mg/L) of most streams in the basin, which indicates that the surface waters are poorly buffered and are very susceptible to acidification. However, a summary of pH data for several sites in the basin in the water-quality section of the report showed that median pH values of streamflow ranged from 6.9 to 7.4, indicating relatively neutral pH conditions. Since pH data for the streams investigated do not indicate a problem with stream acidification at the present time, the streams are not designated as critical surface water areas.

Water quality of streams and reservoirs may be significantly impacted within the next thirty years if point and non-point sources of pollution in the Upper Ouachita Basin are significantly increased. However, impacts resulting from an increase in point-source discharges should be adequately controlled by regulations enforced by the Arkansas Department of Pollution Control and Ecology. Watershed protection projects and implementation of best management practices should reduce additional non-point pollution that might result from an increase in the amount of cropland in the basin.

Therefore, it is projected that no areas in this basin will be critical surface water areas within the next thirty years based on the previously discussed quality problems.

The possibility does exist for streams in the Upper Ouachita Basin to become critical surface water areas within the next thirty years as a result of streamflow acidification since the streams currently are so poorly buffered. However, the effects of acidic precipitation as well as the effects of point and non-point discharges on the acidity of streamflow in this area are not well defined. Therefore, prior to designation of future critical water areas in the basin due to acidification, it is recommended that an investigation be made of the sources contributing to streamflow acidity in the basin (precipitation, soils, point and non-point discharges) and a trend analysis of streamflow acidity be initiated to determine if streamflow quality is being degraded due to the low buffering capacities of the streams and to determine the extent of degradation. Information addressing the trends in streamflow acidification is necessary prior to the designation of future critical water areas in the basin as a result of streamflow acidification.

SURFACE-WATER SOLUTIONS AND RECOMMENDATIONS

The Upper Ouachita Basin has an abundant supply of water that is suitable for most uses. However, at times, the quantity and (or) quality of water necessary to satisfy all water users may not be available. Additional increases in population, industrial activity, and irrigation in the future may intensify the water problems that already exist in the Upper Ouachita Basin. It is imperative that the surface water supplies be managed and protected so that adequate water is available for all future water users in the basin.

State and Federal government programs exist which could provide assistance in solving some of the surface water resource problems that have been identified in the Upper Ouachita Basin. Information regarding some of these programs is summarized in Table 3-28. Purposes of these programs include flood control, water supply, wastewater treatment, and land use planning. The appropriate State or Federal agencies provide assistance in these programs which ranges from technical assistance to loans and grants. The administrating agencies listed in Table 3-28 can be contacted for an update of current program objectives and program guidelines.

Additional solutions and recommendations addressing problems which have been identified in the basin include: (1) alternate water sources, such as construction of water storage reservoirs and diversion of water from the Ouachita River; (2) reallocation of reservoir storage and (or) conjunctive management of reservoir releases; (3) flood prevention and floodplain management; (4) regulation and enforcement of municipal and industrial effluent discharges; and (5) identification and prioritization of streams with potential instream use problems. Best management practices (BMP's) can be used to reduce the water quality problems in the basin, and watershed protection projects can assist in the implementation of BMP's in agricultural areas. Water conservation, if practiced throughout the basin, should provide more water of a higher quality in the basin. Additional detailed information pertaining to these solutions and others for addressing the surface water problems in the basin is provided in the following sections of the report.

TABLE 3-28
SELECTED GOVERNMENT PROGRAMS TO AID IN SOLVING WATER RESOURCES PROBLEMS

NAME OF PROGRAM	PROGRAM OBJECTIVE	ADMINISTRATING AGENCY	TYPE OF ASSISTANCE
	(STATE)		
WATER RESOURCE CONSERVATION AND DEVELOPMENT INCENTIVES ACT OF 1985	TO ENCOURAGE CONSTRUCTION OF SOIL AND WATER CONSERVING STRUCTURES TO REDUCE THE USE OF GROUND-WATER AND POTENTIAL FURTHER DEPLETION.	AR SOIL AND WATER CONS. COMMISSION	TAX CREDIT
WATER DEVELOPMENT FUND	TO ASSIST LOCAL AND REGIONAL ENTITIES IN THE DEVELOPMENT OF URGENTLY NEEDED WATER DEVELOPMENT PROJECTS	ASWCC	LOANS AND GRANTS
WATER, SEWER, AND SOLID WASTE REVOLVING FUND	TO ASSIST CITIES, TOWNS, AND COUNTIES IN FINANCING THE CONSTRUCTION OF FACILITIES FOR WATER, SEWER, AND SOLID WASTE MANAGEMENT SYSTEMS.	ASWCC	LOANS AND GRANTS
WATER RESOURCES DEVELOPMENT GENERAL OBLIGATION BOND PROGRAM	TO LOAN MONEY RAISED BY THE ISSUANCE OF GENERAL OBLIGATION BONDS FOR WATER RESOURCES DEVELOPMENT PROJECTS TO LOCAL ENTITIES FOR CONSTRUCTION OF PROJECTS.	ASWCC	LOANS
ACT 81 OF 1957 AS AMENDED	TO MAKE ALLOCATION AMONG PERSONS TAKING WATER FROM STREAMS DURING PERIODS OF WATER SHORTAGE	ASWCC	TECHNICAL ASSISTANCE
	(FEDERAL)		
COMMUNITY FACILITIES LOANS	TO CONSTRUCT, ENLARGE, EXTEND, OR OTHERWISE IMPROVE COMMUNITY FACILITIES PROVIDING ESSENTIAL SERVICES TO RURAL AREAS	USDA, FHA	LOANS
COMMUNITY DEVELOPMENT BLOCK GRANTS	TO DEVELOP VIABLE URBAN COMMUNITIES, INCLUDING DECENT HOUSING, AND SUITABLE LIVING ENVIRONMENT AND EXPAND ECONOMIC OPPORTUNITIES, PRINCIPALLY FOR LOW AND MODERATE INCOME PERSONS	HUD-AIDC	GRANTS
NATIONAL FLOOD INSURANCE PROGRAM	TO ENABLE PERSONS TO PURCHASE INSURANCE ON REAL AND PERSONAL PROPERTY WHERE FLOOD PLAIN MANAGEMENT MEASURES HAVE BEEN ADOPTED AND ARE ENFORCED.	FEMA-ASWCC	INSURANCE
WATERSHED PROTECTION AND FLOOD PREVENTION ACT (PL-566)	ASSIST LOCAL ORGANIZATIONS IN PLANNING AND CARRYING OUT A PROGRAM FOR THE DEVELOPMENT, USE, AND CONSERVATION OF SOIL AND WATER RESOURCES	USDA, SCS	TECHNICAL AND FINANCIAL
RESOURCE CONSERVATION AND DEVELOPMENT	TO CARRY OUT A PROGRAM OF LAND CONSERVATION AND LAND UTILIZATION	USDA, SCS	TECHNICAL AND FINANCIAL
FLOOD CONTROL ACT OF 1948 AS AMENDED; SECTION 205	TO ASSIST LOCAL SPONSORS IN PLANNING, DESIGNING, AND CONSTRUCTING LOCAL FLOOD PROTECTION PROJECTS, INCLUDING DAMS, LEVEES, RESERVOIRS, AND CHANNELS	CORPS OF ENGINEERS, DEPT. OF THE ARMY	TECHNICAL, FINANCIAL AND CONSTRUCTION
WATER SUPPLY ACT OF 1958 AS AMENDED	TO INSURE A CONTINUING SUPPLY OF FRESH WATER, ADEQUATE FOR URBAN AND RURAL NEEDS, BY COOPERATING WITH STATE AND LOCAL INTEREST IN THE DEVELOPMENT OF WATER SUPPLIES FOR DOMESTIC, MUNICIPAL, AND INDUSTRIAL WATER STORAGE IN RESERVOIR PROJECTS. COST IS 100% NON-FEDERALLY FUNDED.	CORPS OF ENGINEERS, DEPT. OF THE ARMY	TECHNICAL AND CONSTRUCTION

Surface-Water Quantity Solutions and Recommendations

Availability

Availability of streamflow can be a problem on some stream reaches in the Upper Ouachita Basin, particularly during the summer and fall months when water use demands are generally highest. The availability problems are often a result of the natural variability of streamflow in the basin and not a result of significant water withdrawals. These seasonal low-flow problems could be alleviated by construction of off-stream storage reservoirs to capture the high winter and spring flows for use during the summer and fall periods. Act 417 of 1985 (Water Resource Conservation and Development Incentives Act) allows a tax credit for the construction and (or) restoration of surface water impoundments. The impoundment or water control structure must store a minimum of 20 acre-feet of water and be used for the production of food and fiber as a business (excluding aquaculture) or for domestic or industrial purposes. Impoundment tax credits are limited to fifty percent of the actual construction costs or $3,000 annually for a period of eleven years. To qualify for the tax credit, a construction permit must be obtained from the ASWCC, or proof of exemption from the permit must be provided as per the requirements of Act 81 of 1957, as amended.

Availability of streamflow can also be a problem downstream of the reservoirs in the basin. The pattern of water releases from reservoirs in the basin can cause low-flow problems immediately downstream of the reservoirs which may affect instream and off-stream uses of the water. Storage of water in reservoirs that are owned and operated by the Corps of Engineers in the Upper Ouachita Basin (Ouachita, DeGray, and Greeson) has been allocated for specific authorized purposes such as flood control, hydropower generation, and municipal water supply. A possible solution to the streamflow availability problems in the vicinity of reservoirs is the purchase of reservoir storage which would involve a reallocation of storage by the Corps of Engineers. Information regarding the reallocation procedures of the Corps is discussed in a subsequent section of the report.

Reallocation of storage in Corps reservoirs is an expensive proposition and may not be a feasible solution to limited low-flow problems downstream of reservoirs. A second possible solution to this problem would be an adjustment in the pattern of reservoir releases to support downstream uses in conjunction with the established authorized purposes of the reservoirs. For example, streamflow of the Ouachita River downstream of Blakely Mountain Dam during the 1981 water year was often only 20 cfs. The minimum amount of water released from the dam could be increased to support instream and off-stream uses of water below the reservoir while still maintaining releases at a level which would support the authorized purposes of the reservoirs.

In addition to the problems associated with the variability of streamflow in the basin, accessibility of surface water for use by individuals other than riparian landowners is also a problem. Two possible solutions to the problem of accessibility of surface water for non-riparians include on-farm storage and diversion of water from the Ouachita River.

A reservoir can be constructed from a portion of the least productive land to develop on-farm storage. Surface runoff will be stored to be used as needed. Effective irrigation water management can be practiced by having enough water available at the right times. It is recommended that special projects providing technical and financial assistance to install on-farm water supply systems be implemented in cropland areas of the basin.

Irrigation water for non-riparians in the vicinity of the Ouachita River may be available through diversion projects. Regulation of the Ouachita River by Lake Ouachita has resulted in higher base flows during low-flow periods. A portion of the discharge in the Ouachita River should be available for diversion projects within the basin. A preliminary plan for diverting water from the Ouachita River into the Black Branch Watershed (Friendship Bottoms) has been developed by the Soil Conservation Service. Other potential diversion projects should be studied and feasible projects should be constructed.

Reallocation of Reservoir Storage

A change in the operation of Corps of Engineer reservoirs is difficult to accomplish because a reallocation of storage requires the authorization of Congress. Also, the higher of the cost of benefits lost or the updated cost of construction of the storage must be paid along with operation and maintenance costs. Increases in population, industry, irrigation, and tourism are increasing the demand for water. Storage in Corps of Engineer lakes should be evaluated as a source for other water uses.

New reservoir construction has been deemed unsuitable by many special interest groups due to changing the environmental conditions of an area, displacing people, or creating favorable economic conditions for other special interest groups. Reallocation of storage in the Corps of Engineer lakes may often be a more feasible alternative when water supplies are needed.

Studies need to be originated, or reconsidered if existing, on the trade-offs of hydroelectric generation benefits versus recreation benefits. The exposure of submerged obstructions, such as rocks and timber, causes dangerous conditions for boaters. Public and private funds have been spent to develop recreation areas and businesses. These sites may become undesirable when separated from the lake by long mud flats caused by a lowered lake level. All of the above reasons could cause small scale economic hardships throughout the areas surrounding a lake. The scope of a study should outline at what lake level the recreational benefits lost will exceed the hydroelectric benefits gained. At this level the lake could be maintained, with only releases for downstream needs. It is desirable that an authorization of Congress be sought to insure that this lake level will be maintained at no cost to local or state government. However, a recreation use tax of some form may be necessary to allow a payback for construction, operation, and maintenance cost if the storage level must be bought. Another alternative would be to reduce flood control benefits. Holding lake levels higher in the early summer would buffer drawdowns throughout the summer. This action would require intense hydrologic and hydraulic studies. Downstream development may be such that the flood control benefits are above any degree of recreation benefits. This would especially be true if the loss of life is a possibility in reduced flood control benefits.

Downstream fisheries are impacted by releases from the dams. Because of the depth below lake surface of the releases, downstream water temperatures have been reduced. Native species were replaced with cold water species as a mitigation measure. It is unfortunate that mitigation measures are threatened by project operations. Flows can be reduced to only leakage from the dam, especially on weekends and holidays. (See Figure 3-27) Insufficient flows during the summer months can cause temperature rises that can be fatal to cold water species. Releases below the dam should be maintained at a minimum flow to maintain desirable temperature conditions. A determination of desirable flow quantities should be made in conjunction with studies of the recreation lake levels. Study objectives should identify the flow level that will maintain temperature at survivable levels during average summer temperature conditions. Benefit trade-offs should also be compared to ascertain the economic impacts.

With regard to purchasing storage, the Arkansas Soil and Water Conservation Commission supports the position of the Interstate Conference on Water Policy. Policy highlights follow:

> "When storage space is reallocated to water supply, the equitable payment is the actual cost of constructing this amount of storage space at the time of construction, plus the accrued interest charges since construction at the rate in effect at the time of construction. There is no acceptable rationale for requiring non-federal interests to pay these costs inflated to present price levels. When a new project is built, the water supply participants pay their share of the actual cost of construction, even though their use of water will extend 50 to 100 years into the future. No one would suggest that participants in new projects pay a share of the water supply cost as inflated decades into the future when water use will occur. It is equally unjustifiable to take the cost of a project previously constructed and inflate it to present cost levels."
>
> "In cases where storage space is being reallocated from a vendible purpose such as hydropower, it is appropriate for the non-Federal interests to reimburse the cost of structural facilities at the project which would no longer be used, less the portion of the cost of these facilities already paid for by the revenues received since project construction. This payment would be in addition to the payment for storage space."
>
> "The proposed requirement to pay the benefits foregone when storage is reallocated is not a requirement of Federal law and is inconsistent with the long-established compensation practices of federal agencies. In a Federal government project requiring the taking of property, the measure of compensation traditionally has been the value of the property taken - not the benefits foregone over some future time period. The benefits foregone argument may have some theoretical merit, but it has always been rejected as both difficult to calculate and impractical to implement." <44>

Currently, the Corps of Engineers Districts can reallocate 50,000 acre-feet or 15% of the lake storage without Congressional authorization, provided reallocation would not have a significant effect on other authorized purposes. Additionally, storage in excess of design purposes is available for some other beneficial use.

As previously suggested, the Corps of Engineers should re-evaluate the lakes. Study objectives should be to identify where recreational benefits surpass project purposes. The storage of each lake should be evaluated for excesses available for other uses. Districts should also outline the amount of storage they could reallocate (50,000 acre-feet or 15% of storage) and reevaluate their method of charging for the storage.

Flooding Recommendations

Flooding and drainage problems can be solved by structural and/or non-structural alternatives. Structural alternatives include such measures as channel improvement and floodwater detention dams while non-structural measures relate to land treatment and flood plain management. The potential for structural alternatives exists on at least seven watersheds in the basin although project activities have been initiated and suspended on three of these watersheds (See Federal Projects - USDA). Also, the potential for non-structural measures exists in the basin. Pine Creek (within the Terre Rouge Watershed), Deceiper Creek, and other areas have been identified as needing land treatment which will reduce flooding problems (See Water Quality Recommendations). The problem areas should be considered in the Arkansas Highlands River Basin Study which, among other things, will identify feasible flood control projects. The study will be conducted by the Soil Conservation Service during 1988 and 1989.

The United States Congress established the National Flood Insurance Program with the "National Flood Insurance Act of 1968". The program is administered by the Federal Insurance Administration (FIA) within the Federal Emergency Management Agency (FEMA) with the Arkansas Soil and Water Conservation Commission being the coordinating agency for Arkansas. Act 629 of 1969, enacted by the Arkansas General Assembly, authorized the cities, towns, and counties, where necessary, to enact and enforce floodplain management which will curtail losses in flood prone areas.

Surface-Water Quality Solutions and Recommendations

Surface water quality is generally satisfactory for most uses in the basin as discussed in the Water Quality Inventory section of this report. Proper management of the water resources in this basin should prevent further degradation of water quality. Management needs include implementing best management practices, regulation and enforcement, studying potential problems, and operating reservoirs to benefit downstream water quality.

Best Management Practices

Best Management Practices (BMP's) can be used effectively to reduce water quality problems from land use practices occurring in the basin. The problems of excessive erosion and degradation of surface runoff from confined feeding operations can be improved significantly by implementing the Agricultural BMP's shown in Table 3-29. The BMP's shown in Table 3-29 have been recommended by the local conservation districts located within the Upper Ouachita Basin, and may or may not be all inclusive.

TABLE 3-29
BEST MANAGEMENT PRACTICES
RECOMMENDED BY LOCAL CONSERVATION DISTRICTS

AGRICULTURAL BMP'S

1. Irrigation water management
2. Grade stabilization structures
3. Minimum tillage or no-till
4. Crop residue management
5. Conservation cropping system
6. Land use conversion
7. Land grading or smoothing
8. Establishment and management of permanent pasture or hayland
9. Pipe drops
10. Strip cropping
11. Waste management systems
12. Critical area plantings
13. Correct disposal of chemical containers
14. Poultry disposal pits
15. Waste management systems
16. Correct use of pesticide
17. Pasture planting
18. Rotation grazing

TABLE 3-29
BEST MANAGEMENT PRACTICES (CONTINUED)

AGRICULTURAL BMP'S (CONTINUED)

19. Soil testing and plant analysis
20. Terraces
21. Grassed waterways
22. Filter strips
23. Ponds
24. Weed and brush control
25. Winter cover crops
26. Diversions
27. Contour Farming
28. Gully control
29. Water facilities

FORESTRY BMP'S

1. Skid logs on contour
2. Proper construction and maintenance of access roads
3. Critical area treatment
4. Temporary vegetative cover
5. Firebreaks
6. Woodland improved harvesting
7. Tree planting
8. Woodland site preparation
9. Control undesirable species
10. Proper pesticide application
11. Woodland improvement
12. Control grazing
13. Debris basins
14. Contour planting on steep slopes
15. Stream zone management areas
16. Shape heavily damaged areas
17. Minimize mechanical damage
18. Contour strip cutting

CONSTRUCTION BMP'S

1. Stockpile and reuse topsoil
2. Temporary vegetation cover
3. Diversions
4. Sediment basins
5. Mulching
6. Critical area planting

TABLE 3-29
BEST MANAGEMENT PRACTICES (CONTINUED)

CONSTRUCTION BMP'(CONTINUED)

7. Establish permanent vegetation immediately after construction
8. Access road design
9. Grassed waterways
10. Soil testing and plant analysis
11. Lined waterways
12. Limited soil disturbance
13. Conservation of natural vegetation
14. Grade control structures
15. Water control structures
16. Traffic barriers
17. Site planning and proper timing of operations
18. Temporary vegetative cover

SUBSURFACE DISPOSAL BMP'S

1. Septic tanks and filter fields properly installed
2. Provide municipal sewer service to rural areas
3. Sanitary landfills
4. Recycling
5. Alternate systems for sewage disposal
6. Limit housing density
7. Proper site selection

URBAN RUNOFF BMP'S

1. Grade stabilization structures
2. Critical area treatment
3. Grassed waterways
4. Structures for water control
5. Sediment basins
6. Permanent vegetative cover
7. Flood control structures
8. Mulching
9. Water management
10. Diversions
11. Ponds

TABLE 3-29
BEST MANAGEMENT PRACTICES (CONTINUED)

MINING BMP'S

1. Mine land reclamation
2. Reshaping strip mines
3. Sediment retention basins
4. Revegetation
5. Mandatory reclamation plans for new mines
6. Topsoiling
7. Critical area treatment

HYDROLOGICAL MODIFICATION BMP'S

1. Grade control measures
2. Levees to prevent flooding
3. Streambank protection
4. Construction of irrigation reservoirs
5. Water return system in conjunction with reservoir
6. Properly designed channels
7. Stream channel stabilization
8. Revegetation at time of construction
9. Spoil spreading
10. Water control structures
11. Designing of side slopes to facilitate revegetation and maintenance
12. Clearing and snagging
13. Channel excavations
14. Construction of retarding basins
15. Deepen existing ditches
16. Low water weirs
17. Floodwater retarding structures
18. Floodways
19. Rock riprap

RESIDUAL AND LAND DISPOSAL SITES BMP'S

1. Critical area planting
2. Diversions
3. Filter strips
4. Fencing
5. Sanitary landfills

TABLE 3-29
BEST MANAGEMENT PRACTICES (CONTINUED)

RESIDUAL AND LAND DISPOSAL SITES BMP'S (CONTINUED)

6. Sites for disposal of pesticide containers
7. Solid waste collection systems
8. Disposal sites for removal of residual wastes
9. Refuse disposal plan
10. Roadside stabilization
11. Traffic barriers
12. Process waste daily
13. Critical area treatment
14. Cover old sites

ROAD BMP'S

1. Topsoiling ditch banks
2. Paving
3. Grade stabilization structures
4. Diversions
5. Critical area planting
6. Mulching
7. Lined waterways
8. Design, site selection to avoid steep areas
9. Water conveyance structures
10. Establishing and maintaining permanent vegetation
11. Planning and proper timing of operations
12. For unpaved roads, use material with low content of erosive particles for surface
13. Elimination of regular use of road grader for maintenance work

STREAMBANK BMP'S

1. Grade control structures
2. Streambank protection
3. Water control structures
4. Streambank vegetation including trees
5. Reshaping banks
6. Rock riprap
7. Water retarding structures
8. Concrete mats
9. Buffer zones

TABLE 3-29
BEST MANAGEMENT PRACTICES (CONTINUED)

GULLY BMP'S

1. Grade stabilization structures
2. Critical area planting
3. Sediment basins
4. Terraces
5. Diversions
6. Grassed waterways
7. Critical area shaping
8. Water control structures
9. Mulching
10. Fencing
11. Flood retarding structures

SOURCE: ARKANSAS SOIL AND WATER CONSERVATION COMMISSION <10>

Anticipated reductions in nonpoint pollution sources will enhance the environment by improving water quality throughout the region. It is expected that fisheries habitat and the opportunities for water-based recreation will be significantly improved. Wildlife habitat will be enhanced because of improved cover and diversity throughout the region.

In addition to enhancing the environment, implementation of the BMP's is expected to result in economic and social benefits. The resource base (land and water) will be protected. It is anticipated that agricultural income will be increased, additional recreational activities will become available, area residents will take more pride in their community, and social consciousness will be increased.

Watershed Protection: Erosion is a significant nonpoint source of pollution in the Upper Ouachita Basin. As shown in Table 2-10, there are approximately 1.7 million tons of sheet and rill erosion occurring each year. Although cropland covers only 4 percent of the area inventoried, it accounts for approximately 40 percent of total sheet and rill erosion in the basin. <85> Watershed protection projects establish land treatment measures on cropland to reduce erosion, sediment, and runoff. <91>

The Watershed Protection and Flood Prevention Act, PL 83-566, provides for the technical, financial and credit assistance by the Department of Agriculture to local organizations representing the people living in small watersheds. A watershed protection plan includes only on-farm land treatment practices for sustaining productivity, conserving water, improving water quality and reducing off-site sediment damages. <91> Practices might include such BMP's as conservation tillage, terraces, or even land use conversion. Participation within the watershed is voluntary and federal funds may be available.

For practices sustaining agricultural productivity and reducing erosion and sediment damages, cost share rates may be up to 65 percent of the cost of the enduring practices installed, or the existing rate of ongoing conservation programs, whichever is less. Payments for management practices such as conservation tillage, based on 50 percent of the cost of adoption are limited to a one-time payment not to exceed $10,000 per landowner. No more than $100,000 of cost-shared PL 83-566 funds may be paid to any one individual. <91>

The Soil Conservation Service completed its first watershed protection plan in 1986 which is in St. Francis County on Crow Creek. Currently, watershed protection plans are being developed for five other watersheds in Arkansas. Areas with potential for watershed protection projects are watersheds containing fragile soils that are highly erodible and are eroding at excessive rates. <87>

The fragile soils in this basin are found in the Blackland Prairie. When these highly erodible soils are cropped, there is a potential for excessive erosion rates, and watersheds in these areas may qualify for watershed protection projects. <87>

There are approximately 34,000 acres of cropland located in the Blackland Prairie area of the basin which is about 30 percent of the 117,800 acres of cropland in the basin. <85> This area is located in Hempstead, Nevada, and Clark Counties, and the cropland areas that exist on the Blackland Prairie may be considered as potential watershed protection projects. Pine Creek (within the Terre Rouge Watershed) and Deceiper Creek have been specifically identified by SCS personnel as being potential watershed protection projects. <30>

Confined Animal Feeding Operations: Waste management is the key to minimizing degradation of surface waters from confined animal feeding operations. Only three percent of the confined operations in the waste study area have installed waste management systems to effectively handle the waste. <90> Technical and financial assistance should be available for waste management systems, including dead animal disposal systems. Also, technical assistance is needed to provide guidance on proper application techniques. For areas where the ongoing program cannot provide the assistance (technical or financial) necessary to sufficiently handle the problems, targeted areas should be delineated and special assistance should be made available.

Act 168 of 1985 regulates poultry disposal. This regulation affects only on-farm disposal. According to this regulation, acceptable methods of disposal include burial or incineration, however; surface methods of disposal are not allowed. <8> This regulation is significant since surface disposal was a common practice identified in the 1983 SCS Inventory. <93>

Regulation and Enforcement

The Arkansas Department of Pollution Control and Ecology (ADPC&E) has powers of regulation and enforcement over municipal and industrial dischargers in the State. Major additions in personnel to the ADPC&E enforcement division over the past several years have allowed for improvements in the quality and quantity of enforcement actions. Letters giving notice of violations have been mailed resulting in many problems being corrected voluntarily. Administrative actions have been taken against other dischargers. <6> While enforcement of regulations is necessary, a strong information and education program to increase public awareness might prevent some discharge problems before they occur.

Low Buffering Capacities

A potential for acidification of the streams and lakes in the Upper Ouachita Basin exists as discussed in the Water-Quality Problems section of this report. In order to better quantify the magnitude of the problem, a study to determine trends in pH is recommended to determine if acidification is already occurring.

Reservoir Operation

The tailwater of Lake Greeson has low dissolved oxygen concentrations during late summer because the intake structure is at an elevation that coincides with the metalimnetic dissolved oxygen minima that occurs in the lake. During late summer, water with higher dissolved oxygen concentrations can be found both above and below the elevation of the intake structure. This situation could be improved by either changing the elevation of intake or by changing the operation of the reservoir. <55> An operational change would seem to be the more feasible alternative. For example, maintaining the elevation of the reservoir at a higher elevation during early summer might cause the metalimnetic dissolved oxygen minima to develop at a higher elevation, and therefore, allow water with higher dissolved oxygen concentrations to be released from the reservoir. <55>

The upper level of the intake structure on Lake DeGray should be used to release water with high dissolved oxygen concentrations. Also, efforts should be made to maintain minimum release rates necessary to keep dissolved oxygen concentrations at acceptable levels.

Lake Ouachita could possibly be converted to a warm water release in order to increase the "flushing action" of the epilimnion of Lake Hamilton and Lake Catherine. This might flush nutrient rich or polluted water out of the system. However, from a fishery standpoint, constant flushing of the epilimnion would continuously remove water in which the primary productivity is occurring. <55> This impact on the fishery might cause more of a problem than presently exists. The cold water release situation that now exists may be the most desirable situation. A detailed study should be undertaken to predict changes that would occur in the system before any operational changes in the Ouachita - Hamilton - Catherine system are made.

Conservation

Water conservation has not been emphasized in this basin because of the high average annual rainfall as observed at selected recording stations (Mena, 52.2 inches; and Camden, 50.3 inches). As mentioned earlier in this report, an average of 53.3 million gallons of water are used in the study area each day for all purposes and the demand for water continues to escalate.

Water conservation is essential to the future well being of all Arkansans. Although not sufficient in itself, conservation does offer, at least in part, a means of helping to alleviate some of the basic problems.

Drought periods within the basin emphasize the need for conservation. While the average annual rainfall in the area is high, the erratic monthly rainfall patterns at times cause some streams to cease flowing and storage reservoirs to dry up or become dangerously low for most purposes. Conservation practiced during dry periods and the sense of emergency that prevails during droughts are soon forgotten in times of plentiful rainfall.

Agriculture

According to Table 2-1, only three percent of the land in this basin is cropland, and irrigation accounts for approximately 26 percent of the total water use in the study area as shown in Table 3-16. There is potential for a significant increase in the amount of water used for agricultural purposes (See Water Use Projections).

Efforts should be made to make use of the results from the East Arkansas Water Conservation Project. Information from this five year project, which is being administered jointly by SCS, USGS, and ASWCC, will promote irrigation water management.

Irrigation water management includes maintaining high infiltration rates, using efficient delivery systems, choosing proper application methods, achieving high application efficiencies, employing irrigation scheduling, and obtaining sound engineering planning. Each one of these elements of irrigation water management is extremely important in order to make efficient use of our water resources.

With limited groundwater supplies available, development of surface water is necessary to provide agricultural water for irrigation. Development of on-farm water supply systems will be necessary for most areas of this basin. A portion of the least productive land can be converted into a reservoir to recover tailwater, and an irrigation reservoir will be developed. Water will be conserved by recovering tailwater, and additional water will be available for irrigation by storing winter runoff in the reservoir. Although the initial construction is expensive, state tax credits are now available through Act 417, "The Water Resource Conservation and Development Incentives Act of 1985".

Public Supply

Approximately 16.5 million gallons of water per day were used for public supplies during 1980 which is 31 percent of the total quantity of water used in the study area. The water use projections presented in Chapter 1 indicate that there could be a significant increase in the quantity of water used for public supplies. Approximately 40 MGD will be needed within the basin, and as much as 250 MGD may be needed in the future for public supply systems in the basin and in adjacent areas.

Significant quantities of water can be conserved by individuals if water saving techniques are practiced in the home. Several water conservation practices include installing water-use restrictors, checking for leaks, and watering lawns during the coolest part of the day. There are many conservation measures that can save water in the home.

Wastewater reuse and recycling

Wastewater or sewage effluent discharged by municipalities and industries should be recognized as a valuable resource that can be reused or recycled to help meet growing water requirements.

Proponents list as pluses for reuse savings in money and energy, particularly in the cost of treating wastewaters to make them acceptable for discharge. However, due to the availability of high quality water, most municipalities thus far have not sought to develop a market for treated wastewater, but simply dispose of it as quickly as possible. <54>

Water pricing

As with any other commodity, increasing the price is a proven and effective means of reducing water consumption. Pricing techniques to encourage the conservation of water rely primarily on the premise that as the price increases, the quantity purchased decreases. The effect of such a price change on quantity is called demand elasticity.

There is substantial elasticity in the demand for water. The price affects the amount consumers will demand; if the price goes up, consumers will use less water. <54>

Determination of Instream Flow Requirements

Determination of instream flow requirements for streams in the basin is an important first step in ensuring the maintenance of suitable flows to support these important uses. However, three major problems that have been encountered in the determination of instream flow requirements for streams in the basin are the lack of sufficient data, the inflexible methodologies and the effects of reservoir regulation. These problems make it very difficult at the present time to determine instream flow requirements for all streams in the Upper Ouachita Basin.

A solution to the problem of determining instream flow requirements for streams in the basin is to first prioritize the streams to determine those which currently have instream use problems or have the highest potential for instream problems. Once these streams in the basin are identified, determination of instream flow requirements for these priority streams is a much more realistic and manageable task than determining instream uses for all streams in the basin.

The South Carolina Water Resources Commission has taken this approach in their Instream Flow Study <22>. The South Carolina Instream Flow Study is divided into two phases. Phase I includes the identification and listing of streams for which instream flow requirements need to be established. Phase II entails the determination of instream flow needs to protect instream uses in the priority streams identified in Phase I. In the following paragraphs, a summary of their methodology is presented as a recommendation for determining instream flow requirements for streams in the Upper Ouachita Basin.

In Phase I of the South Carolina Instream Flow Study, stream segments in need of streamflow protection were identified and ranked in priority order using the following methods and procedures:

(1.) Stream segment delineation - All permanent streams in the study area were divided into discrete segments. Most of the smaller streams were represented by a single segment, however, larger streams were subdivided into two or more segments based on segment length and significant tributary inflow.

(2.) Data management - Streamflow and water use data for each segment were assimilated and several values were calculated for the stream ranking process (use impact, dam impact, flow variability, protection need, significance value, and overall rating value).

(3.) Stream ranking procedure - A mathematical procedure was developed to rank streams in need of flow protection. For each stream segment in the study area, two numerical values were determined: the protection need value and the significance value. The protection need value is an indicator of the relative need for low-flow protection based on natural streamflow conditions and man's activities within the segment. The significance value indicates the relative importance of each segment based on instream and offstream use activities occurring on the segment. The product of multiplying these two values together equals the overall rating value of a stream. The potential for a stream to experience instream flow problems is proportional to the magnitude of its overall rating value. Therefore, the higher the overall rating value, the greater the need for streamflow protection. The highest priority streams were selected by identifying a significant break point in the ranking of overall rating values. Water use activities, flow characteristics, and existing water use problems of each segment were also considered in selecting the highest priority streams.

(4.) Determination of protection need values - The natural variability of the streamflow and the potential impacts from man's activities in and along the stream were incorporated in the evaluation of streams for need of flow protection. Streams with poorly sustained baseflow and/or relatively extensive offstream water use compared to flow, are at a high risk of having instream use problems. Based on this premise, the following empirically derived equation was used to evaluate the need for flow protection:

$P = A\,(1 + B + C)$ where:

P = Protection need value
A = Average flow/$7Q_{10}$
B = Total water withdrawal/$7Q_{10}$ (100)
C = Reservoir storage/$7Q_{10}$

The higher the protection need value the greater the need for streamflow protection.

(5.) Determination of significance values - Significance was defined as relative importance based on the extent of instream and offstream use occurring within each stream segment. Each stream segment was assessed for the occurrence and extent of use for each of the following water use categories:

(1) Industrial water withdrawals
(2) Municipal water withdrawals
(3) Agricultural water withdrawals
(4) Thermoelectric power water withdrawals
(5) Hydroelectric power water use
(6) Commercial fishery
(7) Recreational fishery
(8) Commercial navigation
(9) Recreational navigation
(10) Maintenance of endangered or threatened species
(11) Wastewater assimilation (water quality)
(12) Unique aesthetic and ecological characteristics

A separate water use value (see below) was determined for each use category for all stream segments. The significance value for a given stream segment was equal to the sum of all water use values determined for that segment.

(6.) Water use values - A common scale of water use values, ranging from 0 to 5, was applied to all use categories. A single water use value was determined for each of the 12 use categories occurring on each stream segment. The water use value for each use category indicates the relative importance of that use within a given stream segment to that same use in all other stream segments. The greater the relative degree of use, the higher the water use value.

Water use values were determined for a given use category by first determining the degree of that use for each stream segment. Then for each use category, stream segments were ranked from lowest to highest. If no use occurred, a value of zero was assigned to the segment. Use values of 1-5 were evenly assigned to the segments with use by assigning a value of one to the first 20 percent of segments with the lowest use for that category, then a value of two for the next highest 20 percent of segments, and so on. Segments with the same degree of use always received the same water use value.

(7.) Results - The result of the stream ranking procedure previously discussed was a priority list of streams that are in the greatest need of establishing instream flow requirements in the study area. The inclusion of a stream segment on the list does not necessarily indicate that instream use problems occur, but rather that the potential for such problems is greater for these streams than for most other streams in the study area.

In the second phase of the Instream Flow Study, the priority streams identified in Phase I are studied in more detail to determine instream flow levels that will adequately assure the "continued viability" of recognized uses within their channels. The three major problems previously identified for determining instream flow requirements (lack of sufficient data, inflexible methodologies, and effects of reservoir regulation) should be significantly easier to deal with since only the priority streams would be evaluated. For instance, the prioritization of streams would limit the areas necessary for evaluation, and additional data collection necessary to quantify instream flow requirements could be concentrated in the identified priority areas. In addition, the methods used to determine instream flow requirements could be more easily modified to address the priority streams rather than attempting to develop methods that are applicable for the entire basin or the entire state. Finally, the problems with the effects of reservoir regulation on instream uses could be more rigorously defined in priority areas. A more complete analysis of the reservoir effects on instream uses may be adequate to promote changes in reservoir releases to support instream uses in conjunction with the established authorized purposes of the reservoirs.

Identification of these priority segments is an important first step in addressing the maintenance of instream uses. However, protection measures can not be limited to these segments alone, as if they are isolated from the rest of the river and stream systems. By the very nature of flowing waters, actions which impact flows in any single segment will also impact flows downstream. Consumption of flows in small headwater streams may not greatly affect uses on each individual stream, but the cumulative loss of water from several small streams may severely affect streamflows in larger downstream segments. Therefore, to provide adequate long-term protection of instream uses, a statewide approach to manage flows in all streams, regardless of size, must be considered.

CHAPTER IV

GROUNDWATER

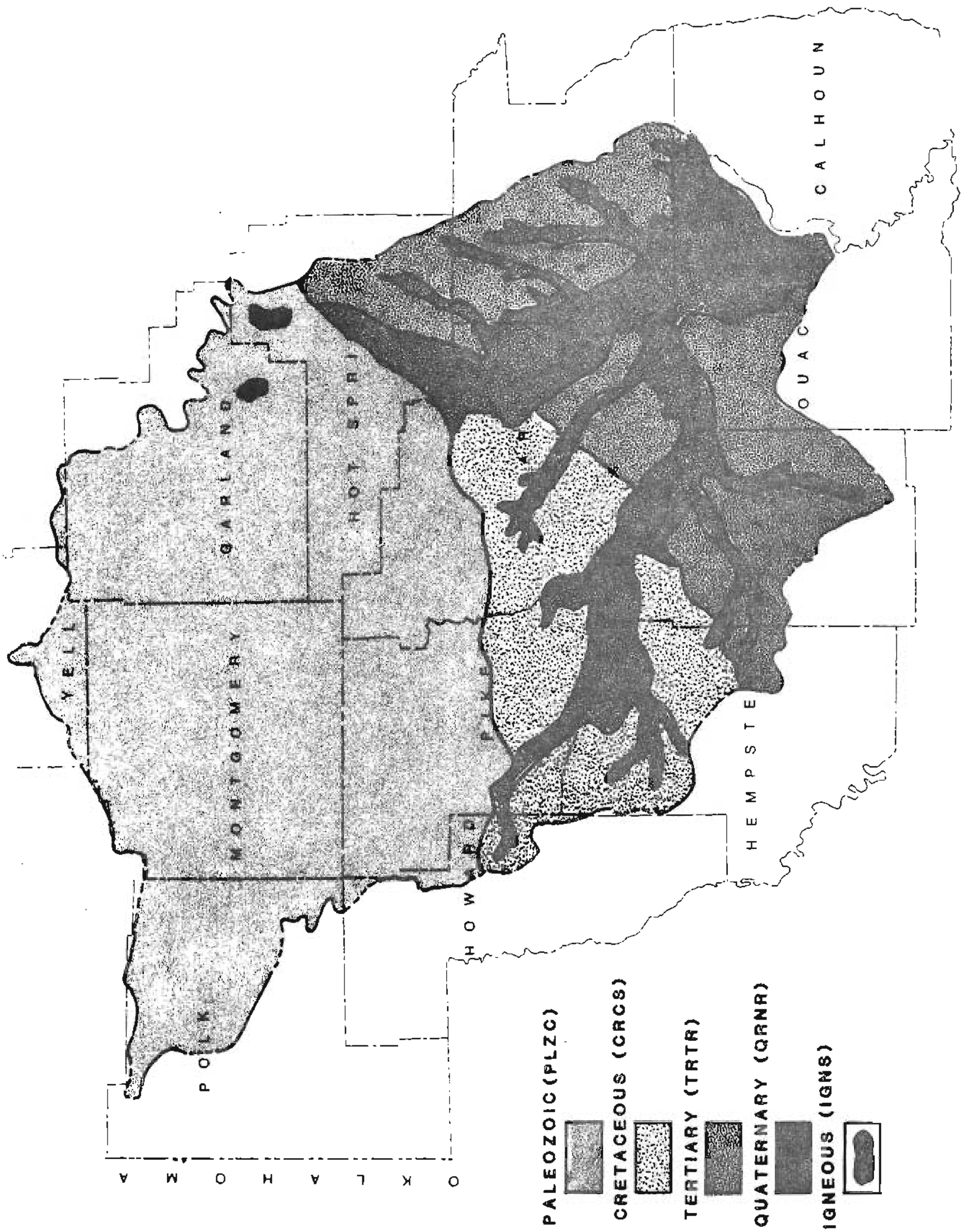
INTRODUCTION

Geologic units from the Paleozoic, Mesozoic and Cenozoic Eras are present on the surface as an outcrop and in the subsurface of the Upper Ouachita Basin. Rocks of Paleozoic Age outcrop in the northern half of the basin, as shown in Figure 4-1. These rocks extend southward as a subcrop under the entire basin. Formations from the Cretaceous System (Mesozoic Era) outcrop to form a wedge in the west-central part of the basin (Figure 4-1), and are covered by Quaternary alluvium along Terre Noire Creek and the Little Missouri River. The southern half of the basin is underlain by a series of northeast-southwest trending layers of unconsolidated and semi-consolidated sediments which range in age from lower Cretaceous to Holocene. The sediments are composed of chalk, marl, calcareous clay, sand and gravel (Cretaceous-age units), lignite, clay, silt, and sand (Tertiary-age units), and clay, silt, sand and gravel (Quaternary-age deposits). Quaternary (Holocene) alluvium forms a relatively thin layer on the surface and generally outlines the major stream systems. More detailed information describing the geologic units of the Upper Ouachita Basin is summarized in the stratigraphic column in Table 4-1.

The sources of groundwater closely correlate with the outcropping units. (See Figure 4-2) The sources of groundwater in the northern half of the basin are limited to consolidated hard rock formations with no other units available. Among the fifteen layers (geologic formations) that exist in the southern half of the basin, seven are considered to be significant as sources of ground-water supply. These include the Trinity Group, Tokio Formation, Nacatoch Sand, Wilcox Group, Carrizo Sand, Sparta Sand, and Quaternary deposits. These formations contain fresh water in their outcrop areas and for varying distances downdip, beneath the surface. The downdip extent to which each formation contains fresh water as well as contours indicating the elevation of the base of fresh water in a given formation are shown in Figure 4-2. Formations beneath those shown contain highly mineralized water. The Quaternary deposits occur on the surface and serve as an aquifer along the major stream systems. <47>

figure 4-1

OUTCROPPING UNITS
UPPER OUACHITA RIVER BASIN



SOURCE: Modified from Haley and Others, ⟨35⟩

TABLE 4-1
GENERALIZED STRATIGRAPHIC COLUMN FOR THE UPPER OUACHITA BASIN
SEDIMENTARY ROCKS

ERATHEM	SYSTEM	SERIES	GROUP	FORMATION	DESCRIPTION	WATER-BEARING CHARACTERISTICS
CENOZOIC	QUATERNARY	HOLOCENE AND PLEISTOCENE		ALLUVIUM AND TERRACE DEPOSITS	RECENT RIVER ALLUVIUM AND TERRACE DEPOSITS: GRAVEL AT THE BASE GRADING UPWARD TO SAND, SILT AND CLAY. THICKNESS VARIES FROM 0 TO APPROXIMATELY 150 FEET IN THE BASIN.	YIELDS UP TO 240 GPM ALONG THE OUACHITA RIVER IN CLARK COUNTY
	TERTIARY	EOCENE	CLAIBORNE	SPARTA SAND	LENTICULAR SAND BODIES INTERSPERSED WITH THIN BEDS OF SANDY TO SILTY CLAY AND LIGNITE. THICKNESS VARIES FROM A FEATHER EDGE AT THE UPDIP LIMIT OF THE OUTCROP AREA TO SLIGHTLY LESS THAN 200 FT. IN OUACHITA COUNTY.	YIELDS RANGE FROM 300 TO 700 GPM IN THE OUTCROP ZONE.
				CANE RIVER	SAND, CLAY, GLAUCONITE, LIGNITE AND IRONSTONE AS MUCH AS 400 FT. THICK	YIELDS RANGE FROM 50 TO 100 GPM.
				CARRIZO SAND	SAND, VERY FINE TO MEDIUM AND CARBONACEOUS, LIGNITIC CLAY. REACHES A MAXIMUM THICKNESS OF 200 FT. IN DALLAS CO. AND AVERAGES 100 FEET THROUGHOUT AREA OF OCCURRENCE IN THIS BASIN.	YIELDS UP TO 100 GPM IN THE BASIN
			WILCOX		THICKNESS VARIES FROM 200 FT. TO A MAXIMUM OF 400 FT. IN DALLAS CO.	YIELDS GENERALLY LESS THAN 25 GPM IN THE BASIN
		PALEOCENE	MIDWAY		MASSIVE BEDDED CALCAREOUS CLAY WITH MINOR QUANTITIES OF FRACTURED LIMESTONE IN THE LOWER HORIZONS. MAY REACH A THICKNESS OF 300 FT. IN BASIN	DOES NOT YIELD WATER TO WELLS IN THE BASIN
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS		ARKADELPHIA MARL	DARK GRAY FOSSILIFEROUS MARL AS MUCH AS 100 FT. THICK	DOES NOT YIELD WATER TO WELLS
				NACATOCH SAND	SAND AND CALCAREOUS CLAY AS MUCH AS 600 FT. THICK	YIELDS AS MUCH AS 200 GPM IN THE BASIN.
				SARATOGA CHALK	WHITE SANDY CHALK, SANDY MARL AND CLAY REACHING A MAXIMUM THICKNESS OF APPROXIMATELY 50 FT.	NON-WATER BEARING
				MARLBROOK MARL	DARK MAHL APPROXIMATELY 100 FT. THICK, MAXIMUM	NON-WATER BEARING
				ANNONA CHALK	CALCAREOUS CLAY AND CHALK. MAXIMUM THICKNESS OF 100 FT.	NON-WATER BEARING
				OZAN	PRINCIPALLY CALCAREOUS CLAY WITH INTERBEDDED GLAUCONITIC SAND BED NEAR BASE. MAXIMUM THICKNESS OF APPROXIMATELY 150 FT.	YIELDS LESS THAN 50 GPM IN CLARK COUNTY
				BROWNSTOWN MARL	CALCAREOUS CLAY, SAND AND SOME LIMESTONE REACHING A THICKNESS OF APPROXIMATELY 150 FT.	YIELDS SMALL QUANTITIES IN THE OUTCROP AREA
				TOKIO	INTERBEDDED CLAY AND LIGNITE AS MUCH AS 200 FT. THICK	YIELD UP TO 300 GPM IN THE BASIN

TABLE 4-1 CONTINUED
GENERALIZED STRATIGRAPHIC COLUMN FOR THE UPPER OUACHITA BASIN
SEDIMENTARY ROCKS

ERATHEM	SYSTEM	SERIES	GROUP	FORMATION	DESCRIPTION	WATER-BEARING CHARACTERISTICS
MESOZOIC	CRETACEOUS	UPPER CRETACEOUS		WOODBINE	CLAY SAND, GRAVEL AND VOLCANIC MATERIAL WITH A MAXIMUM THICKNESS OF 350 FT.	NON-WATER BEARING
			TRINITY		COMPOSED OF ALTERNATING LAYERS OF GRAVEL, LIMESTONE, SHALE, CLAY AND SAND. SAND UNIT AT TOP OF GROUP IS MOST PRODUCTIVE ZONE. MAXIMUM THICKNESS OF GROUP IS APPROXIMATELY 1500 FEET.	YIELDS GENERALLY LESS THAN 50 GPM IN WESTERN HEMPSTEAD CO.
PALEOZOIC	PENNSYL-VANIAN	ATOKAN		ATOKA	SHALE, SILTY, MICACEOUS, DARK TO BLACK, AND HARD MASSIVE AND THIN-BEDDED LIGHT-GRAY TO GREENISH-GRAY, COMMONLY RIPPLE-MARKED SANDSTONE; NEAR BASE IS COARSE GRAINED AND CONTAINS SOME GRIT. SANDSTONE AND SHALE PRESENT IN NEARLY EQUAL AMOUNTS BUT SHALE GENERALLY PREDOMINANT.	THE NATURE OF MOVEMENT AND STORAGE WITHIN ALL PALEOZOIC UNITS IS SIMILAR. WATER OCCURS IN SECONDARY OPENINGS SUCH AS CRACKS, FISSURES AND SEPARATED BEDDING PLANES. MOST OF THE UNITS WILL YIELD FROM 2-7 GPM, HOWEVER, SOME LARGE PRODUCERS UP TO 350 GPM HAVE BEEN REPORTED. THE BIGFORK CHERT IS THE BEST AQUIFER IN THE PALEOZOIC OUT-CROP ZONE. OTHER UNITS THAT ARE RELATIVELY GOOD AQUIFERS ARE THE CRYSTAL MOUNTAIN SANDSTONE, THE ARKANSAS NOVACULITE AND THE LIMESTONE INTERVALS WITHIN THE COLLIER, MAZARN AND WOMBLE SHALE.
		MORROWAN		JOHNS VALLEY SHALE	SNALE AND CLAYSTONE, HIGHLY SHEARED AND CRUMPLED, GRAY AND TAN TO DARK-GRAY; CONTAINS THIN DISCONNECTED BEDS AND LENSES OF SANDSTONE, SILT-STONE, ANU LIMESTONE, AND ERRATIC BLOCKS OF PRE-PENNSYLVANIAN FORMA-TIONS.	
				JACKFORK SANDSTONE	SANDSTONE, FINE TO COARSE-GRAINED MASSIVE, LIGHT-GRAY TO BROWN, QUARTZITIC IN PART, AND A FEW MINOR BEDS OF GREEN FISSILE SHALE; CONTAINS SOME MILLSTONE GRIT NEAR BASE.	
	MISSISSIPPIAN			STANLEY SHALE	SHALE, BLUISH-BLACK TO BLACK, FISSILE, AND GREENISH QUARTZITIC COMPACT FINE-GRAINED SANDSTONE; CONTAINS NOVACULITE CONGLOMERATE AND SEVERAL BEDS OF ACIDIC VITRIC TUFF NEAR BASE. LOWER PART OF SHALE LOCALLY IS SLATY.	
	MISSISSIPPIAN AND DEVONIAN			ARKANSAS NOVACULITE	UPPER MEMBER: NOVACULITE, MASSIVE, LIGHT GRAY TO BLUISH-BLACK, CALCAR-EOUS. MIDDLE MEMBER: NOVACULITE, THIN-BEDDED, DARK, AND INTERBEDDED BLACK CLAY SHALE. LOWER MEMBER: NOVACULITE, DENSE, MASSIVE, WHITE.	
	SILURIAN			MISSOURI MTN. SHALE	SHALE, HARD, RED AND GREEN; CON-TAINS THIN BEDS OF CHERT AND SAND-STONE LOCALLY, A BASAL CHERT- AND LIMESTONE-PEBBLE CONGLOMERATE.	

TABLE 4-1 CONTINUED
GENERALIZED STRATIGRAPHIC COLUMN FOR THE UPPER OUACHTIA BASIN
SEDIMENTARY ROCKS

ERATHEM	SYSTEM	SERIES	GROUP	FORMATION	DESCRIPTION	WATER-BEARING CHARACTERISTICS
PALEOZOIC	SILURIAN			BLAYLOCK SANDSTONE	SANDSTONE, FINE-GRAINED, COMPACT, LIGHT TO DARK-GRAY OR GREEN, AND DARK-GRAY TO BLACK MICACEOUS FISSLE SHALE. THE SANDSTONE GENERALLY IS THIN AND EVEN BEDDED, AND LOCALLY CONTAINS ABUNDANT QUARTZ VEINS.	THE NATURE OF MOVEMENT AND STORAGE WITHIN ALL PALEOZOIC UNITS IS SIMILAR. WATER OCCURS IN SECONDARY OPENINGS SUCH AS CRACKS, FISSURES AND SEPARATED BEDDING PLANES. MOST OF THE UNITS WILL YIELD FROM 2-7 GPM, HOWEVER, SOME LARGE PRODUCERS UP TO 350 GPM HAVE BEEN REPORTED. THE BIGFORK CHERT IS THE BEST AQUIFER IN THE PALEOZOIC OUT-CROP ZONE. OTHER UNITS THAT ARE RELATIVELY GOOD AQUIFERS ARE THE CRYSTAL MOUNTAIN SANDSTONE, THE ARKANSAS NOVACULITE AND THE LIMESTONE INTERVALS WITHIN THE COLLIER, MAZARN AND WOMBLE SHALE.
	ORDOVICIAN			POLK CREEK SHALE	SHALE, FISSILE, GRAPHITIC, BLACK, MOSTLY SOFT, BUT SLATY NEAR BASE; CONTAINS ABUNDANT GRAPTOLITES.	
				BIGFORK CHERT	CHERT, GRAY TO BLACK, THIN-BEDDED, MUCH SHATTERED; CONTAINS THIN INTERBEDDED LAYERS OF BLACK SILICEOUS AND CARBONACEOUS SHALE AND SOME BLACK SILICEOUS LIMESTONE.	
		LOWER ORDOVICIAN		WOMBLE SHALE	SHALE, BLACK AND GREEN, AND SOME FINE-GRAINED SANDSTONE AND BLUE-BLACK LIMESTONE.	
				BLAKELY SANDSTONE	SHALE, BLACK AND GREEN, ARGIL-, LACEOUS, AND INTERBEDDED GRAY SILICEOUS MEDIUM-GRAINED SANDSTONE CONTAINING DARKER CALCAREOUS LAYERS. ALTHOUGH SHALE PREDOM-INATES, THE SANDSTONE FORMS CONSPICUOUS RIDGES.	
				MAZARN SHALE	SHALE, CLAYEY, FISSILE, BLACK AND GREEN; CONTAINS THIN LAYERS OF GRAY FINE-GRAINED SANDSTONE AND BLUISH-BLACK LIMESTONE.	
				CRYSTAL MTN. SANDSTONE	SANDSTONE, COARSE-GRAINED, MASSIVE, WHITE TO LIGHT GRAY; BEDS WITH CALCAREOUS CEMENT WEATHER BROWN; CONTAINS MANY QUARTZ VEINS AND CRYSTALS.	
				COLLIER SHALE	SHALE, SOFT, BLACK, GRAPHITIC; CONTAINS THIN BEDS OF DARK LIME-STONE AND SOME DENSE BLACK CHERT.	

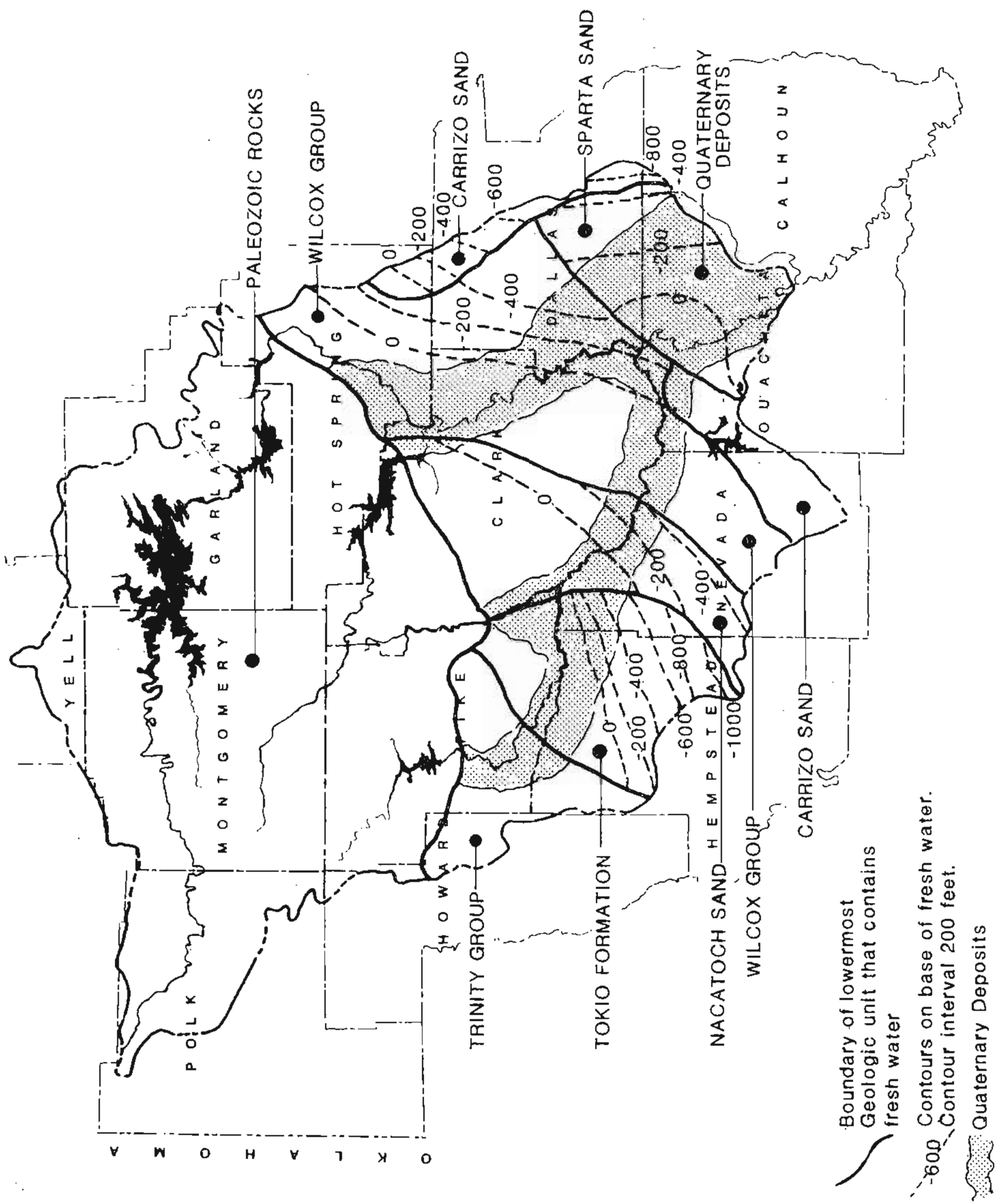
IGNEOUS ROCKS

		CRETACEOUS			LARGE BODIES THAT INCLUDE NEPHELINE SYENITE AND PHONOLITE	YIELD ABOUT 10 GPM FROM FRACTURES AND JOINTS.

SOURCES: <1, 2, 15, 18, 34, 35, 48, 57, 59, 65, 67>

figure 4-2

EXTENT OF FRESH WATER IN GEOLOGIC FORMATIONS USED AS SOURCES OF GROUNDWATER



SOURCE: Lower Mississippi Region Comprehensive Study Coordinating Committee. ⟨47⟩
Cushing⟨19⟩

Groundwater Withdrawals

Groundwater withdrawals in the study area in 1980 amounted to 12.97 MGD which represents less than one percent of the groundwater withdrawn from all formations statewide. Pumpage from the Paleozoic rocks (4.58 MGD) and the Nacatoch Sand (2.41 MGD) accounted for 54% of the total groundwater withdrawn in the study area in 1980 (See Table 4-2).

Paleozoic withdrawals in the study area are equal to approximately 6% of the statewide Paleozoic use. Paleozoic rocks outcrop in approximately half of the Upper Ouachita Basin. The relatively limited withdrawals from the Paleozoic rocks in the basin indicate the limited availability of groundwater in this area as compared with groundwater availability in other Paleozoic outcrop areas, such as the northwestern part of the State. In contrast, the Nacatoch Sand has a very limited outcrop-use area in the Upper Ouachita Basin, however, the study area withdrawals account for approximately 37 percent of the total statewide use from the Nacatoch Formation. <40>

The remaining 47% of groundwater withdrawals in the study area were from ten other units as follows: Sparta Sand (1.75 MGD), Tokio (1.56 MGD), Wilcox (.91 MGD), Quaternary (.56 MGD), Ozan (.52 MGD), Cane River (.39 MGD), Carrizo (.13 MGD), Cockfield (.08 MGD), Midway (.06 MGD), and Trinity Group (.02 MGD). <40> Additional information on groundwater withdrawals in the study area is compiled by county in Table 4-2 for each aquifer.

Except for the Quaternary deposits and the Wilcox Formation, groundwater use from aquifers in the study area has increased from 1965 to 1980, as shown in Figure 4-3. Withdrawals from Paleozoic rocks, for example, have increased from 1.94 MGD in 1965 to 4.58 MGD in 1980. The largest percentage increase was in the Ozan Formation from 0.13 MGD to 0.52 MGD. Use from the Quaternary aquifer has been variable; increasing from 1965 to 1970, declining in 1975 and rebounding to 1965 levels in 1980. Withdrawals from the Wilcox have also been variable with use declining in 1970 and then increasing in 1975 and 1980. <31, 32, 33, 40>

Groundwater use by county has generally increased from 1965 to 1980 with some variability for separate five year periods. (See Table 4-3) Total groundwater withdrawals in the area increased 65% from 1965 to 1970. Between 1970 and 1975, total groundwater withdrawals increased a meager 6%, but

TABLE 4-2
GROUNDWATER WITHDRAWALS FROM THE STUDY AREA IN 1980 - BY AQUIFER
(MGD)

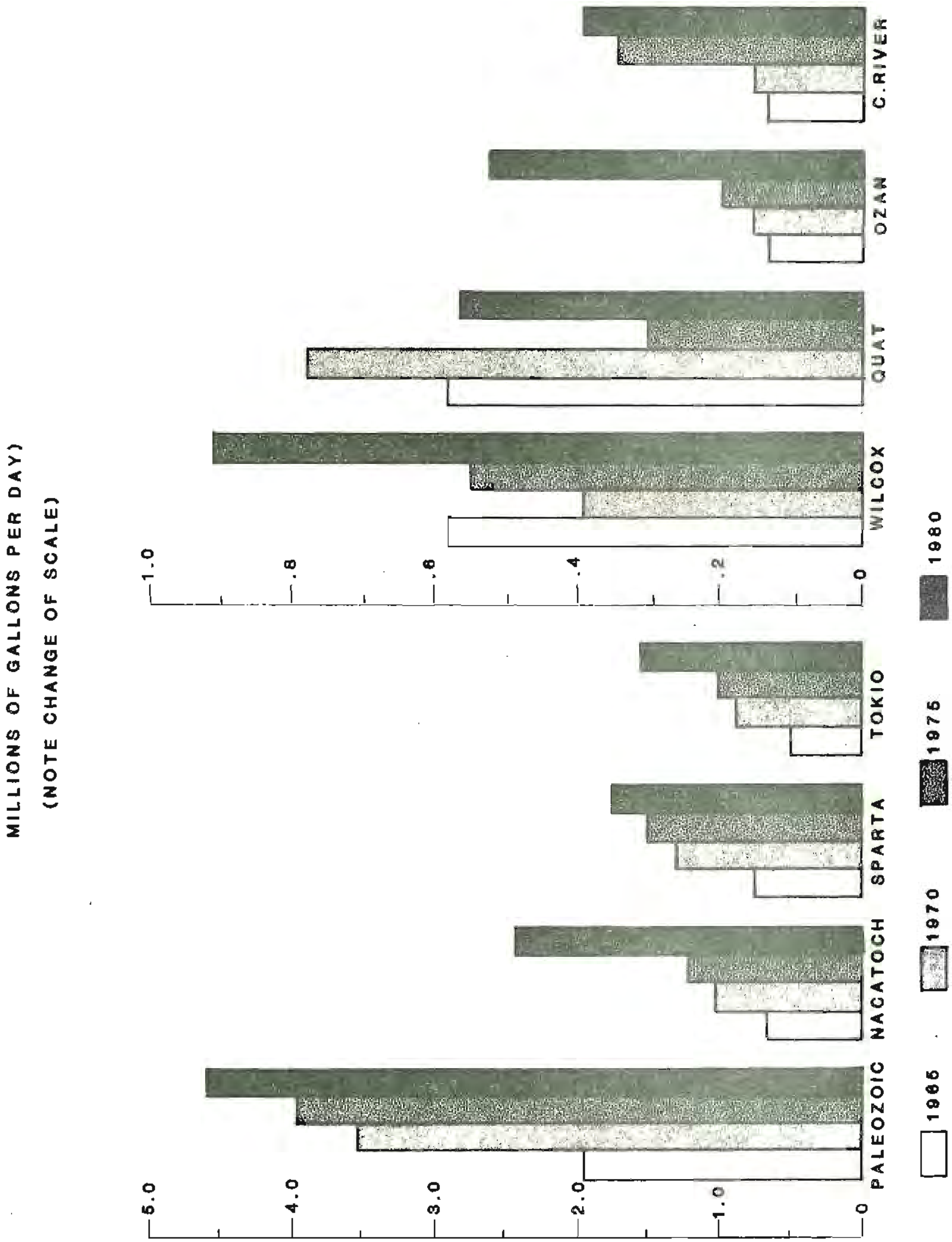
	PALEOZOIC	NACATOCH	SPARTA	TOKIO	WILCOX	QUATERNARY	OZAN	CANE RIVER	CARRIZO	COCKFIELD	MIDWAY	TRINITY	TOTALS
CLARK	.28	1.73	--	.06	.52	.35	.52	--	--	--	--	--	3.46
DALLAS	--	--	1.42	--	--	--	--	.15	--	.08	--	--	1.65
GARLAND	1.84	--	--	--	--	--	--	--	--	--	--	--	1.84
HOT SPRING	.56	--	.17	--	.30	.15	--	.08	.07	--	.06	--	1.39
MONTGOMERY	.93	--	--	--	--	--	--	--	--	--	--	--	.93
NEVADA	--	.68	.16	.68	.09	--	--	.16	.06	--	--	--	1.83
PIKE	.97	--	--	.82	--	.06	--	--	--	--	--	.02	1.87
TOTALS	4.58	2.41	1.75	1.56	.91	.56	.52	.39	.13	.08	.06	.02	12.97
% OF TOTAL WITHDRAWALS IN STUDY AREA	35.3	18.6	13.5	12.0	7.0	4.3	4.0	3.0	1.0	.6	.5	.2	100%
% OF AQUIFER TOTALS IN STATE	6.2	37.3	1.0	25.9	1.8	.02	100	7.4	17.6	1.1	4.8	1.6	

SOURCE: HOLLAND AND LUDWIG <40>

figure 4-3

GROUNDWATER WITHDRAWALS BY AQUIFER
1965 - 1980

MILLON GALLONS PER DAY - IN STUDY AREA



SOURCES: Halberg ⟨31,32,33⟩
Holland and Ludwig ⟨40⟩

TABLE 4-3

GROUNDWATER WITHDRAWALS

BY COUNTY IN STUDY AREA

1965-80

COUNTY	GROUNDWATER WITHDRAWALS (MGD) 1965	1970	1975	1980
CLARK	.79	.96	1.27	3.46
DALLAS	.75	1.15	1.39	1.65
GARLAND	1.05	1.53	2.22	1.84
HOT SPRING	.82	1.56	1.30	1.39
MONTGOMERY	.38	.63	.63	.93
NEVADA	.71	1.48	1.47	1.83
PIKE	.79	1.44	.98	1.87
TOTALS	5.29	8.75	9.26	12.97

SOURCES: HALBERG <31, 32, 33>
HOLLAND AND LUDWIG <40>

withdrawals were up by 40% in 1980. The largest increase for the period (1965 to 1980) was Clark County with an increase of 2.67 MGD (440%). <31, 32, 33, 40>

In 1980, the largest percentage of groundwater withdrawn in the study area, about 45%, was used for livestock and domestic supplies which accounted for 5.82 MGD. Other categories of use were approximately equal with public supplies using 16.5 percent, crops other than rice using 11.9%, followed by fish farming (11.4%), self supplied industry (11.3%) and rice irrigation (4.5%). Domestic and livestock use were the dominant uses in Garland, Hot Spring, Montgomery, Nevada, and Pike Counties, as shown in Figure 4-4. Public supply systems were the largest users in Dallas County (46%) and fish production accounted for about 39% of groundwater use in Clark County. Thirty-one percent of Pike County's use was for rice production. <40>

Groundwater Quality

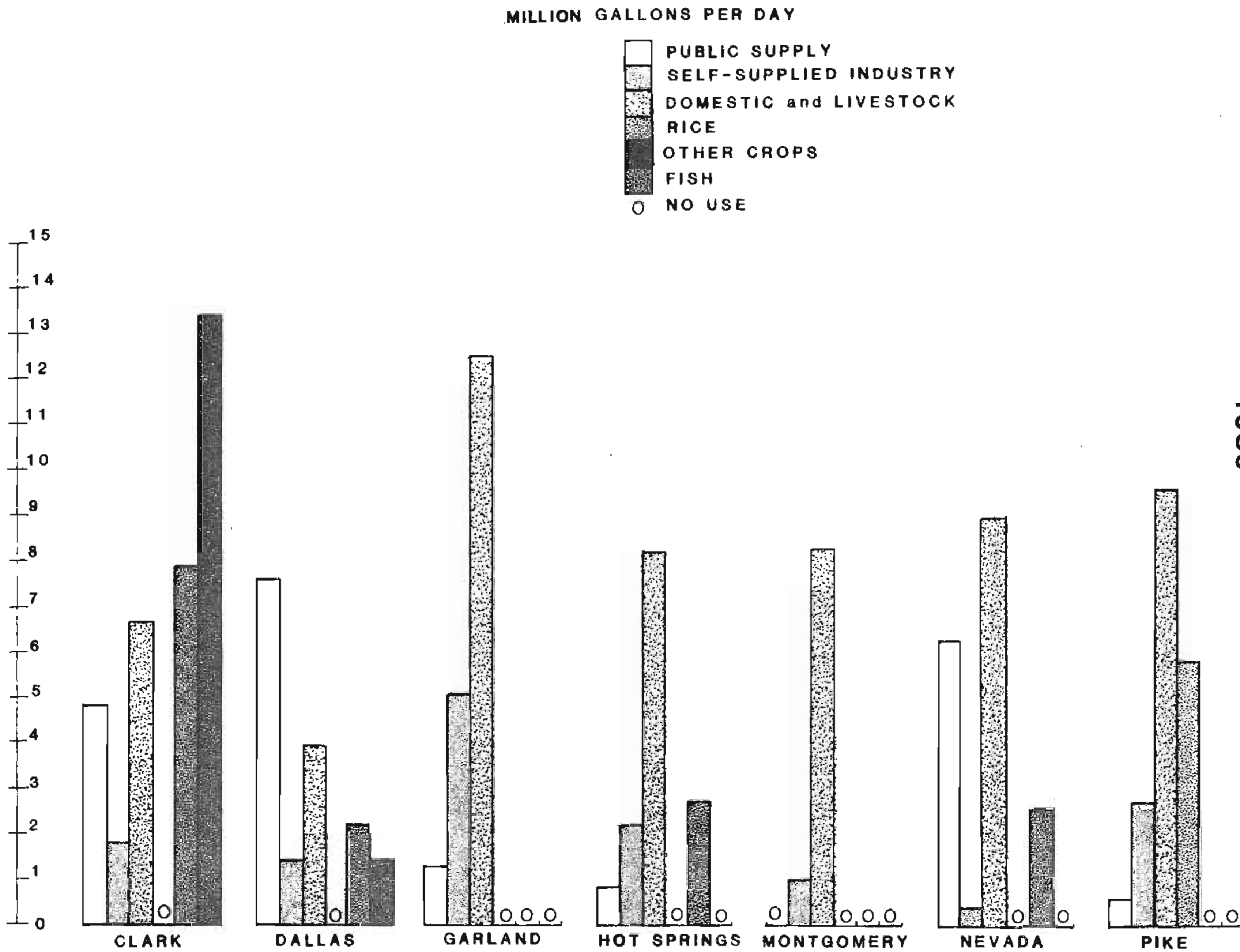
There are several factors which affect water quality in the formations of this basin. Most of these formations were inundated and emerged from a marine environment, saturated with mineralized water. Precipitation infiltrating recharge zones tends to flush connate water out of the formation if adequate downdip discharge outlets are possible. Another factor is the farther water moves downdip, the more minerals are dissolved. Both processes result in formations that yield high quality water near the recharge area and more mineralized water downdip.

Another source of water quality degradation is leakage from one aquifer to another. All of the Cretaceous formations are under artesian conditions, except in their outcrop areas. Artesian aquifers are especially susceptable to this problem when they have been over-pumped. The lowered artesian pressure from over pumping can promote upward movement of water from deeper formations which have higher pressures. Since saltwater is in the lower sections of most of the fresh water aquifers in the area, there is the possibility that saltwater contamination can be induced by over-pumping.

In general, water from the Sparta Sand is the least mineralized water from any of the formations in the basin and is used for public supply and self supplied industry with little treatment required. Water from the Nacatoch Sand and the Tokio Formation is utilized by public supply systems and is of good quality near the outcrop zone but changes rapidly downdip where it contains excessive sodium, chloride, and

figure 4-4

GROUNDWATER WITHDRAWALS BY COUNTY DISTRIBUTION OF USE 1980



SOURCE: Holland and Ludwig <40>

iron. Total dissolved solids concentrations and specific conductance increase accordingly. Paleozoic rocks contain water that is highly variable from area to area and commonly contains excessive iron. Groundwater quality data by geologic unit are summarized in Table 4-4.

Groundwater quality standards are primarily related to drinking water sources. The recommended limits (Primary Drinking Water Regulations) were established by the Safe Drinking Water Act and were adopted by most states. The Arkansas Department of Health uses the National Primary Standards to set state standards for public water supply systems. (See Tables 4-5 and 4-6). Table 4-7 lists the Environmental Protection Agency recommended limits for constituents in water used for agriculture. Table 4-8 summarizes water quality requirements for a few of the more common industrial uses in Arkansas.

TABLE 4-4

GROUNDWATER QUALITY

MEAN VALUES BY GEOLOGIC UNIT

GEOLOGIC UNIT	TEMP.	COLOR	S.C.	pH	HCO-3	CO-3	CaCO-3	N.C.H.	Ca	Mg	Na	S.A.R.	K	Cl	SO-4	F	SiO-2	Fe	T.D.S.	NO-3
STANLEY SHALE	17.5	2	282	7.0	108	12	100	20	30	6.1	32	2	3	14	12	0.1	24	1000	168	16
NACATOCH SAND	22.0	6	1080	8.2	240	7	100	35	47	11	300	18	7	210	32	0.7	23	1100	942	2.0
TOKIO FORMATION	21.9	6	1260	7.9	230	4	45	9	13	2.1	290	29	5	240	86	1.1	15	100	797	0.95
SPARTA SAND	18.9	3	122	6.6	54	0	33	13	7.7	2.6	9.8	1	4	9.4	4.0	-	15	2600	82	14
WILCOX GROUP	21.2	4	179	7.3	87	0	49	2	16	3.3	22	3	3	8.9	10	0.1	21	460	143	2.4
QUATERNARY SYSTEM	19.7	3	258	7.0	45	0	71	36	27	4.6	26	1	3	20	39	0.1	8.3	3500	192	14

TEMP. - DEGREES - CENTIGRADE
COLOR - PLATINUM - COBALT UNITS
S.C. - SPECIFIC CONDUCTANCE (umhos)
pH - STANDARD UNITS
HCO-3 - BICARBONATE mg/L
CO-3 - CARBONATE mg/L
CaCO-3 - CALCIUM CARBONATE HARDNESS mg/L

N.C.H. - NON-CARBONATE HARDNESS mg/L
Ca - CALCIUM DISSOLVED mg/L
Mg - MAGNESIUM DISSOLVED mg/L
Na - SODIUM DISSOLVED mg/L
S.A.R. - SODIUM ADSORPTION RATIO
K - POTASSIUM DISSOLVED mg/L
Cl - CHLORIDE DISSOLVED mg/L

SO-4 - SULFATE DISSOLVED mg/L
F - FLUORIDE DISSOLVED mg/L
SiO-2 - SILICA DISSOLVED mg/L
Fe - IRON DISSOLVED ug/L
T.D.S. - TOTAL DISSOLVED SOLIDS mg/L SUM OF CONSTITUENTS
NO-3 - NITRATE DISSOLVED mg/L

SOURCE: U.S.G.S. FILE DATA

TABLE 4-5
NATIONAL INTERIM PRIMARY DRINKING-WATER REGULATIONS

[Data in milligrams per liter unless otherwise specified. tu - turbidity; pCi/L - picocurie per liter; mrem - millirem (one thousandths of a rem)].

CONSTITUENT	MAXIMUM CONCENTRATION
ARSENIC	0.05
BARIUM	1
CADMIUM	0.010
CHROMIUM	0.05
LEAD	0.05
MERCURY	0.002
NITRATE (AS N)	10
SELENIUM	0.01
SILVER	0.05
FLUORIDE	4.0
TURBIDITY	1-5 tu
COLIFORM BACTERIA	1/100 mL (mean)
ENDRIN	0.0002
LINDANE	0.004
METHOXYCHLOR	0.1
TOXAPHENE	0.005
2,4-D	0.1
2,4,5-TP SILVEX	0.01
TOTAL TRIHALOMETHANES [THE SUM OF THE CONCENTRATIONS OF BROMODICHLOROMETHANE, DIBROMOCHLOROMETHANE, TRIBROMOMETHANE (BROMOFORM) AND TRICHLOROMETHANE (CHLOROFORM)]	0.10
RADIONUCLIDES:	
RADIUM 226 AND 228 (COMBINED)	5 pCi/L
GROSS ALPHA PARTICLE ACTIVITY	15 pCi/L
GROSS BETA PARTICLE ACTIVITY	4 mrem/year

SOURCES: U.S. ENVIRONMENTAL PROTECTION AGENCY <98, 100>.

TABLE 4-6

NATIONAL SECONDARY DRINKING-WATER REGULATIONS

CONSTITUENT	MAXIMUM LEVEL
CHLORIDE	250 mg/L
COLOR	15 COLOR UNITS
COPPER	1 mg/L
CORROSIVITY	NONCORROSIVE
DISSOLVED SOLIDS	500 mg/L
FOAMING AGENTS	0.5 mg/L
IRON	0.3 mg/L (300 ug/L)
MANGANESE	0.05 mg/L
ODOR	3 (THRESHOLD ODOR NUMBER)
pH	6.5-8.5 UNITS
SULFATE	250 mg/L
ZINC	5 mg/L

SOURCE: MODIFIED FROM U.S. ENVIRONMENTAL PROTECTION AGENCY <99>

TABLE 4-7
RECOMMENDED LIMITS FOR CONSTITUENTS IN
IRRIGATION WATER
[ALL UNITS IN mg/L]

CONSTITUENT	FOR WATERS USED CONTINUOUSLY ON ALL SOIL	FOR USE UP TO 20 YEARS ON FINE TEXTURED SOILS OF pH 6.0 TO 8.5	REMARKS
ALUMINUM	5.0	20.0	CAN CAUSE NON-PRODUCTIVITY IN ACID SOILS, BUT SOILS AT pH 5.5 TO 8.0 WILL PRECIPITATE THE ION AND ELIMINATE TOXICITY.
ARSENIC	0.10	2.0	TOXICITY TO PLANTS VARIES WIDELY, RANGING FROM 12 mg/L FOR SUDAN GRASS TO LESS THAN 0.05 mg/L FOR RICE.
BERYLLIUM	0.10	0.5	TOXICTY TO PLANTS VARIES WIDELY, RANGING FROM 5 mg/L FOR KALE TO 0.5 mg/L FOR BUSH BEANS.
BORON	0.75	2.0	ESSENTIAL TO PLANT GROWTH, OPTIMUM YIELDS FOR MANY OBTAINED AT A FEW-TENTHS mg/L IN NUTRIENT SOLUTIONS. TOXIC TO MANY SENSITIVE PLANTS (e.g., CITRUS PLANTS AT 1 mg/L)
CHROMIUM	0.1	1.0	NOT GENERALLY RECOGNIZED AS ESSENTIAL GROWTH ELEMENT. CONSERVATIVE LIMITS RECOMMENDED DUE TO LACK OF KNOW-LEDGE ON TOXICITY TO PLANTS.
COBALT	0.05	5.0	TOXIC TO TOMATO PLANTS AT 0.2 mg/L IN NUTRIENT SOLUTIONS. TENDS TO BE INACTIVATED BY NEUTRAL AND ALKALINE SOILS.
COPPER	0.2	5.0	TOXIC TO A NUMBER OF PLANTS AT 0.1 TO 1.0 mg/L IN NUTRIENT SOLUTION.
FLUORIDE	1.0	15.0	INACTIVATED BY NEUTRAL AND ALKALINE SOILS.
IRON	5.0	20.0	NOT TOXIC TO PLANTS IN AERATED SOILS, BUT CAN CONTRIBUTE TO SOIL ACIDIFICATION AND LOSS OF ESSENTIAL PHOSPHORUS AND MOLYBEDENDUM.
LEAD	5.0	10.0	CAN INHIBIT PLANT CELL GROWTH AT VERY HIGH CONCENTRATIONS.
LITHIUM	2.5	2.5	TOLERATED BY MOST CROPS AT UP TO 5 mg/L; MOBILE IN SOIL. TOXIC TO CITRUS AT LOW DOSES - RECOMMENDED LIMIT IS 0.075 mg/L.

TABLE 4-7 CONT.
RECOMMENDED LIMITS FOR CONSTITUENTS IN IRRIGATION WATER

CONSTITUENT	FOR WATERS USED CONTINUOUSLY ON ALL SOIL	FOR USE UP TO 20 YEARS ON FINE TEXTURED SOILS OF pH 6.0 TO 8.5	REMARKS
MANGANESE	0.2	10.0	TOXIC TO A NUMBER OF CROPS AT A FEW-TENTHS TO A FEW mg/L IN ACID SOILS.
MOLYBDENUM	0.01	0.05	NOT TOXIC TO PLANTS AT NORMAL CONCENTRATIONS IN SOIL AND WATER. CAN BE TOXIC TO LIVESTOCK IF FORAGE IS GROWN IN SOILS WITH HIGH LEVELS OF AVAILABLE MOLYBDENUM.
NICKEL	0.2	2.0	TOXIC TO A NUMBER OF PLANTS AT 0.5 TO 1.0 mg/L; REDUCED
SELENIUM	0.02	0.02	TOXIC TO PLANTS AT LOW CONCENTRATIONS AND TO LIVESTOCK IF FORAGE IS GROWN IN SOILS WITH LOW LEVELS OF ADDED SELENIUM.
TIN, TUNGSTEN AND TITANIUM	-	-	EFFECTIVELY EXCLUDED BY PLANTS; SPECIFIC TOLERANCE LEVELS UNKNOWN.
VANADIUM	0.1	1.0	TOXIC TO MANY PLANTS AT RELATIVELY LOW CONCENTRATIONS.
ZINC	2.0	10.0	TOXIC TO MANY PLANTS AT WIDELY VARYING CONCENTRATIONS; REDUCED TOXICITY AT INCREASED pH (6 OR ABOVE) AND IN FINE-TEXTURED OR ORGANIC SOILS.

CONSTITUENT	RECOMMENDED LIMIT	REMARKS
pH	4.5-9.0	MOST EFFECTS OF pH ON PLANT GROWTH ARE INDIRECT (e.g., pH EFFECTS ON HEAVY METALS; TOXICITY DESCRIBED ABOVE).
TDS	500-5,000 mg/L	BELOW 500 mg/L, NO DETRIMENTAL EFFECTS ARE USUALLY NOTICED. BETWEEN 500 AND 1,000 mg/L, TDS IN IRRIGATION WATER CAN AFFECT MANY CROPS, AND CAREFUL MANAGEMENT PRACTICES SHOULD BE FOLLOWED. ABOVE 2,000 mg/L, WATER CAN BE USED REGULARLY ONLY FOR TOLERANT PLANTS ON PERMEABLE SOILS.

SOURCE: DONOVAN AND BATES <23>

TABLE 4-8
WATER QUALITY REQUIREMENTS FOR SELECTED USES
(UNLESS OTHERWISE INDICATED, UNITS ARE mg/L AND VALUES ARE MAXIMUMS)

CHARACTERISTICS	BOILER FEEDWATER <933kPa (<150 PSIG)	BOILER FEEDWATER <10241 kPa (<150 PSIG)	COOLING WATER: ONCE THROUGH CIRCULATION FRESH	COOLING WATER: ONCE THROUGH CIRCULATION BRACKISH	COOLING WATER: MAKEUP FOR RECIRCULATION FRESH	COOLING WATER: MAKEUP FOR RECIRCULATION BRACKISH	PROCESS WATER BY INDUSTRY: TEXTILE	LUMBER	PULP AND PAPER	CHEMICAL PRODUCTS	PETROLEUM AND COAL PRODUCTS	PRIMERY METAL	FOOD CANNING	BOTTLED AND CANNED SOFT DRINKS	TANNING
SILICA (SiO-2)	30	0.01	50	25	50	25			50	50	60		50		
ALUMINUM (Al)	5	0.01			0.1										
IRON (Fe)	1	0.01			0.5		0.10		0.3	0.1	1.0		0.02	0.30	50
MANGANESE (Mn)	0.3				0.5		0.01		0.1	0.1			0.02	0.05	0.2
COPPER (Cu)	0.5	0.01					0.05								
CALCIUM (Ca)			200	520	50	420			20	70	75		100		60
MAGNESIUM (Mg)									12	20	30				
SODIUM AND POTASSIUM (Na+k)											230				
AMMONIA (NH3)	0.1	0.7									40				
BICARBONATE (HCO-3)	170		600		25					130	480				
SULFATE (SO-4)			680	2700	200	2700				100	600		250	500	250
CHLORIDE (Cl)			600		500				200	500	300	500	250	500	250
FLUORIDE (F)			600	19000	500	19000				5	1.2		1	1.7	
NITRATE (NO-3)											10		10		
PHOSPHATE (PO-4)															
DISSOLVED SOLIDS	700	0.5	1000	35000	500	35000	100		100	1000	1000	1500	500		
SUSPENDED SOLIDS	10	0	5000	2500	100	100	5	<3-MM DIAMETER	10	5	10	3000	10		
HARDNESS (CaCO-3)	20	0.07	850	6250	130	6250	25		475	250	350	1000	250		150
ALKALINITY (CaCO-3)	140	0	500	115	20	115				125	500	200	250	85	
ACIDITY (CaCO-3)												75			
pH	8-10	8.8-9.2	5-8.3				6-8	5-9	4.6-9.4	5.5-9	6-9	5-9	6.5-8.5		6-8
COLOR-UNITS							5		10	20	25		5	10	5
ORGANICS															
MBAS					1							30			
CCl_4					1										
COD	5	0	75	75	75	75									
DISSOLVED OXYGEN	<0.03	<0.005													
TEMPERATURE - DEG. C -	48	48	37	48		37	48		37			37			
(DEG. F)	(120)	(120)	(100)	(120)		(100)	(120)		(100)			(100)			
TURBIDITY - tu	10	0.05	5000	100											

MBAS - METHYLENE BLUE ACTIVE SUBSTANCES
DETERMINED BY TREATMENT OF OTHER CONSTITUENTS

CCl_4 - CARBON TETRACHLORIDE EXTRACT

COD - CHEMICAL OXYGEN DEMAND

SOURCE: MODIFIED FROM NATIONAL ACADEMY OF SCIENCES - NATIONAL ACADEMY OF ENGINEERING COMMITTEE (50)

SELECTED GEOLOGIC UNITS

Paleozoic Rocks

Geology

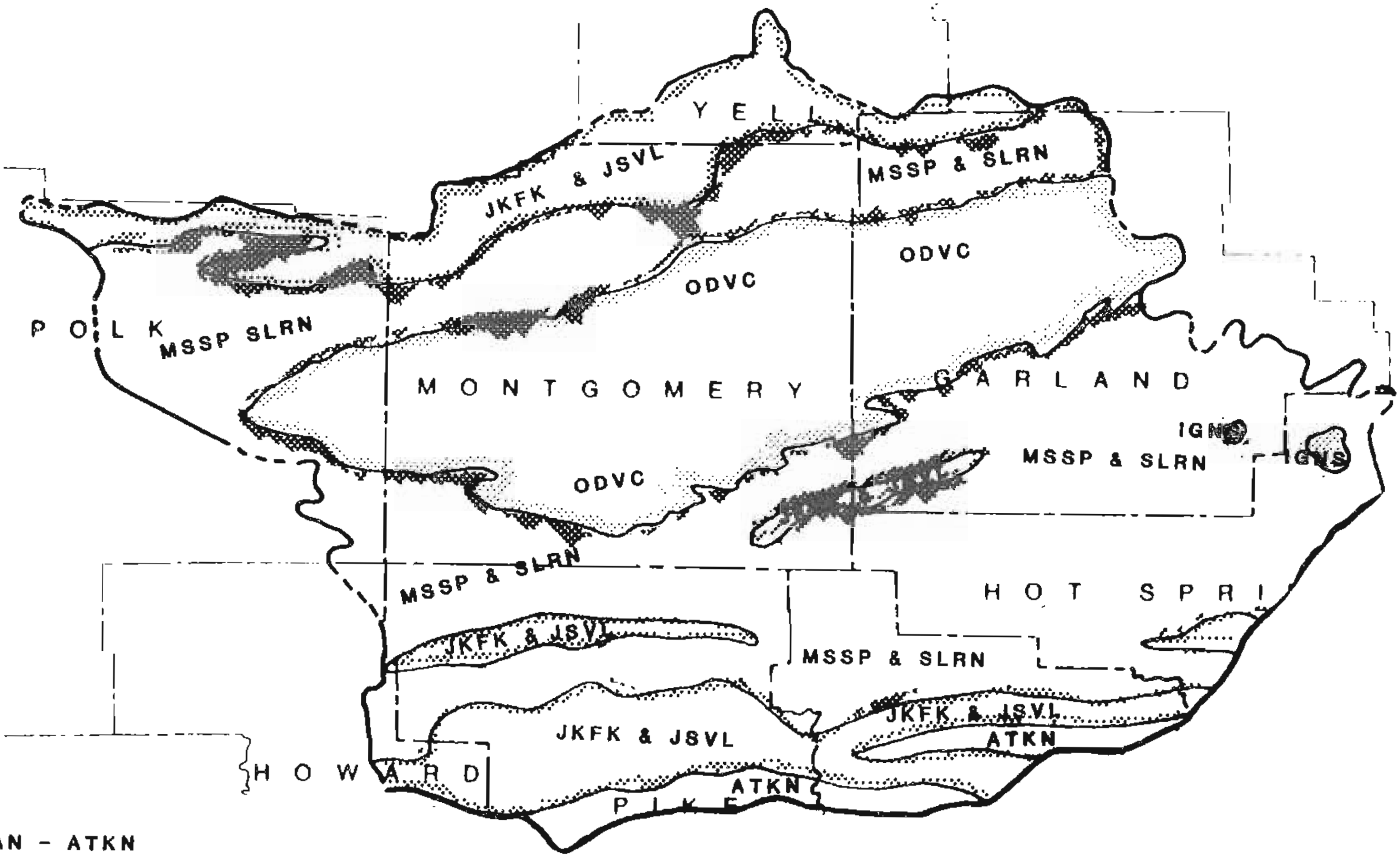
Approximately half of the surface material in the Upper Ouachita Basin is from the Paleozoic Era. The topography of east-west ridges and valleys is underlain by extensively folded shales, sandstones, chert, and Novaculite with some limestone and igneous intrusive rocks. These units were originally deposited in horizontal beds of mud, sand, gravel, marl, lime, volcanic ash and silica in a marine environment. Compression changed these deposits to the shale, sandstone, conglomerate, limestone, tuff, chert and Novaculite found there today. The Ouachita Orogeny followed, causing extensive folding and faulting. The additional heat metamorphosed some of the shale to slate and sandstone to Quartzite. Following the north-south compression were erosional cycles with minor arching and faulting. <65> The outcrop zones for the formations of Paleozoic age are illustrated in Figure 4-5.

The elevation of the top of the Paleozoic rocks where they exist in the subsurface beneath coastal plain sediments is shown in Figure 4-6. The dip of the top of the Paleozoic rocks is generally to the south in the western part of the basin and to the southeast in the eastern portion of the basin. Through Clark and Dallas Counties, the dip is approximately 65 feet per mile. In Pike, northern Hempstead, and Nevada Counties, the dip is at a much steeper rate, exceeding 250 feet per mile. The Paleozoic rocks in a consolidated, buried state act as a thick impervious barrier in the subcrop zone under Cretaceous, Jurassic, Tertiary, and Quaternary Systems. <57>

Hydrology

The nature of groundwater occurrence in the different formations of Paleozoic age is very similar and, therefore, will be discussed together in this report. All formations in the Highlands are relatively impermeable due to compaction from deep burial. The primary porosity has essentially been destroyed. Groundwater usually occurs within twenty feet of land surface in fractured rocks, soil, and loose particles created by weathering. Below the weathered zone, groundwater movement and storage occurs in secondary openings such as joints, fractures and separated bedding planes created by deformation. Movement within these fractures is down gradient

figure 4-6
PALEOZOIC ROCKS OUTCROPPING UNITS



ATOKAN - ATKN

JACKFORK SANDSTONE and
JOHNS VALLEY SHALE - JKFK & JSVL

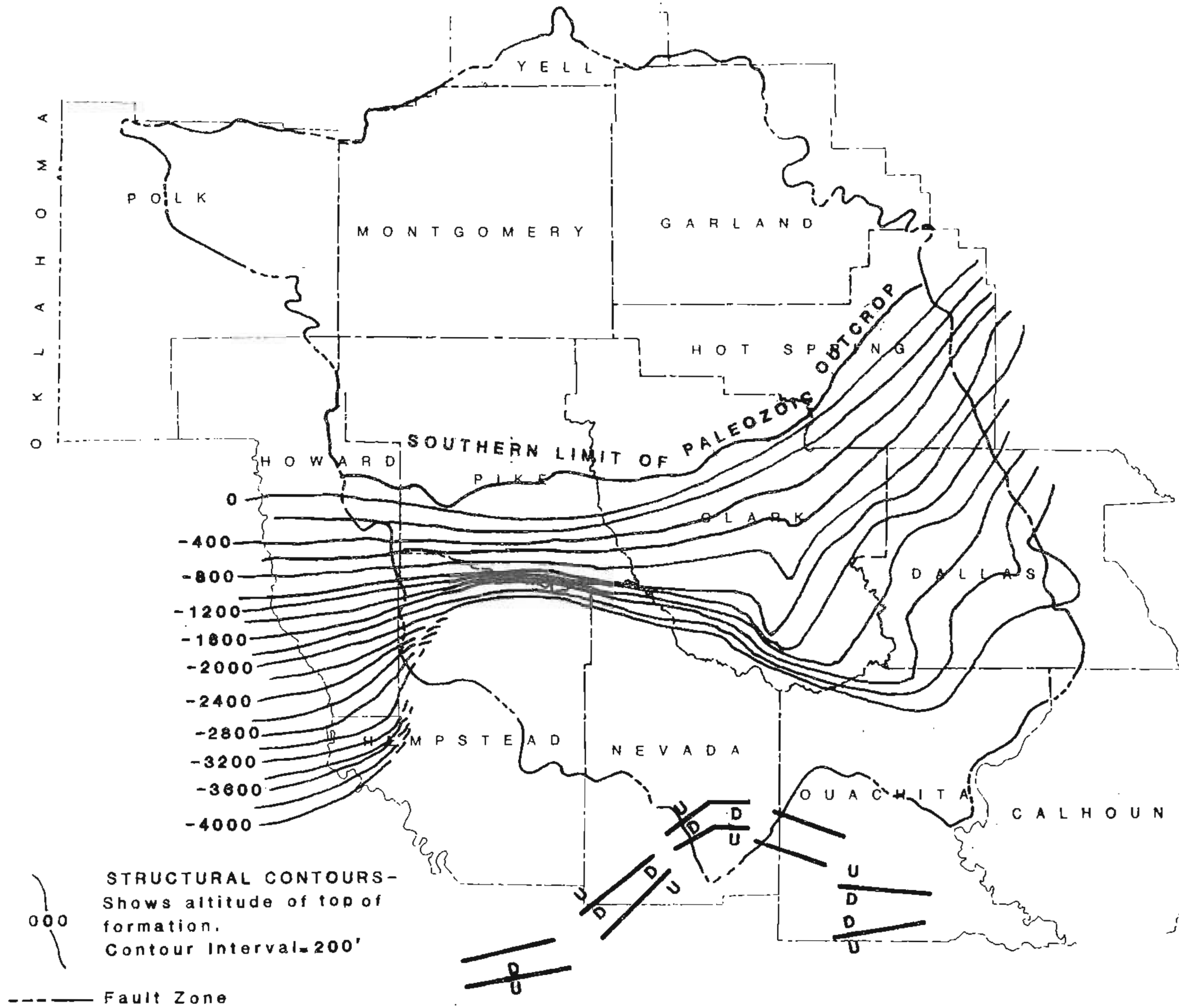
MISSISSIPPIAN and SILURIAN - MSSP & SLRN

ORDOVICIAN - ODVC

IGNEOUS - IGNS

SOURCE: Modified from Haley and Others ⟨35⟩

figure 4-6
PALEOZOIC ROCKS STRUCTURAL CONTOURS



SOURCE: Modified from Petersen and Others ⟨57⟩

created by geologic structure or withdrawals. Movement is generally toward the synclinal axes and away from the anticlinal axes. The depth to water varies with precipitation, evapotranspiration, topography and withdrawals. The depth to water is generally greatest: after prolonged drought, after extensive withdrawals, during conditions favoring high evaporation rates, or near the tops of ridges. The opposite set of conditions would tend to produce a shallower depth to water. Commonly, the depth to water is less than 20 feet below land surface while the pumping water level may be three to five times that depth. Most wells are less than 100 feet deep. Normal seasonal variation in the water level is generally 10 to 20 feet. Water level changes following precipitation are rapid which suggests that water moves quickly into the groundwater system but storage capacity is small. Yields are primarily controlled by the pattern, distribution, and density of fractures within the formation being tapped. Fracture lineaments are generally oriented east-west due to the folded pattern in the Ouachita Mountains from north-south compression. Therefore, wells located north and south of each other may have quite different yields while east-west aligned wells commonly have similar yields. Yields are generally in the range of two to seven gallons per minute, however, some large producers have been reported. One well in the Bigfork Chert north of Hot Springs has been known to yield as much as 350 GPM, but this is exceptional. <2, 34, 59>

All exposed formations on the surface have secondary porosity and can store and transmit water through joints and fractures. Practically all formations can yield adequate quantities for a domestic supply, however, several formations are much more permeable than others. The best aquifer by far seems to be the Bigfork Chert because it is so highly fractured. "The Crystal Mountain Sandstone, the Arkansas Novaculite and the limestone intervals of the Collier Shale, Mazarn Shale and Womble Shale may also be good aquifers". These same formations tend to be sources of many springs in the area. <65>

<u>Water Use</u>

Paleozoic rocks are the most important aquifers in the study area, based on use. In 1980, withdrawals totaled 4.58 MGD in the study area, which is twice the quantity withdrawn in 1965. (See Table 4-9) Paleozoic use in Montgomery, Pike, and Clark Counties has gradually increased from 1965 to 1980. Garland and Hot Spring county withdrawals have shown some variability from one five-year period to the next. <31, 32, 33, 40>

TABLE 4-9

PALEOZOIC ROCKS

GROUNDWATER WITHDRAWALS

1965-1980

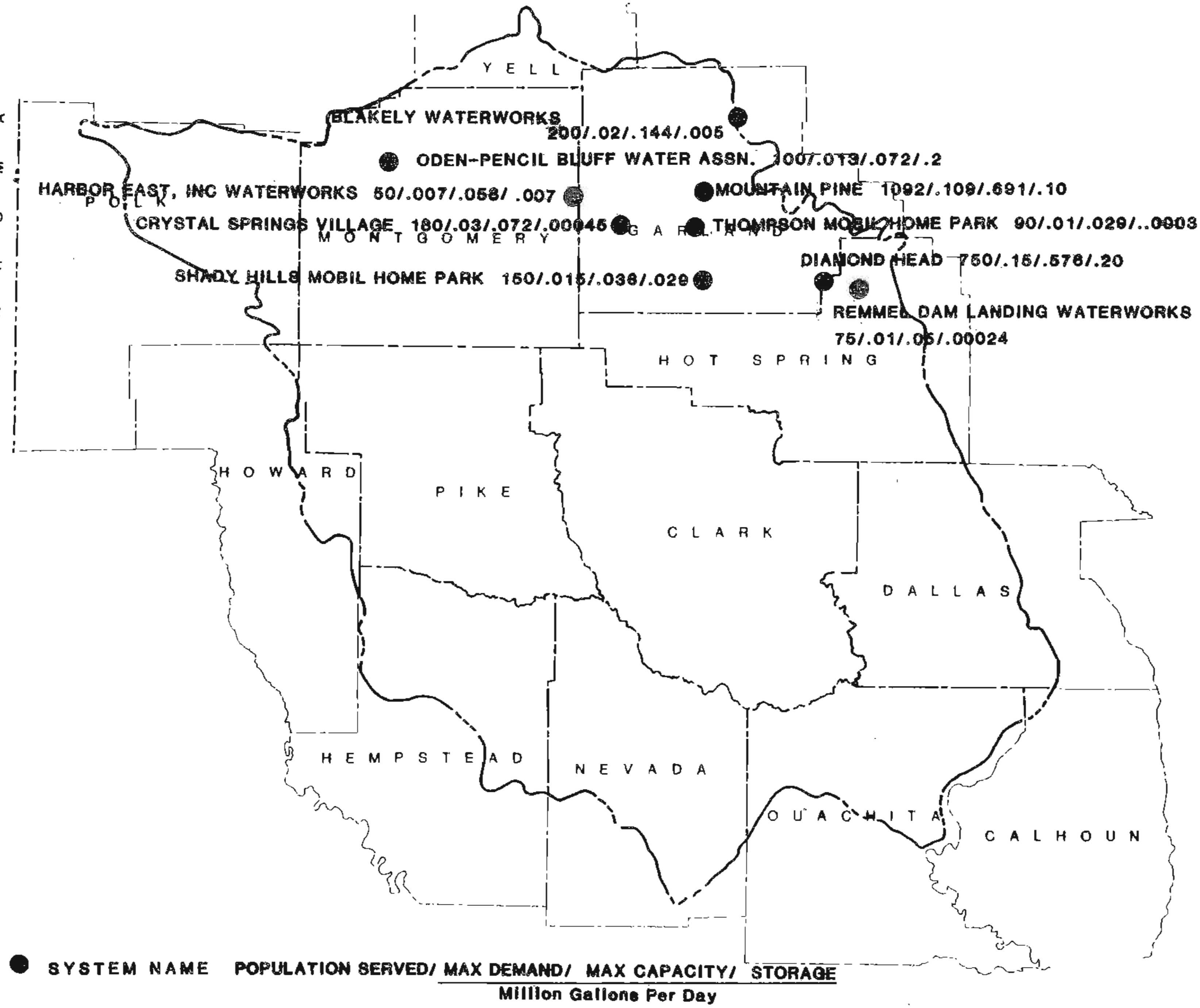
COUNTY	Withdrawals (MGD) 1965	1970	1975	1980
CLARK	.03	.04	.10	.28
GARLAND	1.05	1.53	2.22	1.84
HOT SPRING	.23	.88	.53	.56
MONTGOMERY	.38	.63	.63	.93
PIKE	.25	.47	.51	.97
TOTALS	1.94	3.55	3.99	4.58

SOURCES: HALBERG <31, 32, 33>
HOLLAND AND LUDWIG <40>

According to Arkansas Department of Health file data, nine public supply systems withdraw groundwater from Paleozoic formations within the basin. (See Figure 4-7) These systems serve a population of approximately 2700 persons in Hot Spring, Montgomery, and Garland Counties. About a third of those persons rely on the system at Mountain Pine. The system has a maximum demand of 109,000 GPD with a maximum capacity of almost 700,000 GPD. Storage facilities, however, are only 100,000 gallons which is less than one days supply under maximum demand conditions. Diamond Head serves 750 persons which makes it the second largest system based on the population served. Maximum demand at Diamond Head is 150,000 GPD with a maximum capacity of 576,000 GPD and storage facilities for 200,000 gallons. Information on the other systems that serve 200 persons or less is provided in Figure 4-7. <3>

figure 4-7

PALEOZOIC ROCKS PUBLIC SUPPLY SYSTEMS



SOURCES: Arkansas Department of Health file Data
Arkansas Soil and Water Conservation Commission ⟨8⟩

Water Quality

Based on very limited groundwater quality data for the study area, the quality of water from Paleozoic rocks can be characterized as highly variable from formation to formation and area to area. For example, total dissolved solids ranged from 25 mg/L for a well in the Arkansas Novaculite to 960 mg/L for a well in the Womble Shale. (See Table 4-10) Similarly, hardness of water ranged from soft (6 mg/L of $CaCO_3$) for a well in the Jackfork Sandstone to very hard (570 mg/L of $CaCO_3$) for a well in the Womble Shale.

Groundwater quality is also variable within the same geologic formation. Dissolved iron concentrations ranged from 10-620,000 ug/L for wells in the Womble Shale in Garland County and ranged from 10-4100 ug/L for wells in the Stanley Shale in Hot Spring County.

Additional data on selected constituent concentrations are summarized in Table 4-10 by county for seven formations of Paleozoic age. These data show that, with the exception of frequent high dissolved iron concentrations, the quality of water from Paleozoic rocks is generally well within the limits established for drinking water standards.

Mesozoic Erathem

Within the Mesozoic Era are the Cretaceous, Jurassic, and Triassic Systems. Only the Cretaceous System is present in Arkansas. In the Upper Ouachita Basin, 17 formations are present from the Cretaceous System. Most of these are non-water bearing or yield water of unsuitable quality for most uses and are not discussed in this report. The Trinity group of lower Cretaceous age occurs along the flanks of the Fall line, and is a source of water for domestic wells mainly in western Pike and Howard Counties. Two water-bearing geologic units used for municipal supplies in the study area are the Tokio Formation and the Nacatoch Sand.

Tokio Formation

Geology. The Tokio Formation is of Cretaceous age and is overlain by the Brownstown Marl. The Formation outcrops in a narrow band trending NE-SW from Clark County to Howard County interrupted by Quaternary deposits in the Little Missouri River Basin. (See Figure 4-8) The outcrop zone tends to broaden toward the southwest. The dip of the beds is southeastward at a rate of approximately 60 feet per mile. <57, 59>

TABLE 4-10
PALEOZOIC ROCKS
GROUNDWATER QUALITY

COUNTY		TEMP.	COLOR	S.C.	pH	HCO-3	CO-3	CaCO-3	N.C.H.	Ca	Mg	Na	S.A.R.	K	Cl	SO-4	F	SiO-2	Fe	T.D.S.	NO-3
JACKFORK SANDSTONE																					
CLARK	# SAMPLES	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	MIN	18.9	80	32	5.8	9	0	6	0	1.4	0.7	3.0	0.5	2	2.5	2.0	0	13	360	29	0
	MAX	18.9	80	32	5.8	9	0	6	0	1.4	0.7	3.0	0.5	2	2.5	2.0	0	13	360	29	0
	MEAN	18.9	80	32	5.8	9	0	6	0	1.4	0.7	3.0	0.5	2	2.5	2.0	0	13	360	29	0
STANLEY SHALE																					
CLARK	# SAMPLES	2	3	4	4	4	4	4	4	4	4	4	4	4	4	4	3	2	3	4	4
	MIN	17.8	1	295	5.9	8	0	18	0	6.2	0.7	19	0.9	1	8.0	10	0.1	20	0	160	0
	MAX	18.0	5	501	8.4	300	6	200	42	41	23	120	12	11	59	30	0.2	43	800	292	68
	MEAN	17.9	3	416	7.2	170	2	88	14	18	10	52	4	5	28	18	0.1	32	280	232	17
GARLAND	# SAMPLES	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1
	MIN	-	2	288	7.7	170	0	130	0	42	5.6	11	0.4	0.4	4.0	10	0	-	600	-	0.30
	MAX	-	2	288	7.7	170	0	130	0	42	5.6	11	0.4	0.4	4.0	10	0	-	600	-	0.30
	MEAN	-	2	288	7.7	170	0	130	0	42	5.6	11	0.4	0.4	4.0	10	0	-	600	-	0.30
HOT SPRING	# SAMPLES	9	6	9	3	7	7	8	8	8	8	8	8	8	8	8	8	7	9	7	0
	MIN	16.0	0	55	5.4	9	0	7	0	1.6	0.8	5.3	0.5	0.4	1.0	0	0	21	10	45	-
	MAX	19.0	5	475	7.4	180	0	170	16	48	11	23	0.9	3	47	27	0.3	46	4100	250	-
	MEAN	17.6	2	214	6.7	93	0	77	2	22	5.2	13	0.7	1	8.8	8.4	0.2	31	1400	151	-
MONTGOMERY	# SAMPLES	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1	5	1	5
	MIN	16.0	2	34	5.6	0	2	31	0	4.3	0.7	7.2	0.3	0.6	2.0	3.6	0	7.6	600	120	2.9
	MAX	20.0	5	340	8.2	0	190	270	250	110	6.4	210	6	12	30	17	0.2	7.6	3500	120	68
	MEAN	17.1	3	210	6.5	0	44	110	65	38	3.7	53	2	6	16	10	0.1	7.6	1900	120	32
MEAN OF MEANS		17.5	2	282	7.0	108	12	100	20	30	6.1	32	2	3	14	12	0.1	24	1000	168	16
POLK CREEK SHALE																					
GARLAND	# SAMPLES	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1
	MIN	-	4	76	7.0	39	0	31	0	8.2	2.5	1.6	0.1	0.9	2.0	6.4	0	-	8500	-	0.40
	MAX	-	4	76	7.0	39	0	31	0	8.2	2.5	1.6	0.1	0.9	2.0	6.4	0	-	8500	-	0.40
	MEAN	-	4	76	7.0	39	0	31	0	8.2	2.5	1.6	0.1	0.9	2.0	6.4	0	-	8500	-	0.40
POLK	# SAMPLES	2	0	2	2	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	0
	MIN	14.0	-	160	4.8	-	-	33	2	7.5	1.1	1.0	0.0	0.3	1.8	6.3	0.1	6.8	110	54	-
	MAX	18.0	-	176	6.6	-	-	77	31	29	3.4	5.0	0.4	6	11	11	0.1	8.1	170	93	-
	MEAN	16.0	-	168	5.7	-	-	55	16	18	2.2	3.0	0.2	3	6.4	8.6	0.1	7.4	140	74	-

TABLE 4-10 (CONT'D)
PALEOZOIC ROCKS
GROUNDWATER QUALITY

COUNTY		TEMP.	COLOR	S.C.	pH	HCO-3	CO-3	CaCO-3	N.C.H.	Ca	Mg	Na	S.A.R.	K	Cl	SO-4	F	SiO-2	Fe	T.D.S.	NO-3
BLAKELY MTN. SANOSTONE																					
DALLAS	# SAMPLES	2	0	2	2	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	0
	MIN	17.0	-	236	7.2	-	-	130	4	41	6.9	1.8	0	2	1.9	3.8	0.3	14	4	140	-
	MAX	23.0	-	291	7.3	-	-	130	18	42	7.0	1.9	0	2	2.3	12	0.3	14	10	160	-
	MEAN	20.0	-	264	7.2	-	-	130	11	42	7.0	1.8	0	2	2.1	7.9	0.3	14	7	150	-
ARKANSAS NOVACULITE																					
HOT SPRING	# SAMPLES	3	1	3	2	1	1	3	3	3	3	3	3	3	3	3	3	3	3	3	0
	MIN	18.0	0.0	36	7.4	8	0	10	0	2	0.8	1.1	0.2	0.4	0.9	3.0	0.1	8.4	30	25	-
	MAX	23.0	0.0	241	7.5	8	0	83	3	23	6.0	14	0.7	1	2.0	4.8	0.1	25	120	140	-
	MEAN	2D.2	0.0	166	7.4	8	0	59	1	16	4.3	9.4	0.5	0.6	1.5	3.6	0.1	19	70	102	-
WOMBLE SHALE																					
GARLAND	# SAMPLES	1	3	4	4	3	3	4	4	4	4	4	4	4	4	4	4	1	4	1	3
	MIN	20.5	3	87	7.0	48	0	49	0	0	6.9	2.1	0.1	0.7	2.0	2.8	0.1	20	6	180	0.10
	MAX	20.5	5	568	7.7	300	0	200	34	62	12	48	2	2	22	45	2.0	20	620000	180	0.60
	MEAN	20.5	4	294	7.4	130	0	110	11	28	10	16	0.7	1	8.3	23	0.7	20	170000	180	0.30
MONTGOMERY	# SAMPLES	3	1	3	3	2	2	3	3	3	3	3	3	3	3	3	3	2	3	2	2
	MIN	16.5	3	150	7.1	0	74	52	0	17	2.3	3.9	0	0.5	6.0	4.4	0.1	9.7	3	690	0.20
	MAX	20.0	3	1080	7.7	0	270	570	170	170	35	7.7	0.5	3	14	220	0.2	11	4500	960	0.50
	MEAN	17.9	3	686	7.5	0	170	360	58	110	23	6.0	0.2	2	8.8	140	0.1	10	1500	825	0.35
COLLIER SHALE																					
MONTOOMERY	# SAMPLES	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1
	MIN	16.5	2	340	8.2	0	190	170	0	56	6.4	7.2	0.3	1	14	6.8	0.2	-	3500	-	5.4
	MAX	16.5	2	340	8.2	0	190	170	0	56	6.4	7.2	0.3	1	14	6.8	0.2	-	3500	-	5.4
	MEAN	16.5	2	340	8.2	0	190	170	0	56	6.4	7.2	0.3	1	14	6.8	0.2	-	3500	-	5.4

TEMP. - DEGREES - CENTRIGRADE
COLOR - PLATINUM - COBALT UNITS
S.C. - SPECIFIC CONDUCTANCE (umhos)
pH - STANDARD UNITS
HCO-3 - BICARBONATE mg/L
CO-3 - CARBONATE mg/L
CaCO-3 - CALCUIM CARBONATE HARDNESS mg/L

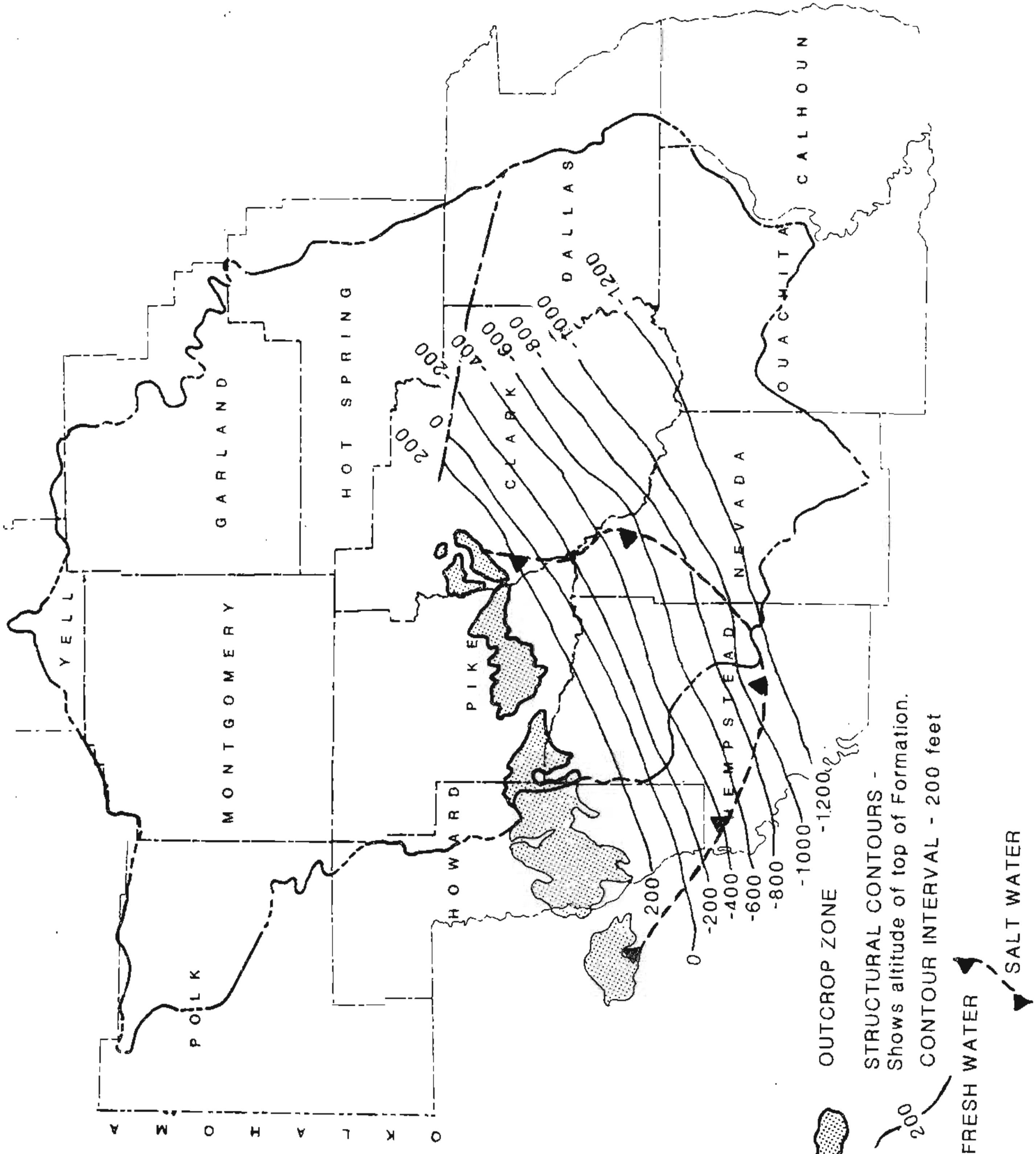
N.C.H. - NON-CARBONATE HARDNESS mg/L
Ca - CALCIUM DISSOLVED mg/L
Mg - MAGNESIUM DISSOLVED mg/L
Na - SODIUM DISSOLVED mg/L
S.A.R. - SODIUM ADSORPTION RATIO
K - POTASSIUM DISSOLVED mg/L
Cl - CHLORIDE DISSOLVED mg/L

SO-4 - SULFATE DISSOLVED mg/L
F - FLUORIDE DISSOLVED mg/L
SiO-2 - SILICA DISSOLVED mg/L
Fe - IRON DISSOLVED ug/L
T.D.S. - TOTAL DISSOLVED SOLIDS mg/L SUM OF CONSTITUENTS
NO-3 - NITRATE DISSOLVED mg/L

SOURCE: U.S.G.S. FILE DATA

figure 4-8

TOKIO FORMATION
OUTCROP ZONE, STRUCTURAL CONTOURS AND EXTENT OF FRESH WATER



SOURCE: Modified from Petersen and others ⟨57⟩, and Cushing ⟨19⟩

The formation generally consists of poorly sorted, cross-bedded quartz sands, gray clay, some lignite with a basal gravel. Thickness of the beds varies from a feather edge at the northern-most extent to a maximum of 200 feet, southeastward. <13, 59>

Hydrology. Recharge is from precipitation entering the outcrop zone or percolating through Quaternary deposits into the formation. Movement is downdip to the southeast and is under artesian conditions except in the outcrop zone where water table conditions prevail. <13> Yields of as much as 300 GPM have been reported in Hempstead County, however, yields of 100 GPM to 150 GPM are more common. <48, 59>

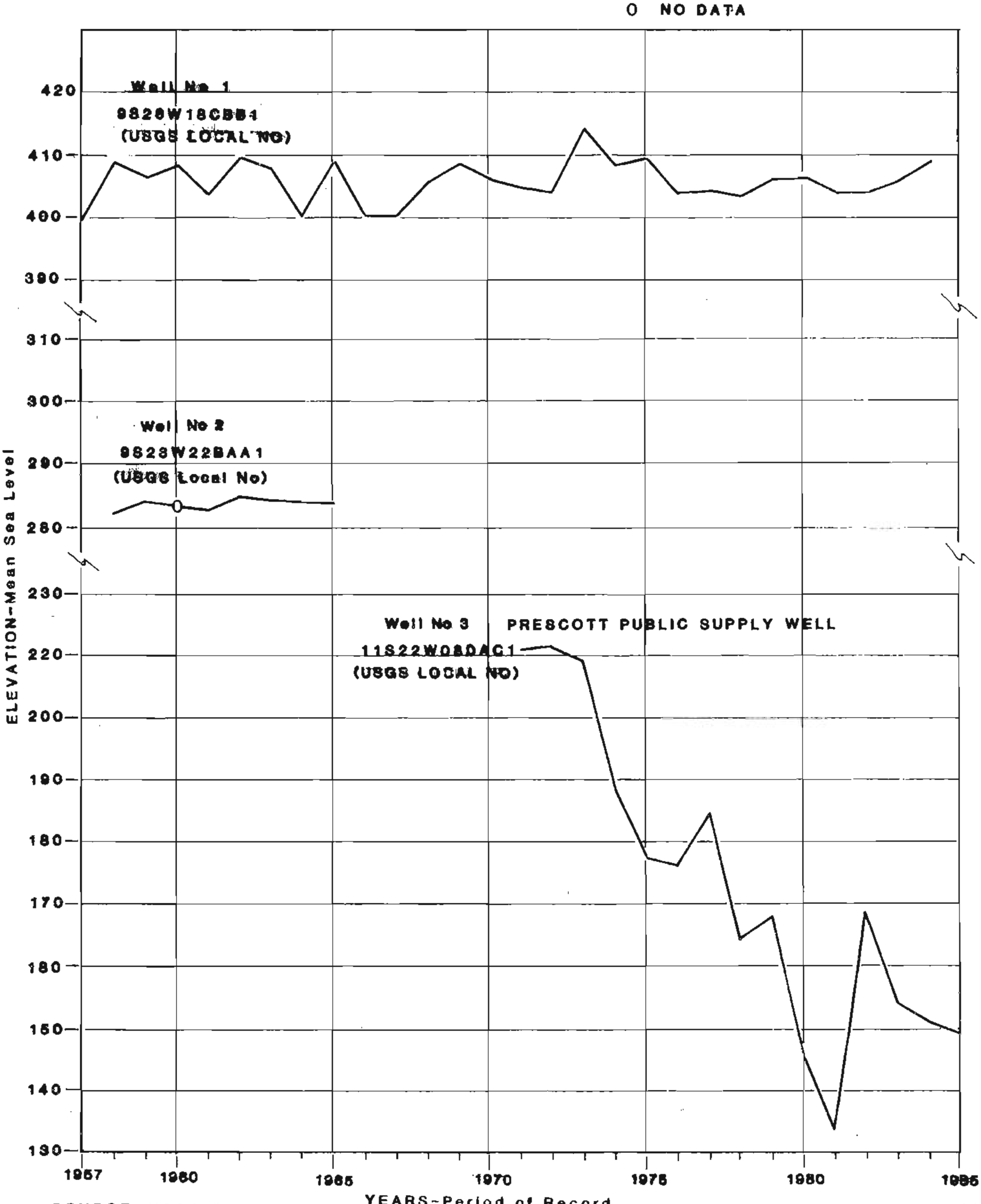
Water-level hydrographs for three wells in the Tokio Formation are illustrated in Figure 4-9. Water levels for wells 1 and 2 showed relatively little variation for the period of record. However, well no. 3, which was used by Prescott for public supply, has shown considerable variability over the past 15 years. From 1971 to 1981, the level dropped approximately 75 feet. The net change for the period of record (1971-85) was 60.7 feet of decline. The variation in water levels for well no.3 has apparently been due to pumping schedule changes that were made in the operation of the Prescott well field before the city converted to a surface-water supply. Well no. 3 is just one of the eight wells that Prescott had in the Tokio and Nacatoch Sand formations. As pumping demands increased, the cone of depression in the Tokio deepened and yields declined accordingly until a surface-water source had to be developed.

Water Use. The Tokio Formation ranked fourth in the basin in 1980 based on groundwater withdrawals. Water use in 1980 from the Tokio Formation totaled 1.56 MGD from Clark, Nevada, and Pike Counties. During the period of 1965-80, the amount of water withdrawn from the Tokio Formation tripled. The total groundwater withdrawals for each county have shown a gradual but steady increase from 1965 to 1980, as illustrated in Figure 4-10. <31, 32, 33, 40>

Five public supply systems in the basin rely on the Tokio Formation to supply an adequate amount of water to meet their needs. These systems parallel the outcrop zone in northern Hempstead County, southeastern Pike County, and west-central Clark County. (See Figure 4-11) Information pertaining to the five public supply systems in the basin is compiled in Table 4-11. These data show that all of the systems are relatively small with the Antoine system, which serves 194 persons, exhibiting the largest demand (90,000 GPD). Antoine

figure 4-9

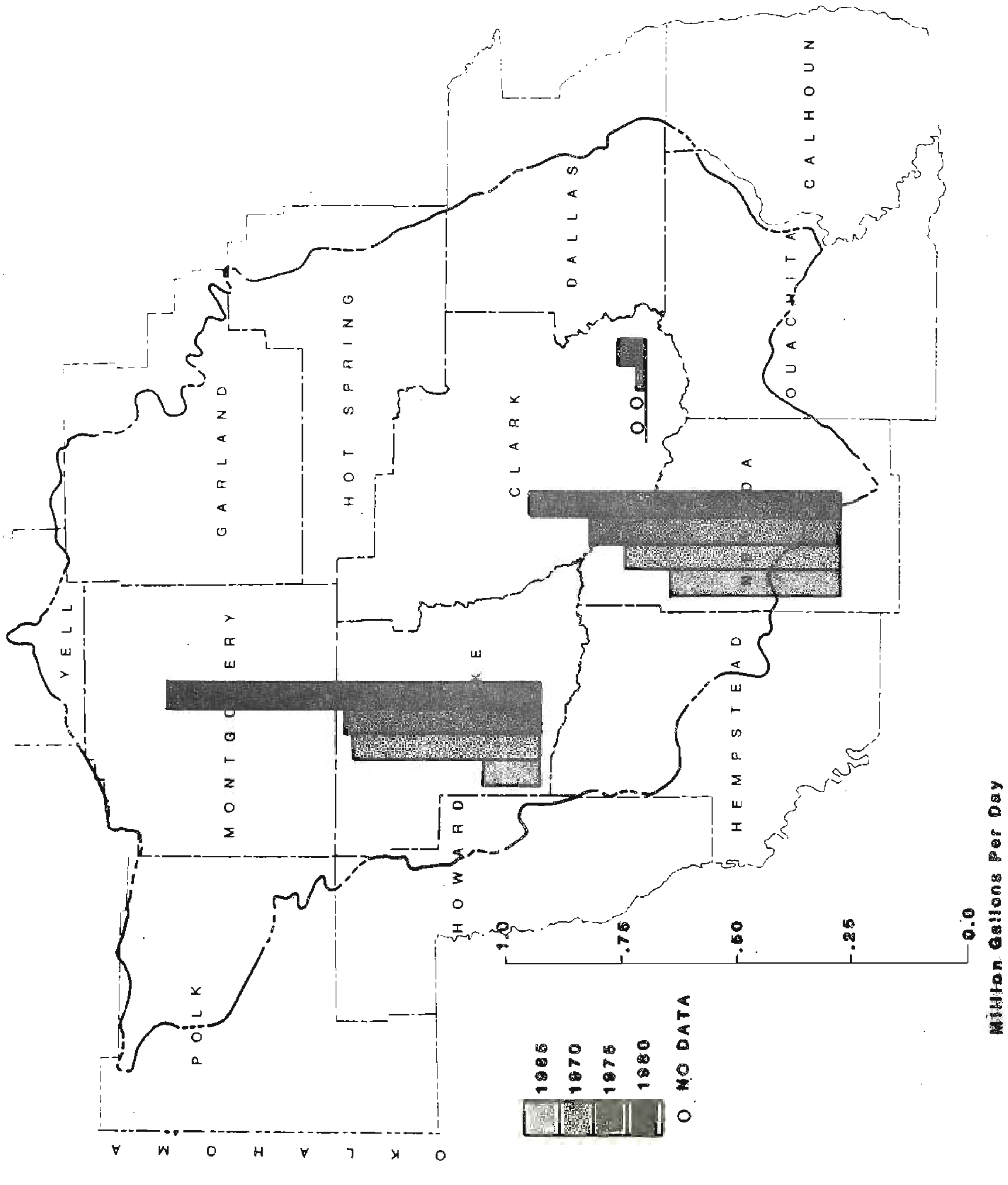
TOKIO FORMATION
HYDROGRAPHS for SELECTED WELLS



SOURCE: USGS File Data

figure 4-10

TOKIO FORMATION GROUNDWATER WITHDRAWALS 1965-1980

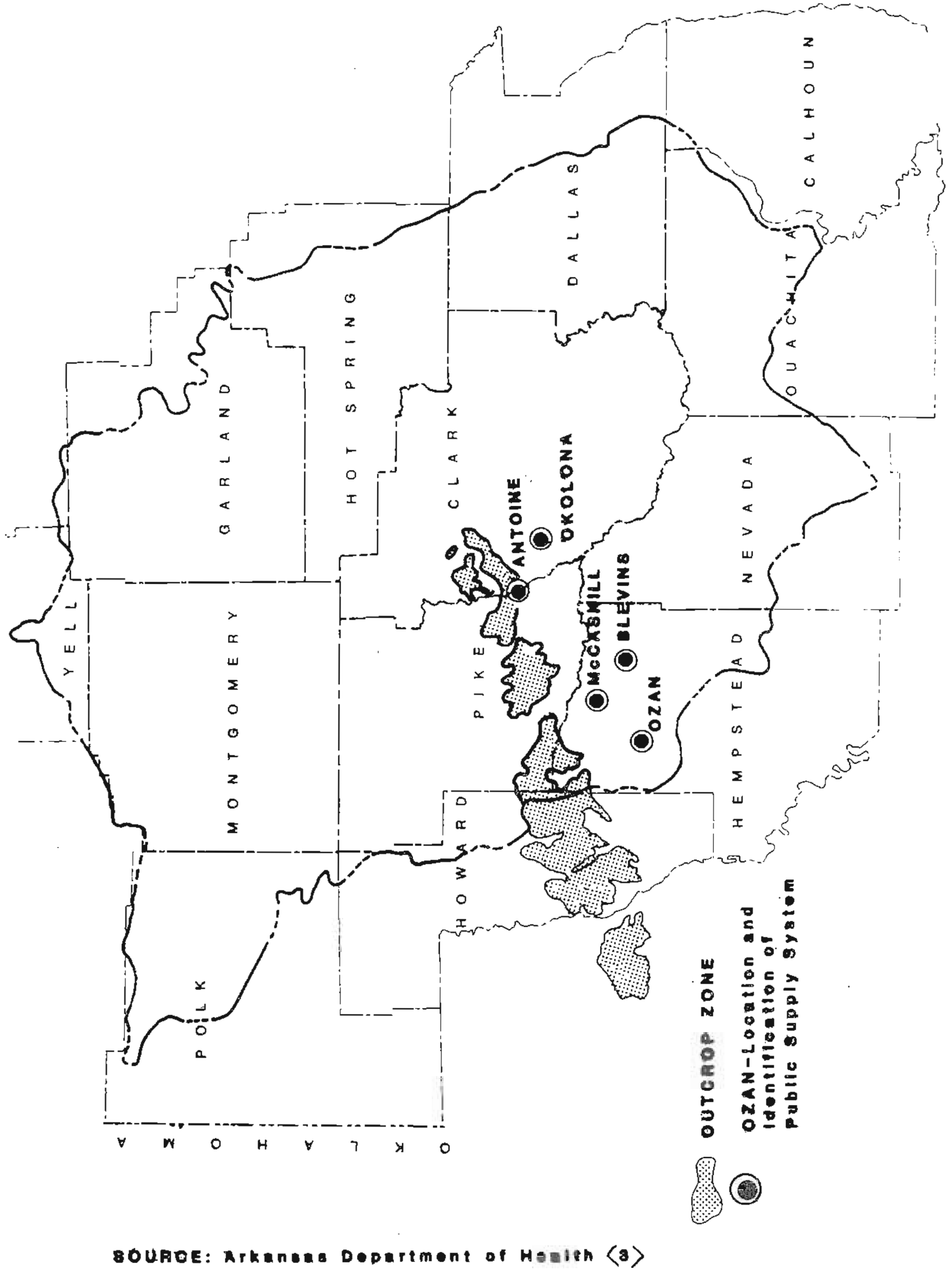


SOURCES: Halberg ⟨31,32,33⟩

Holland and Ludwig ⟨40⟩

figure 4-11

TOKIO FORMATION
PUBLIC SUPPLY SYSTEMS



SOURCE: Arkansas Department of Health ⟨3⟩

TABLE 4-11

TOKIO FORMATION

PUBLIC SUPPLY SYSTEMS

TOWN (COUNTY)	MAXIMUM DEMAND	MAXIMUM CAPACITY	STORAGE
OZAN (HEMPSTEAD)	.03 MGD	.03 MGD	.002 MGD
MCCASKILL (HEMPSTEAD)	UNKNOWN	.034 MGD	.006 MGD
BLEVINS (HEMPSTEAD)	.045 MGD	.14 MGD	.0053 MGD
OKOLONA (CLARK)	.05 MGD	.144 MGD	.08 MGD
ANTOINE (PIKE)	.09 MGD	.144 MGD	.05 MGD
TOTAL	.215 MGD		

SOURCES: ARKANSAS DEPARTMENT OF HEALTH <3>
ARKANSAS SOIL AND WATER COMMISSION <9>

has one well at a depth of 172 feet which yields approximately 150 GPM. The smallest system is Ozan with a maximum demand of 30,000 GPD for 110 people. Storage for three of the five systems is less than one day's supply. <3>

Water Quality. The quality of water from the Tokio Formation in the Upper Ouachita Basin is extremely variable. Water-quality data compiled in Table 4-12 for wells that tap the Tokio Formation in Clark, Hempstead, and Nevada Counties illustrate the variability in constituent concentrations. For example, chloride concentrations for wells in Clark County ranged from 7.0 to 1200 mg/L and total dissolved solids ranged from 50 to 1800 mg/L. Concentrations of chloride, total dissolved solids, and other constituents significantly increase with increasing distance from the outcrop area.

The temperature of water in the Tokio Formation is considerably higher than groundwater temperatures measured in other formations in the state. The maximum water temperature measured in the study area was 37.5°C for a water sample from a well near Hope.

The extent of fresh water in the Tokio Formation in the Upper Ouachita Basin is identified in Figure 4-8. Groundwater in the area designated as fresh water in Figure 4-8 contains less than 1000 mg/L of total dissolved solids. <19> As indicated by the fresh water-salt water interface, water from the Tokio Formation in most of Clark County is very mineralized and is unsuitable for most uses without treatment.

Nacatoch Sand

Geology. The Nacatoch Sand is the second youngest formation of Cretaceous Age, being overlain by the Arkadelphia Marl and underlain by the Saratoga Chalk. <13, 21> The unit outcrops in a narrow band from two to eight miles wide trending NE-SW across Hempstead, Clark, and Nevada Counties, as shown in Figure 4-12. It forms a low, wide ridge from the Little River Basin to the Missouri River where it is buried under Quaternary terraces and alluvium. <48> The outcrop zone is also interrupted by Quaternary deposits along Terre Noire Creek in central Clark County.

Composition of the unit is highly variable, laterally and vertically. Three lithologic units of the formation have been distinguished in Clark County. The lower unit consists primarily of clay, sandy clay, fine grained sand, irregular concretionary beds, and glauconitic sand. The middle unit consists of irregular concretionary beds and fossiliferous green sand. The upper unit is composed of a massive bed of

TABLE 4-12

TOKIO FORMATION

GROUNDWATER QUALITY

COUNTY		TEMP.	COLOR	S.C.	pH	HCO-3	CO-3	CaCO-3	N.C.H.	Ca	Mg	Na	S.A.R.	K	Cl	SO-4	F	SIO-2	Fe	T.D.S.	NO-3
CLARK	# OF SAMPLES	2	5	6	6	6	6	6	6	5	5	5	5	5	6	6	3	3	3	5	6
	MIN	20.0	2	86	6.0	3	0	27	0	7.9	1.3	4.1	0.3	0.7	7.0	26	0.3	11	20	50	0.20
	MAX	23.9	5	4760	8.2	430	0	200	76	66	9.2	690	43	7	1200	400	1.0	26	200	1800	3.5
	MEAN	21.9	4	1980	7.4	220	0	82	24	24	3.9	280	17	4	450	140	0.7	16	90	807	1.0
HEMPSTEAD	# OF SAMPLES	29	4	37	37	37	37	37	37	5	5	6	5	5	37	37	5	5	1	5	37
	MIN	14.0	3	41	5.9	3	0	3	0	0.8	0.4	9.0	1	0.8	3.2	1.0	0	8.0	60	51	0
	MAX	37.5	12	1920	8.9	570	31	200	24	10	1.9	440	62	16	320	120	2.4	17	60	1100	18
	MEAN	20.5	6	432	7.9	160	4	28	2	4.4	1.1	280	35	5	36	36	1.1	11	60	722	1.4
NEVADA	# OF SAMPLES	20	7	23	23	22	16	24	24	9	9	9	9	9	24	23	9	9	16	9	21
	MIN	19.0	3	380	7.7	170	0	5	0	0.8	0.2	49	2	1	10	4.9	0	8.9	0	240	0
	MAX	32.0	15	3820	8.8	460	25	140	0	48	6.0	590	93	29	920	190	2.8	53	600	1500	1.0
	MEAN	23.4	7	1360	8.4	310	9	24	0	11	1.4	310	35	6	230	83	1.6	17	140	862	0.45
MEAN OF MEANS		21.9	6	1260	7.9	230	4	45	9	13	2.1	290	29	5	240	86	1.1	16	100	797	0.95

TEMP. - DEGREES - CENTIGRADE
COLOR - PLATINUM - COBALT UNITS
S.C. - SPECIFIC CONDUCTANCE (umhos)
HCO-3 - BICARBONATE mg/L
CO-3 - CARBONATE mg/L
CaCO-3 - CALCIUM CARBONATE HARDNESS mg/L

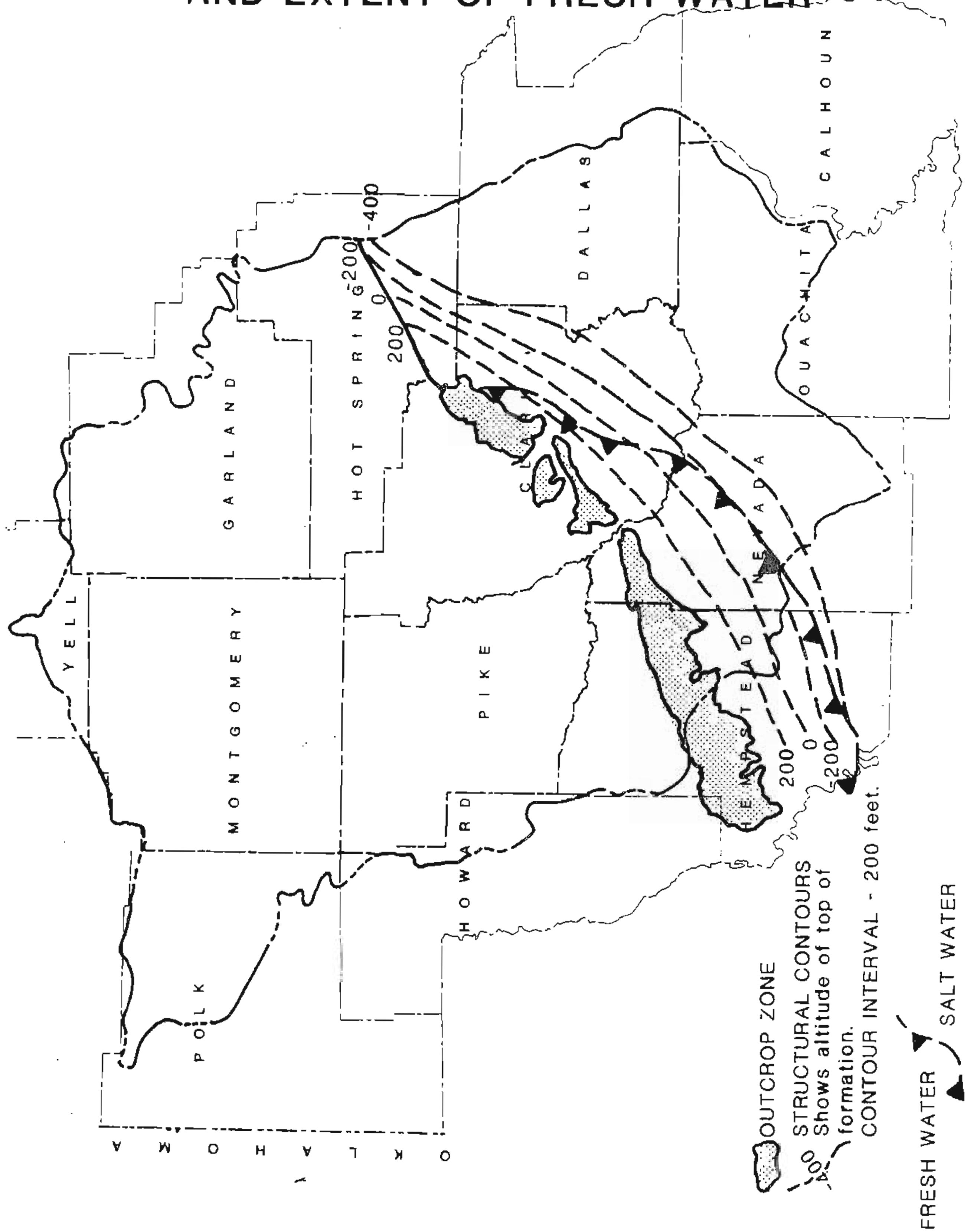
N.C.H. - NON-CARBONATE HARDNESS mg/L
Ca - CALCIUM DISSOLVED mg/L
Mg - MAGNESIUM DISSOLVED mg/L
Na - SODIUM DISSOLVED mg/L
S.A.R. - SODIUM ADSORPTION RATIO
K - POTASSIUM DISSOLVED mg/L
Cl - CHLORIDE DISSOLVED mg/L

SO-4 - SULFATE DISSOLVED mg/L
F - FLUORIDE DISSOLVED mg/L
SIO-2 - SILICA DISSOLVED mg/L
Fe - IRON DISSOLVED ug/L
T.D.S. - TOTAL DISSOLVED SOLIDS mg/L SUM OF CONSTITUENTS
NO-3 - NITRATE DISSOLVED mg/L

SOURCE: U.S.G.S. FILE DATA

figure 4 -12

NACATOCH SAND
OUTCROP ZONE, STRUCTURAL CONTOURS AND EXTENT OF FRESH WATER



SOURCE: Modified from Petersen and others ⟨57⟩, and Cushing ⟨19⟩.

gray, commonly cross bedded quartz sand containing a few hard lenses of fossiliferous sandy limestone. Thickness of the unit varies from less than 200 feet in Clark County to over 300 feet in Nevada County, generally becoming thicker to the southwest. <48, 67> Sand percentages for the entire formation vary from less than 20% in southern Nevada County to over 60% in Clark County. The highest sand percentages were found in east-central Clark County adjacent to the outcrop zone (See Figure 4-13).

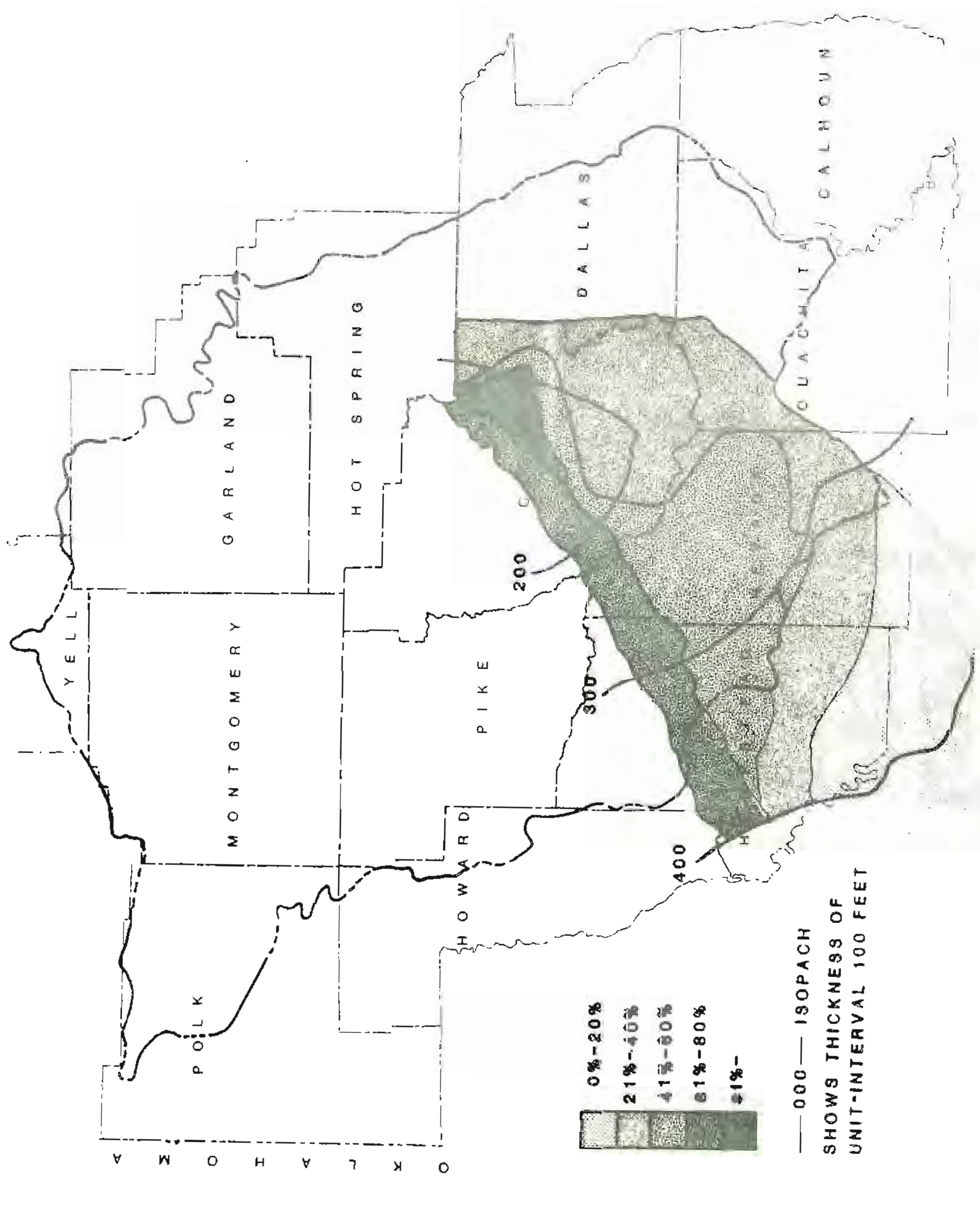
Hydrology. Most withdrawals from the Nacatoch are from the upper portion of the formation which is the principal water-bearing unit. <67> Yields commonly range from 100 to as much as 300 GPM in and near the outcrop zone. <59, 67> Groundwater movement on a large scale is toward the southeast as precipitation entering the aquifer in the outcrop zone moves downdip under artesian conditions. An additional source of recharge is percolation through Quaternary deposits into the underlying Nacatoch. <13, 48, 59, 67>

Potentiometric changes in the water levels in six wells screened in the Nacatoch Sand are illustrated in Figure 4-14. These wells were selected because of their long period of record. Well number 1 is located south of Prescott in Nevada County. Continuous record for the well is available from 1963 to the present. In 1963, the water level was at approximately 227 feet (msl). In 1985, the water level was at 203 feet. The net loss has been about 24 feet over 23 years which is a little over one foot per year. Well number 2 is located northeast of Gurdon and had a net rebound of exactly one foot for the period of record, 1958 to 1968. Another well south of Arkadelphia (well no. 3) had records from 1963 to 1985. The net decline for the period of record was approximately four feet. Water levels in these three wells in the Nacatoch Sand show very little deviation from one year to another.

Water levels for the three other wells illustrated in Figure 4-14 (wells 4, 5, and 6) show considerable variation. Well no. 4 is one of four wells in the Gurdon well field. From 1970 to 1985, the water level showed a net decline of approximately 21 feet. The greatest change for any single year was from the spring of 1979 to the spring of 1980 with a decline of 29 feet. Well no. 5 is in the Hope well field and has also shown considerable variability over 19 years of record from 1966 to 1985. The overall net change has indicated a rebound of about 34 feet. Well no. 6, in the Prescott well field, showed a net decline of about 1 foot for the 12-year period of record. Since wells 4, 5, and 6 are city wells, the variability in water levels for these three

figure 4-13

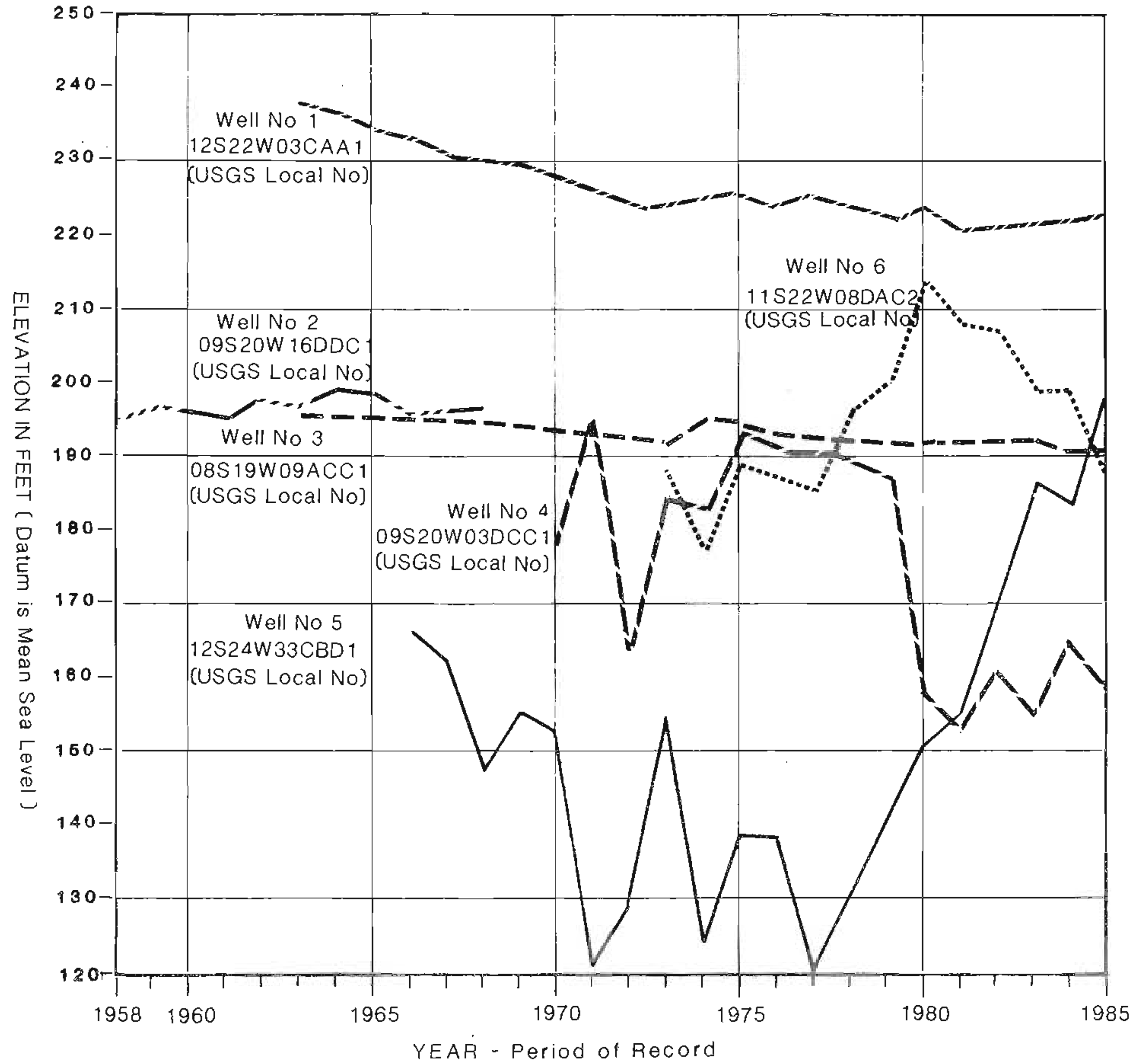
NACATOCH SAND
ISOPACH and PERCENT SAND



SOURCE: Modified from Terry and Others <67>

figure 4-14

NACATOCH SAND HYDROGRAPHS FOR SELECTED WELLS



SOURCE: USGS File Data

wells indicates that levels are probably changing in response to pumping schedule changes. Therefore, the variability in water levels does not represent long-term problems or declines.

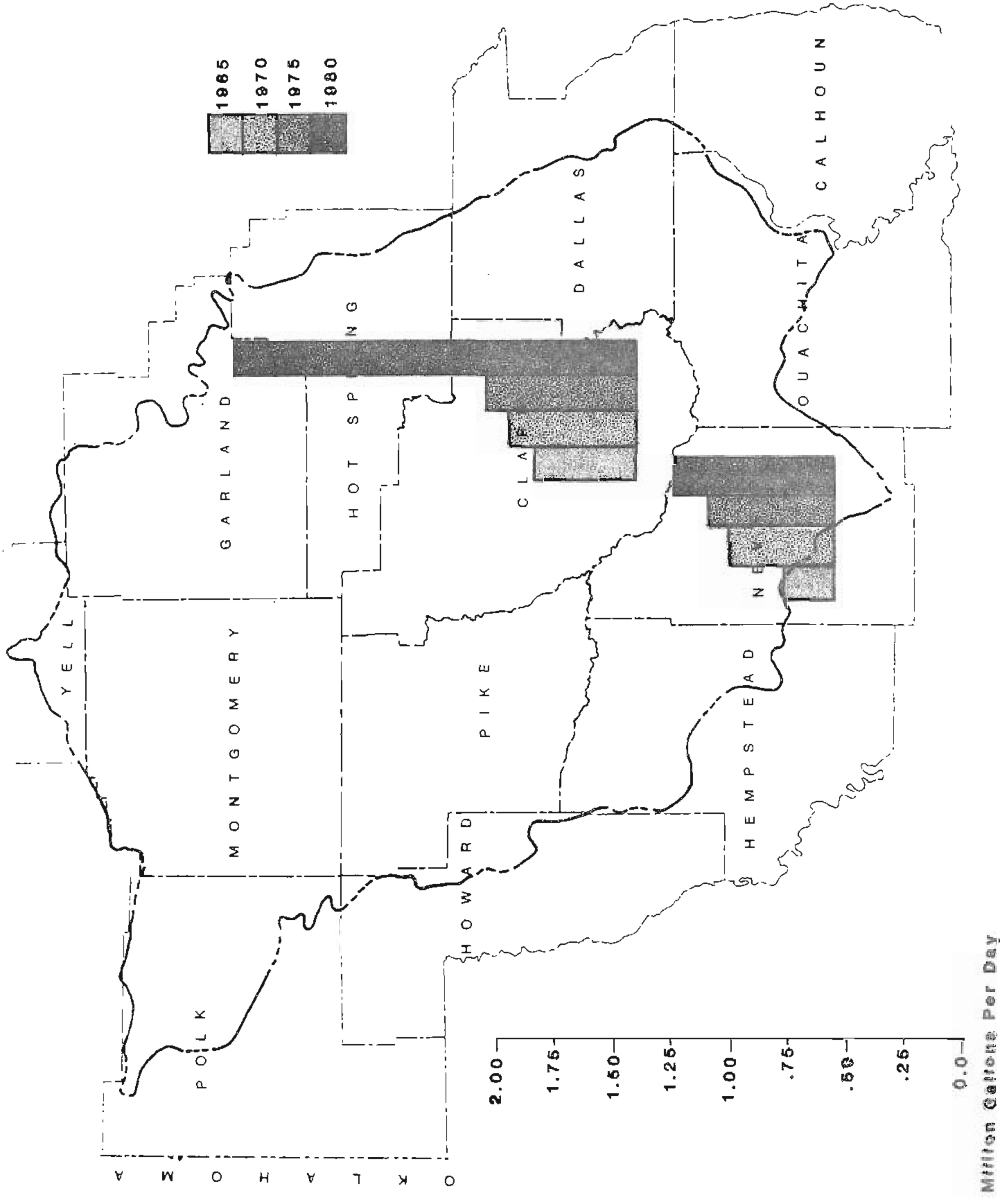
Water Use. The Nacatoch Sand is the second most important aquifer in the basin according to withdrawals in 1980. Use in 1980 totaled 2.41 MGD in Clark and Nevada Counties. Use has increased for every five-year period since 1965 in both counties as shown in Figure 4-15. Major uses in Clark County are for fish production, crops other than rice, and public supply systems. Withdrawals in Nevada County were for domestic, livestock, and public supply systems. Withdrawals from the Nacatoch in the study area represent only 18.6% of the total groundwater withdrawals from all aquifers in the study area and approximately 37% of statewide Nacatoch withdrawals in 1980. <31, 32, 33, 40>

In Nevada, Hempstead, and Clark Counties, three public supply systems depend on the Nacatoch Sand to meet their needs. The City of Emmet in Nevada County has a public supply well in the Nacatoch that is 400 feet deep. This well serves approximately 600 persons in the area. The maximum demand is only about 25% of maximum capacity (.216 MGD) with storage capability equal to one day's demand of 0.05 MGD. The City of Perrytown, just northeast of Hope in Hempstead County, serves a population of 85 persons with a maximum demand of 0.01 MGD, which is only 12% of maximum capacity. Storage facilities, however, are only 3% of one days demand. Perrytown has only one well screened in the Nacatoch at 300 feet below land surface. The City of Gurdon in Clark County has four wells in the Nacatoch ranging in depth from 257 to 376 feet below land surface. The system serves a population of approximately 3000 persons with a maximum demand of 0.38 MGD and a maximum capacity of 0.53 MGD. Storage facilities are roughly equal to one day's supply. The three systems supply water to approximately 3600 persons with a maximum demand of about 0.5 MGD. All three systems have less than one day's supply in storage facilities. <3>

Several municipalities that previously used water from the Nacatoch Sand as a source of water supply have changed to surface-water sources due to quantity and (or) quality problems. For example, the city of Prescott which previously withdrew water from the Nacatoch Sand currently uses the Little Missouri River as a water supply source. The Hope Municipal Water System has reduced withdrawals from the Nacatoch Formation and is currently using water from Millwood Reservoir to supplement the water supply for the city.

figure 4-15

NACATOCH SAND GROUNDWATER WITHDRAWALS 1965-1980



SOURCES: Halberg ⟨31,32,33⟩

Holland and Ludwig ⟨40⟩

However, according to data collected in 1987 by the Arkansas Department of Health, the Hope utility still obtains slightly more than 50% of its water from wells which tap the Nacatoch and Tokio Formation (Arkansas Department of Health, written communication, 1987 - See Appendix A).

Water Quality. The chemical characteristics of water from the Nacatoch Sand are highly variable, but the water is generally of good quality and is suitable for most uses. Concentrations of iron, total dissolved solids, chloride, and color in water from the Nacatoch Formation have, at times, exceeded drinking water limits. A summary of data for selected constituents is provided in Table 4-13 to characterize the quality of water from the Nacatoch Sand in Clark, Hempstead, and Nevada Counties within the Upper Ouachita Basin.

Concentrations of chloride, total dissolved solids, and other constituents generally increase downdip from the outcrop area. In fact, within a distance of about five miles from the outcrop, the water can become unusable for most purposes. The fresh water-salt water interface in the Nacatoch Formation is identified in Figure 4-12. Groundwater in the area designated as fresh water contains less than 1000 mg/L of total dissolved solids. Fresh water in the Nacatoch Formation is available from the outcrop zone southeastward to include most of Hempstead County, the northwestern half of Nevada County, and the central portion of Clark County. A few miles downdip from this area the water quality rapidly deteriorates.

Cenozoic Erathem

Within the Cenozoic Erathem are the Tertiary and the Quaternary Systems. The Tertiary System contains the Paleocene and Eocene Series. The Wilcox Group from the Paleocene is discussed in the report. Within the Eocene Series are formations from the Claiborne Group which include the Carrizo Sand, the Cane River, and the Sparta Sand. The Carrizo Sand is composed primarily of fine or very fine sand and is used as a source of water for domestic wells. The Cane River is composed primarily of silt and clay and generally is not considered to be an aquifer. However, the town of Sparkman obtains its water supply from the Cane River Formation. The Sparta Sand is a major aquifer in the basin and is discussed in a subsequent section of the report. The Quaternary System contains the Pleistocene (terraces) and the Holocene (alluvium) Series and is also discussed in the report.

TABLE 4-13

NACATOCH SAND

OROUNDWATER QUALITY

COUNTY		TEMP.	COLOR	S.C.	pH	HCO-3	CO-3	CaCO-3	N.C.H.	Ca	Mg	Na	S.A.R.	K	Cl	SO-4	F	SiO-2	Fe	T.D.S.	NO-3
CLARK	# OF SAMPLES	29	5	30	30	30	30	30	30	8	8	8	8	8	30	30	8	8	5	8	29
	MIN	17.6	1	69	6.9	16	0	6	0	2.0	0.1	6.5	0.6	2	7.0	1.0	0	7.8	20	96	0
	MAX	21.7	18	19900	8.9	430	35	2700	2600	750	200	3700	37	80	7600	120	3.6	63	7400	12000	4.2
	MEAN	19.5	6	1920	8.4	280	14	140	92	100	27	590	20	15	500	21	1.0	26	3000	1910	1.2
HEMPSTEAD	# OF SAMPLES	3	0	13	13	13	13	13	13	3	3	3	3	3	13	13	2	3	1	3	13
	MIN	25.5	-	83	4.7	2	0	18	0	16	2.9	110	6	3	3.0	1.0	0.4	17	160	360	0
	MAX	25.5	-	635	8.6	270	10	280	64	21	4.0	120	8	3	44	100	0.6	19	160	390	26
	MEAN	26.5	-	478	7.9	190	3	100	12	19	3.4	120	7	3	24	41	0.5	18	160	373	4.1
NEVADA	# OF SAMPLES	16	9	24	24	23	22	24	24	10	10	10	10	10	24	24	9	10	16	10	22
	MIN	15.5	0	330	7.4	190	0	4	0	0.6	0.2	14	0.5	1	5.5	6.0	0	7.8	3	250	0
	MAX	32.5	10	2530	8.9	410	24	210	29	67	6.0	450	52	5	550	180	1.4	53	1300	1200	1.9
	MEAN	20.9	5	828	8.2	260	5	63	1	22	2.5	180	26	3	110	33	0.5	24	160	543	0.71
MEAN OF MEANS		22.0	6	1080	8.2	240	7	100	35	47	11	300	18	7	210	32	0.7	23	1100	942	2.0

TEMP. - DEGREES - CENTIGRADE
COLOR - PLATINUM - COBALT UNITS
S.C. - SPECIFIC CONDUCTANCE (umhos)
HCO-3 - BICARBONATE mg/L
CO-3 - CARBONATE mg/L
CaCO-3 - CALCIUM CARBONATE HARDNESS mg/L

N.C.H. - NON-CARBONATE HARDNESS mg/L
Ca - CALCIUM DISSOLVED mg/L
Mg - MAGNESIUM DISSOLVED mg/L
Na - SODIUM DISSOLVED mg/L
S.A.R. - SODIUM ADSORPTION RATIO
K - POTASSIUM DISSOLVED mg/L
Cl - CHLORIDE DISSOLVED mg/L

SO-4 - SULFATE DISSOLVED mg/L
F - FLUORIDE DISSOLVED mg/L
SiO-2 - SILICA DISSOLVED mg/L
Fe - IRON DISSOLVED ug/L
T.D.S. - TOTAL DISSOLVED SOLIDS mg/L SUM OF CONSTITUENTS
NO-3 - NITRATE DISSOLVED mg/L

SOURCE: U.S.G.S. FILE DATA

Wilcox Group

Geology. The Wilcox Group is the oldest and lowermost unit of the Eocene series in the Upper Ouachita Basin. The group occurs at the surface or in the subsurface in the southern part of the basin. The Wilcox Group is overlain by the Carrizo Sand of the Claiborne Group and underlain by the clays of the Midway Group. The group outcrops in a relatively narrow band across the basin trending northeast-southwest extending from Hempstead to Hot Spring County. (See Figure 4-16). The dip of the beds is generally to the southeast at the rate of 80 feet per mile. <16, 57>

The interbedding characteristics of the Wilcox Group hinder prediction of depth to fresh water at any specific site. Most of the sands were deposited in a delta environment, where they were alternately inundated and exposed with rapid shoreline movement. The result was relatively thin sand beds and clay. <57, 59>

Hydrology. The Wilcox Group contains discontinuous sand lenses in and near the outcrop zone that serve as aquifers for household and other small domestic needs. The area of use extends only a few miles downdip from the outcrop area due to deteriorating quality. <59, 67>

Recharge to the Wilcox occurs when precipitation enters the sand lenses in the outcrop and subcrop zones. Movement is generally downdip toward the southeast. <57>

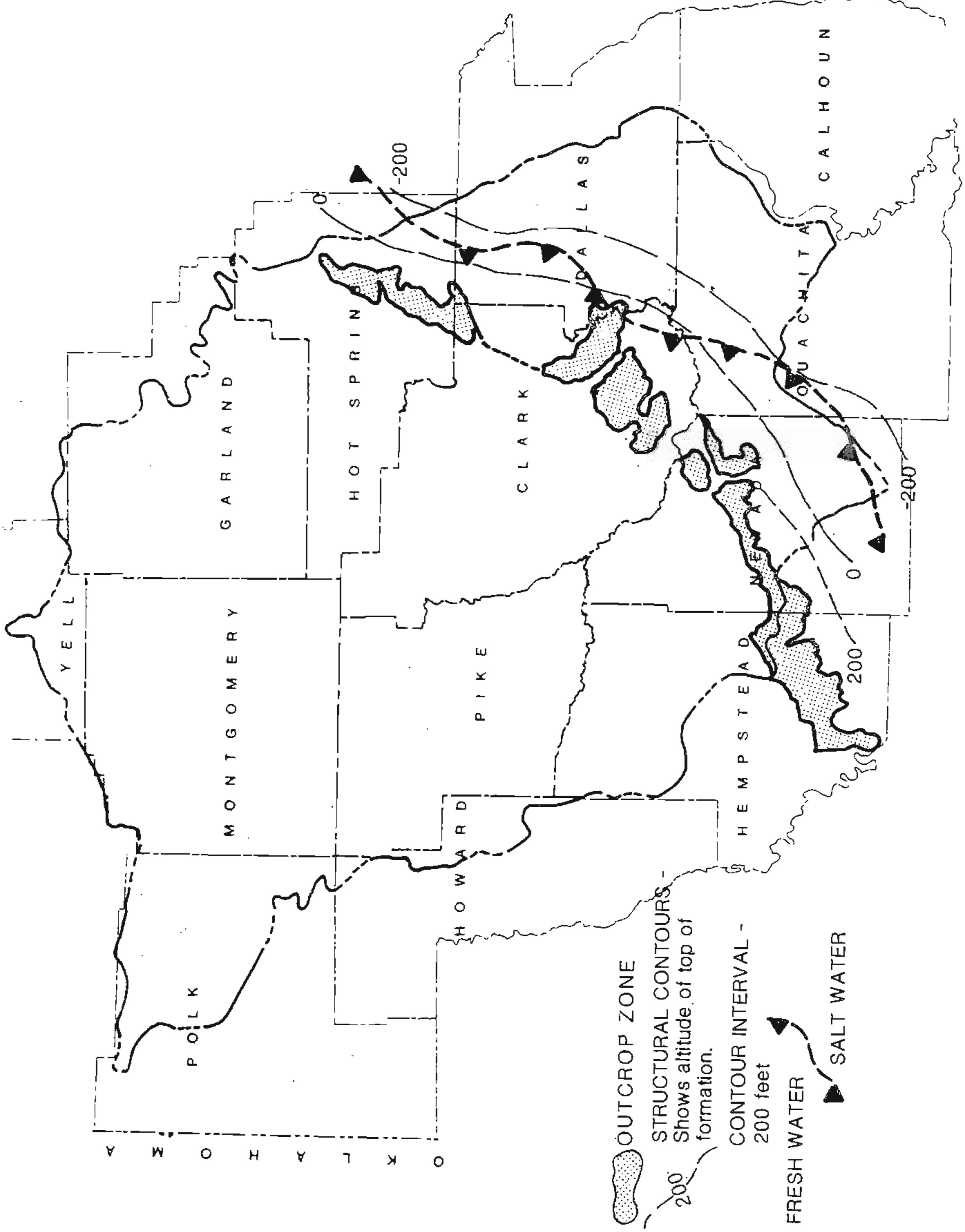
Water-level data for wells in the Wilcox are insufficient to show any trends or problems in the study area. Numerous water-level measurements have been made, however, no long-term data is available for evaluation.

Water Use. Withdrawals from the Wilcox Group in 1980 in Clark, Hot Spring, and Nevada Counties totaled 0.91 MGD. Total use has approximately doubled since 1965. Use in Hot Spring and Nevada Counties has not changed significantly during the period of 1965-80, as illustrated in Figure 4-17. However, use in Clark County has increased from 0.07 MGD in 1965 to 0.52 MGD in 1980. <31, 40>

The Rosston public supply system in Nevada County is the only system in the basin utilizing water from the Wilcox. The system is supplied by one well approximately 350 feet deep. The maximum demand on the system is 50,000 GPD which is equal to the storage in the system. The total population served is approximately 1000 persons. <3>

figure 4-16

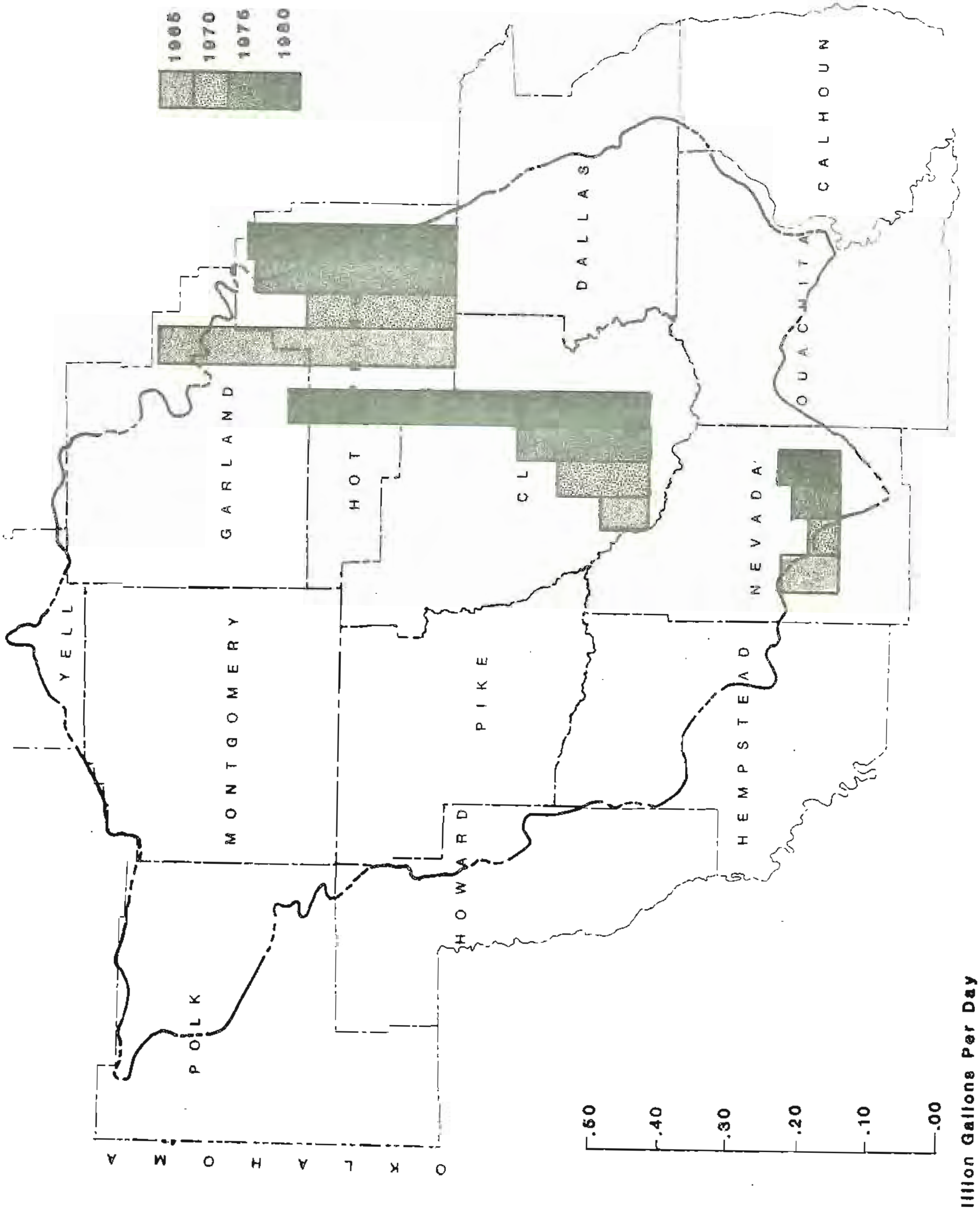
WILCOX GROUP
OUTCROP ZONE, STRUCTURAL CONTOURS AND EXTENT OF FRESH WATER



SOURCE: Modified from Petersen and Others ⟨57⟩

figure 4-17

WILCOX GROUP GROUNDWATER WITHDRAWALS 1965-1980



SOURCE: Halberg ⟨31,32,33⟩

Holland and Ludwig ⟨40⟩

Water Quality. Limited data are available to characterize the water quality of the Wilcox. In fact, as shown in Table 4-14, data for only one water sample were available for three of the five counties. The water-quality data summarized in the table do, however, indicate that the water is generally of good quality and is suitable for most uses. Concentrations of sodium, chloride, and total dissolved solids are generally well within the limits established for drinking water standards.

The fresh water-salt water interface in the Wilcox is identified in Figure 4-16. Groundwater in the area designated as fresh water contains less than 1000 mg/L of total dissolved solids. The water quality rapidly deteriorates downdip from the fresh water area.

Sparta Sand

Geology. The Sparta Sand is the youngest aquifer of the Claiborne Group that outcrops in the Upper Ouachita Basin. The formation is underlain by the Cane River Formation and is overlain by the Cook Mountain Formation. <59> The Sparta Sand outcrops in a semi-continuous band trending northeast-southeast from Hot Spring and Dallas Counties to Nevada County, as shown in Figure 4-18. <57> The outcrop band is interrupted in Ouachita County where it is overlain by terrace gravels and alluvium of Quaternary Age. <42> The dip of the beds is generally southeasterly at approximately 15 feet per mile. Thickness of the formation varies from a feather edge along the western outcrop limit to slightly less than 200 feet in Ouachita County. <57>

Composition of the Sparta Sand varies considerably both laterally and vertically over short distances due to the depositional environment of the formation. The Sparta is mostly sand of continental origin, which was deposited over long periods of time by meandering rivers. The result was lenticular, overlapping and interfingered thick bodies of sand interspersed with thin beds of sandy to silty clay and lignite. The outcrop zone consists of over 60% fine to medium sand with an interbedded sandy lignite clay. <59, 67>

Hydrology. The source of recharge to the Sparta Sand is precipitation infiltrating into the outcrop area and percolating through Quaternary deposits, where present. Movement of water in the study area is generally to the southeast. Well yields commonly range from 300 GPM to 700 GPM

TABLE 4-14
WILCOX GROUP
GROUNDWATER QUALITY

COUNTY		TEMP.	COLOR	S.C.	pH	HCO-3	CO-3	CaCO-3	N.C.H.	Ca	Mg	Na	S.A.R.	K	Cl	SO-4	F	SiO-2	Fe	T.D.S.	NO-3
CLARK	# OF SAMPLES	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	MIN	20.0	1	231	7.9	110	0	4	0	1.6	0	51	12	1	17	2.4	0.1	39	260	170	0.20
	MAX	20.0	1	231	7.9	110	0	4	0	1.6	0	51	12	1	17	2.4	0.1	39	260	170	0.20
	MEAN	20.0	1	231	7.9	110	0	4	0	1.6	0	51	12	1	17	2.4	0.1	39	260	170	0.20
DALLAS	# OF SAMPLES	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	MIN	23.0	10	245	7.0	120	0	88	0	28	4.3	8.2	0.4	4	3.0	19	0.1	11	20	140	0
	MAX	23.0	10	245	7.0	120	0	88	0	28	4.3	8.2	0.4	4	3.0	19	0.1	11	20	140	0
	MEAN	23.0	10	245	7.0	120	0	88	0	28	4.3	8.2	0.4	4	3.0	19	0.1	11	20	140	0
HEMPSTEAD	# OF SAMPLES	0	0	1	1	1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	1
	MIN	-	-	90	7.4	33	0	26	0	-	-	-	-	-	5.8	1.0	-	-	-	-	3.7
	MAX	-	-	90	7.4	33	0	26	0	-	-	-	-	-	5.8	1.0	-	-	-	-	3.7
	MEAN	-	-	90	7.4	33	0	26	0	-	-	-	-	-	5.8	1.0	-	-	-	-	3.7
HOT SPRING	# OF SAMPLES	12	12	12	13	12	12	12	12	12	12	12	12	12	12	12	0	10	12	12	10
	MIN	16.5	0	21	4.8	2	0	3	0	0.5	0.4	1.5	0.3	0.1	2.4	0	-	8.2	0	13	0
	MAX	20.5	4	661	8.5	180	4	84	38	18	9.5	110	7	3	110	31	-	51	9700	350	11
	MEAN	18.8	2	146	6.6	50	1	27	6	6.1	2.9	18	1	1	14	5.5	-	19	1500	94	2.6
NEVADA	# OF SAMPLES	1	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
	MIN	23.0	0	29	7.4	76	0	69	0	26	1.0	3.3	0.2	5	4.8	13	0	11	10	130	0
	MAX	23.0	4	301	8.1	150	0	120	7	35	8.7	18	0.8	10	5.0	29	0.1	20	60	190	15
	MEAN	23.0	2	181	7.8	120	0	100	3	30	6.1	12	0.5	7	4.9	23	0.1	15	40	167	5.4
MEAN OF MEANS		21.2	4	179	7.3	87	0	49	2	16	3.3	22	3	3	8.9	10	0.1	21	460	143	2.4

TEMP. - DEGREES - CENTIGRADE
COLOR - PLATINUM - COBALT UNITS
S.C. - SPECIFIC CONDUCTANCE (umhos)
pH - STANDARD UNITS
HCO-3 - BICARBONATE mg/L
CO-3 - CARBONATE mg/L
CaCO-3 - CALCIUM CARBONATE HARDNESS mg/L

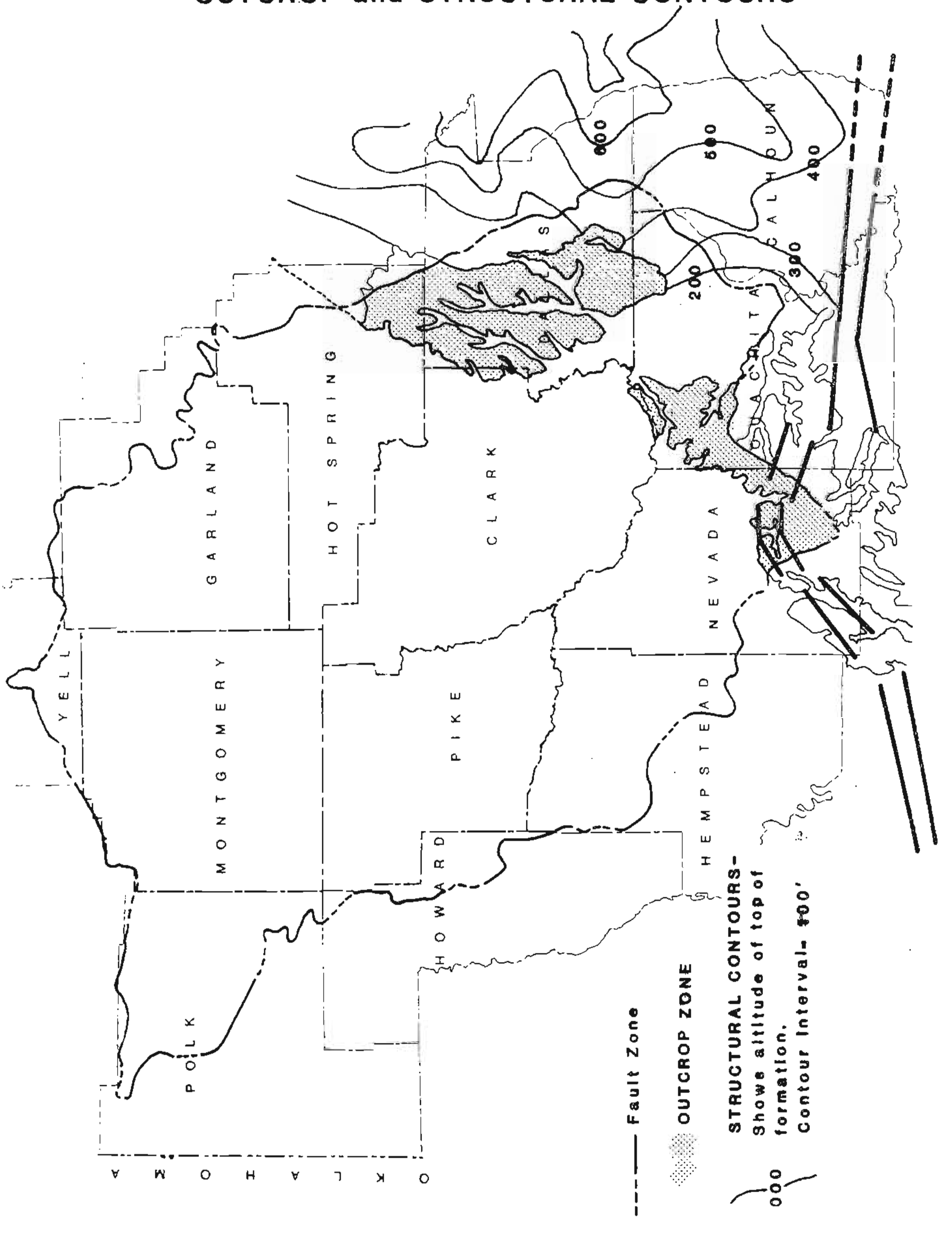
N.C.H. - NON-CARBONATE HARDNESS mg/L
Ca - CALCIUM DISSOLVED mg/L
Mg - MAGNESIUM DISSOLVED mg/L
Na - SODIUM DISSOLVED mg/L
S.A.R. - SODIUM ADSORPTION RATIO
K - POTASSIUM DISSOLVED mg/L
Cl - CHLORIDE DISSOLVED mg/L

SO-4 - SULFATE DISSOLVED mg/L
F - FLUORIDE DISSOLVED mg/L
SiO-2 - SILICA DISSOLVED mg/L
Fe - IRON DISSOLVED ug/L
T.D.S. - TOTAL DISSOLVED SOLIDS mg/L SUM OF CONSTITUENTS
NO-3 - NITRATE DISSOLVED mg/L

SOURCE: U.S.G.S. FILE DATA

figure 4-18

SPARTA SAND
OUTCROP and STRUCTURAL CONTOURS



SOURCE: Modified from Petersen and Others ⟨57⟩

depending on aquifer characteristics such as thickness and percent sand at any one location. <1, 57>

The potentiometric surface for 1985 in the Sparta Sand is illustrated in Figure 4-19. In the Upper Ouachita Basin, essentially all of the Sparta Sand formation is within the outcrop zone which is under water-table conditions. The isolines illustrate the gradient and the direction of flow, which is perpendicular to these isolines. The gradient is steepest in Dallas County as indicated by the tightly-spaced isolines. <24> Movement of ground water in this part of the study area is generally southward toward the Ouachita River. South of the Ouachita River, several changes occur that influence the gradient and direction of groundwater movement. Immediately west and south of the river, movement is eastward to the river. The river in this reach may be a gaining stream. The Sparta Sand that underlies the Quaternary deposits is recharging the Quaternary and/or the Ouachita River. South of this area, isolines are influenced by the cone of depression that exists southeast of Camden. The southwestern part of Ouachita County is the portion of the recharge zone that supplies the wells in El Dorado and in northwestern Union County.

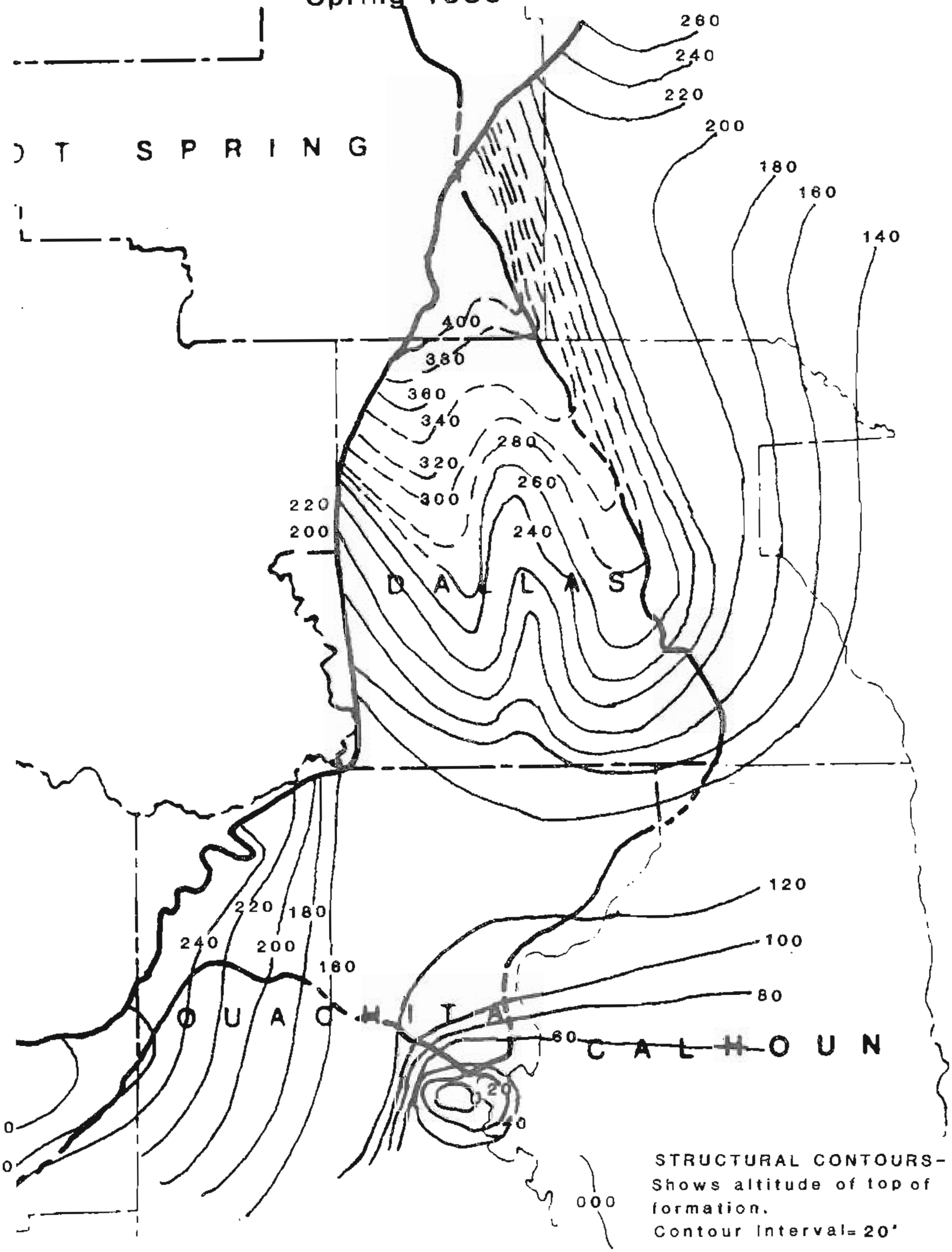
Hydrographs for three wells in Ouachita County are illustrated in Figure 4-20. The wells are located near Chidester (well no. 1), Eagle Mills (well no. 2), and Bearden (well no. 3). In general, the wells showed some variation from year to year but the annual change for rebound and declines was less than six feet for any year from spring to spring.

Water Use. Based on withdrawals in the study area in 1980, the Sparta Sand is the third most important aquifer in the basin. Withdrawals in 1980 totaled 1.75 MGD which represents about 14% of the water withdrawn in the study area, but represents less than 1% of the total statewide withdrawals from the Sparta formation. Use has increased in Hot Spring, Dallas, and Nevada Counties during the period of 1965-80, as indicated by the data compiled in Table 4-15. <31, 32, 33, 40>

The Sparta is used primarily for public supplies and self-supplied industry in the study area. Public supply systems relying on the Sparta within the basin are Chidester, East Camden, Camden Industrial Park, and Harmony Grove. The city of Chidester has its own wells, while Harmony Grove, East Camden, and Camden Industrial Park purchase water from Shumaker Water Company which has wells in the Sparta. <3>

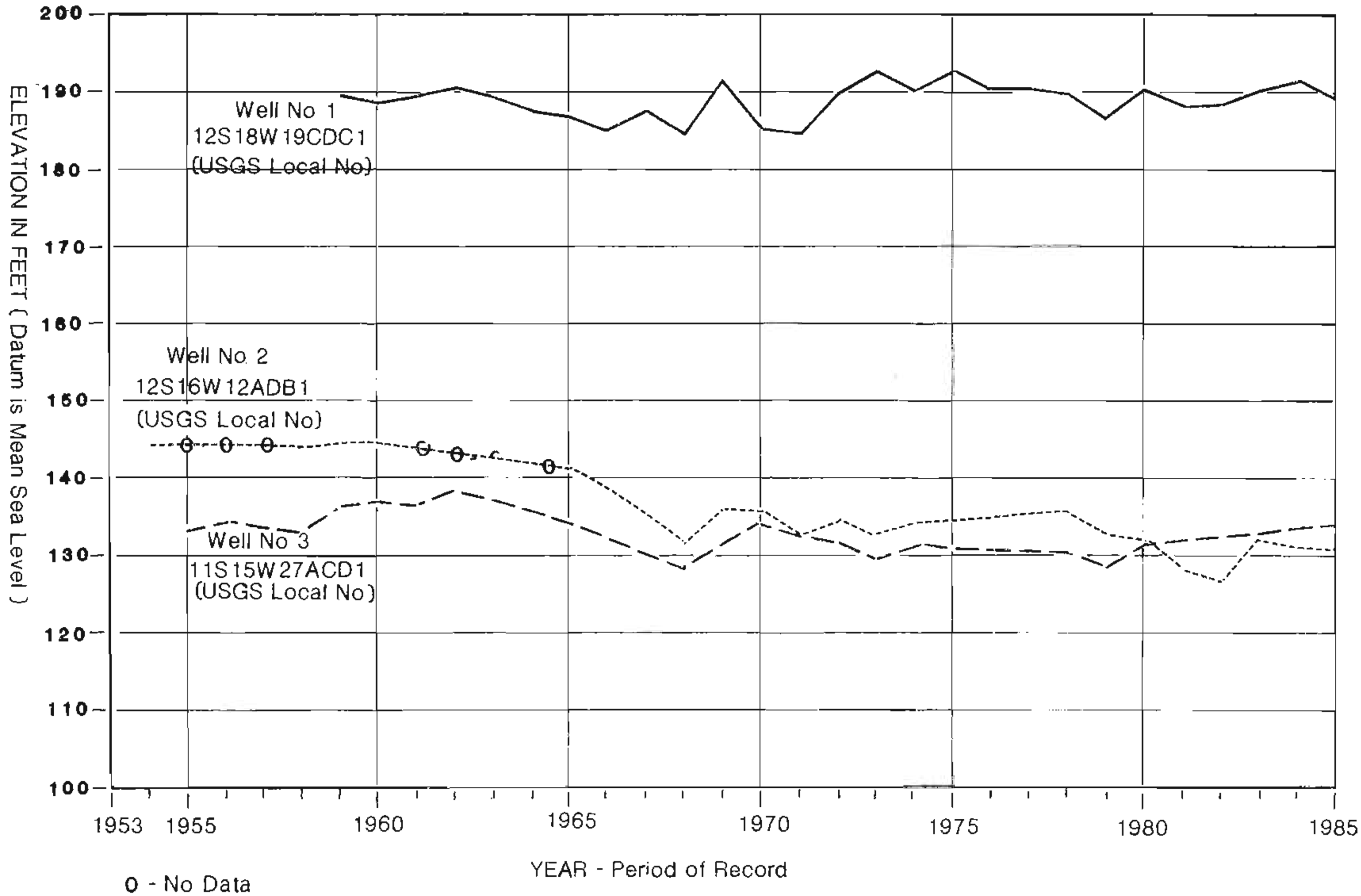
figure 4-19

SPARTA SAND POTENTIOMETRIC SURFACE Spring 1985



SOURCE: Modified from Edds and Fitzpatrick ⟨24⟩

figure 4-20
SPARTA SAND
HYDROGRAPHS for SELECTED WELLS



SOURCE: USGS File Data

TABLE 4-15

SPARTA SAND

GROUNDWATER WITHDRAWALS

1965-1980

COUNTY	WITHDRAWALS (MGD) 1965	1970	1975	1980
HOT SPRING	.06	.15	.15	.17
DALLAS	.67	1.04	1.19	1.42
NEVADA	.0	.10	.13	.16
TOTALS	.73	1.29	1.47	1.75

SOURCES: HALBERG <31, 32, 33>
HOLLAND AND LUDWIG <40>

Water Quality. Water from the Sparta Sand formation is of good quality and is generally suitable for most uses with little or no treatment required. Water quality data for selected constituents (summarized in Table 4-16) show that water from the Sparta Sand formation generally is soft and very low in mineralization. Most constituent concentrations are less than the limits established for drinking water standards. However, dissolved iron concentrations have, at times, exceeded the 300 ug/L concentration that is recommended for drinking water supplies.

TABLE 4-16

SPARTA SAND

GROUNDWATER QUALITY

COUNTY		TEMP.	COLOR	S.C.	pH	HCO-3	CO-3	CaCO-3	N.C.H.	Ca	Mg	Na	S.A.R.	K	Cl	SO-4	F	SiO-2	Fe	T.D.S.	NO-3
DALLAS	# OF SAMPLES	4	7	7	7	6	6	7	7	7	7	7	7	7	7	7	7	7	4	7	7
	MIN	15.5	0	14	6.1	6	0	4	0	0.6	0.5	1.0	0.1	0.6	0	0	0	11	20	19	0
	MAX	22.0	5	298	6.9	39	0	70	57	15	7.8	22	1	6	45	7.0	0.3	40	9600	140	52
	MEAN	19.0	2	96	6.5	19	0	25	9	6.9	1.9	5.7	0.5	2	9.0	2.9	0.1	21	2500	62	8.2
HOT SPRING	# OF SAMPLES	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	2	2	2	2
	MIN	18.5	0	83	5.5	3	0	31	0	8.8	2.3	1.7	0.1	2	2.4	2.2	-	12	550	66	0
	MAX	18.5	3	169	7.2	40	0	44	42	8.8	5.4	12	0.8	4	17	6.2	-	18	10000	120	53
	MEAN	18.5	2	126	6.4	22	0	38	21	8.8	3.8	6.8	0.4	3	9.7	3.7	-	15	5300	93	26
OUACHITA	# OF SAMPLES	17	10	18	18	18	18	18	18	11	11	11	11	11	18	17	0	3	11	3	16
	MIN	17.0	1	43	5.7	4	0	7	0	1.0	0.7	3.2	0.5	1	4.5	0.2	-	3.9	0	24	0.31
	MAX	21.0	15	297	7.9	1280	0	110	59	23	6.3	42	5	56	36	18	-	16	280	200	44
	MEAN	19.1	6	145	6.9	120	0	37	8	7.4	2.2	17	2	8	9.5	5.5	-	7.9	70	90	6.6
MEAN OF MEANS		18.9	3	122	6.6	54	0	33	13	7.7	2.6	9.8	1	4	9.4	4.0	-	16	2500	82	14

TEMP. - DEGREES - CENTIGRADE
COLOR - PLATINUM - COBALT UNITS
S.C. - SPECIFIC CONDUCTANCE (umhos)
HCO-3 - BICARBONATE mg/L
CO-3 - CARBONATE mg/L
CaCO-3 - CALCIUM CARBONATE HARDNESS mg/L

N.C.H. - NON-CARBONATE HARDNESS mg/L
Ca - CALCIUM DISSOLVED mg/L
Mg - MAGNESIUM DISSOLVED mg/L
Na - SODIUM DISSOLVED mg/L
S.A.R. - SODIUM ADSORPTION RATIO
K - POTASSIUM DISSOLVED mg/L
Cl - CHLORIDE DISSOLVED mg/L

SO-4 - SULFATE DISSOLVED mg/L
F - FLUORIDE DISSOLVED mg/L
SiO-2 - SILICA DISSOLVED mg/L
Fe - IRON DISSOLVED ug/L
T.D.S. - TOTAL DISSOLVED SOLIDS mg/L SUM OF CONSTITUENTS
NO-3 - NITRATE DISSOLVED mg/L

SOURCE: U.S.G.S. FILE DATA

Quaternary System

Geology. The Quaternary System can be divided into the Holocene (recent alluvium) and the Pleistocene (terrace) Series. The terraces are older but usually are located at higher elevations than the alluvium. The process of alluvial deposition continues today along the Ouachita and the Little Missouri Rivers, as well as along all streams in the Gulf Coastal Plain Province of the basin. In some areas the alluvium and terraces are at different elevations, are highly dissected and function as independent aquifers. In other areas, the two units are indistinguishable, and can be treated as one hydrologic unit. <14, 19, 20, 67> The outcrop areas are shown in Figure 4-21.

The terraces in the basin are a result of several periods of glaciation and melting which were characterized by many alternating cycles of erosion and alluviation. This resulted in well sorted and semi-stratified beds in some areas with highly interfingered wedges and lenses in others. The unit generally grades upward from coarse sand and gravel at the base to silt and clay at the top. Gravel and sand may compose as much as fifty percent of the total thickness of the unit in small areas. <14, 19, 20, 67>

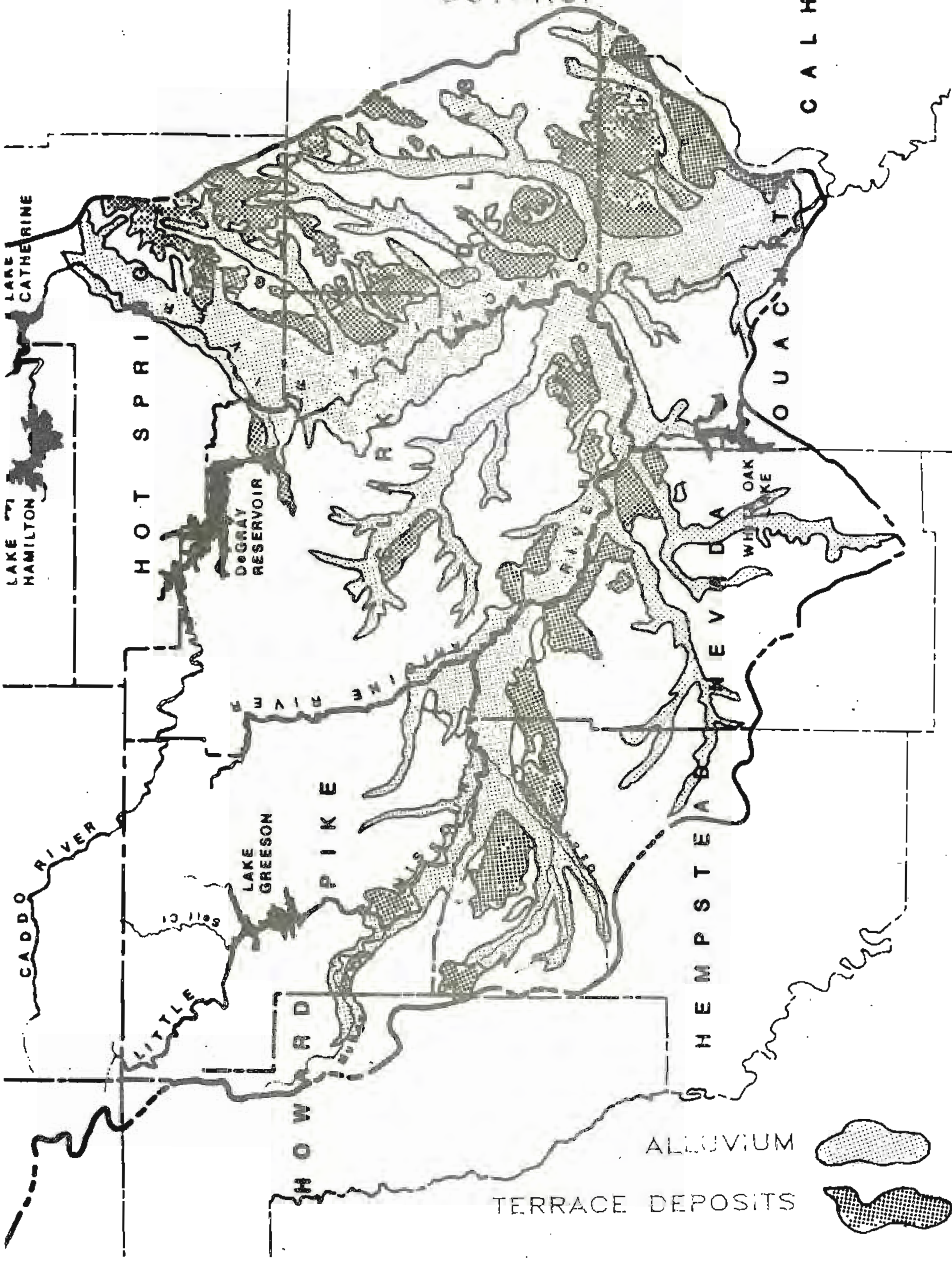
In general, the terrace deposits occur at elevations above 300 feet. The beds are nearly horizontal and consist of rounded chert, quartz, and quartzite pebbles intermixed with sand and clay up to 12 feet thick. <49> Some of the larger terrace deposits occur near the crest of a ridge trending northwest-southeast through southeastern Hot Spring and central Dallas Counties. (See Figure 4-21) Other deposits in these counties occur near the Ouachita River.

Alluvial deposits are generally composed of gravel, sand, silt, and clay. Stratification in the alluvium is similar to zones in the terrace deposits. There is a progressive change from gravel and coarse sand in the basal section to fine-grained materials near the top. <1, 34, 57> Figure 4-21 illustrates the spatial distribution of the recent alluvium that outlines the Ouachita and Little Missouri Rivers as well as Ozan, Terre Noire, L'Eau Frais, Cypress, and Tulip Creeks. <35> Generally, thickness is less than 50 feet except in Ouachita County where thickness increases to nearly 150 feet along the Ouachita River. <14>

Hydrology. Recharge to the terrace and alluvial deposits is principally from precipitation percolating into surface materials of the outcrop area. High conductivity values make

figure 4-21

QUATERNARY SYSTEM OUTCROP



SOURCE: Modified from Haley and Others <35>

the Quaternary terraces and alluvium an aquifer throughout the area of occurrence, but thickness of the unit makes it a principal aquifer only in Clark, Hot Spring, and Pike Counties. <59> Yields as high as 240 GPM have been reported in thicker sections of the aquifer, however, yields of approximately 25 GPM are common from the thinner deposits of Hot Spring County. <34>

The terrace and alluvial deposits can store and transmit relatively large quantities of water. Where these deposits rest on materials of lower permeability, the water table in the deposit tends to be perched and will supply water to streams in the area. For example, terrace deposits in Dallas County overlie the Sparta Sand and both geologic units contribute water to sustain the baseflows in Cypress and Tulip Creeks.

Water Use. Use in 1980 from the Quaternary deposits in Clark, Hot Spring, and Pike Counties totaled 0.56 MGD. As shown in Figure 4-22, use has been quite variable during the period of 1965-80. <31, 32, 33, 40>

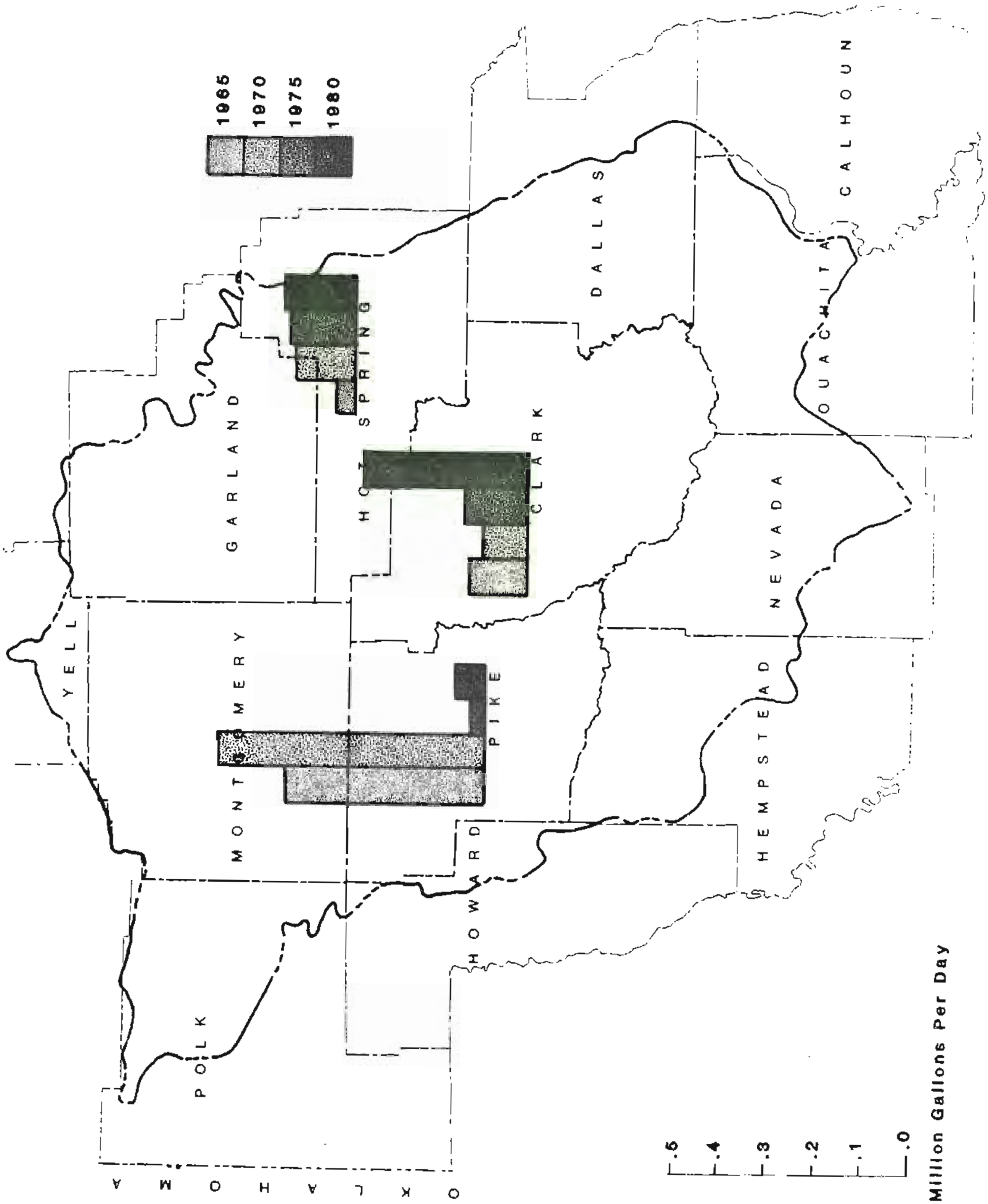
While the Quaternary aquifer is used in several counties, it is still a minor aquifer in the basin. Currently there are no public supply systems withdrawing water from the Quaternary. <3>

Very little data are available on water levels in these deposits. No data of sufficient duration are available to evaluate water-level trends or problems.

Water Quality. Generally, water from Quaternary deposits in the study area is of good quality and is suitable for most uses with only minimal treatment required. Water-quality data for wells in the alluvial deposits are compiled in Table 4-17. It should be noted that the data compiled in Table 4-17 for Clark County contain two samples that may represent industrial contamination. <59> Therefore, the Clark County data are probably not representative of water-quality conditions of Quaternary deposits in the study area. Water-quality data compiled for the other counties in the study area show that the water from Quaternary deposits is usually soft and low in mineralization. Concentrations of iron and nitrate have at times, however, exceeded the limits established for drinking water standards.

figure 4-22

QUATERNARY SYSTEM GROUNDWATER WITHDRAWALS 1965-1980



SOURCE: Halberg ⟨31,32,33⟩

Holland and Ludwig ⟨40⟩

TABLE 4-17
QUATERNARY SYSTEM
GROUNDWATER QUALITY

COUNTY		TEMP.	COLOR	S.C.	pH	HCO-3	CO-3	CaCO-3	N.C.H.	Ca	Mg	Na	S.A.R.	K	Cl	SO-4	F	SiO-2	Fe	T.D.S.	NO-3
CLARK	# OF SAMPLES	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	MIN	17.8	2	224	6.6	27	0	35	13	6.7	4.0	11	0.9	2	20	10	0.1	.11	60	99	0.20
	MAX	19.4	11	1600	8.4	330	7	480	360	160	21	180	4	9	110	590	0.2	39	27000	1200	40
	MEAN	18.3	5	859	7.3	130	1	260	150	83	12	85	3	5	66	220	0.2	2.4	13000	574	14
DALLAS	# OF SAMPLES	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	MIN	17.5	0	74	5.5	8	0	11	0	2.5	1.2	5.3	0.7	2	6.6	0	0.1	9.8	40	46	6.2
	MAX	25.0	4	102	6.8	16	0	22	15	3.2	3.3	8.4	0.8	3	15	3.5	0.1	11	1300	49	18
	MEAN	21.2	2	88	6.2	12	0	16	8	2.8	2.2	6.8	0.8	3	11	1.8	0.1	10	670	48	12
HEMPSTEAD	# OF SAMPLES	0	0	1	1	1	1	1	1	0	0	0	0	0	1	1	0	0	0	0	1
	MIN	-	-	124	7.7	30	0	38	13	-	-	-	-	-	7.0	5.0	-	-	-	-	6.6
	MAX	-	-	124	7.7	30	0	38	13	-	-	-	-	-	7.0	5.0	-	-	-	-	6.6
	MEAN	-	-	124	7.7	30	0	38	13	-	-	-	-	-	7.0	5.0	-	-	-	-	6.6
HOT SPRING	# OF SAMPLES	16	7	18	18	7	7	7	7	7	7	7	7	7	7	7	0	10	12	7	18
	MIN	15.5	1	27	4.9	2	0	5	[illegible]	0.6	0.8	4.3	0.5	1	6.0	0	-	9.6	30	46	4.9
	MAX	22.0	5	335	7.7	17	0	36		7.3	7.5	17	1	2	27	5.6	-	21	610	110	49
	MEAN	18.9	3	148	6.7	7	0	22	.7	4.2	3.0	8.9	0.8	1	13	2.2	-	13	300	72	21
MONTGOMERY	# OF SAMPLES	2	0	2	2	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	0
	MIN	19.0	-	122	6.6	-	-	48	0	17	1.2	2.8	0.2	2	1.9	3.2	0.1	7.3	9	64	-
	MAX	20.0	-	152	7.6	-	-	59	5	21	1.5	3.3	0.2	2	2.9	3.7	0.1	8.1	11	81	-
	MEAN	19.5	-	137	7.1	-	-	54	2	19	1.4	3.0	0.2	2	2.4	3.4	0.1	7.7	10	72	-
OUACHITA	# OF SAMPLES	5	0	5	5	5	5	4	5	0	0	0	0	0	5	5	0	0	0	0	5
	MIN	18.5	-	59	6.1	13	0	11	0	-	-	-	-	-	5.0	1.0	-	-	-	-	2.3
	MAX	23.0	-	330	7.3	130	0	78	53	-	-	-	-	-	51	5.0	-	-	-	-	80
	MEAN	20.8	-	193	6.8	48	0	38	24	-	-	-	-	-	22	3.0	-	-	-	-	19
MEAN OF MEANS		19.7	3	258	7.0	45	0	71	36	27	4.6	26	1	3	20	39	0.1	8.3	3500	192	14

TEMP. - DEGREES - CENTIGRADE
COLOR - PLATINUM - COBALT UNITS
S.C. - SPECIFIC CONDUCTANCE (umhos)
HCO-3 - BICARBONATE mg/L
CO-3 - CARBONATE mg/L
CaCO-3 - CALCIUM CARBONATE HARDNESS mg/L

N.C.H. - NON-CARBONATE HARDNESS mg/L
Ca - CALCIUM DISSOLVED mg/L
Mg - MAGNESIUM DISSOLVED mg/L
Na - SODIUM DISSOLVED mg/L
S.A.R. - SODIUM ADSORPTION RATIO
K - POTASSIUM DISSOLVED mg/L
Cl - CHLORIDE DISSOLVED mg/L

SO-4 - SULFATE DISSOLVED mg/L
F - FLUORIDE DISSOLVED mg/L
SiO-2 - SILICA DISSOLVED mg/L
Fe - IRON DISSOLVED ug/L
T.D.S. - TOTAL DISSOLVED SOLIDS mg/L SUM OF CONSTITUENTS
NO-3 - NITRATE DISSOLVED mg/L

SOURCE: U.S.G.S. FILE DATA

GROUNDWATER PROBLEMS

Quantity

The most common ground water problems in the basin are low yields and poor water quality. Yields in the northern half of the basin from the Paleozoic rocks are commonly less than 10 GPM. The low yields are due to the nature of occurrence of groundwater in secondary openings which keeps storage capacities small. Evapotranspiration, droughts, and large withdrawals have significant impacts on water levels.

Seventeen units of Cretaceous and Tertiary age outcrop in the basin. Seven of these units either do not yield water to wells or yield such minor amounts in small areas to be insignificant. These unproductive units are the Cook Mountain Formation and Midway Group of Tertiary Age and the Arkadelphia Marl, Saratoga Chalk, Marlbrook Marl, Annona Chalk, and Woodbine Formation of Cretaceous Age.

Generally, the maximum yields from producing units of Cretaceous age are less than 300 GPM, and commonly are 100 to 150 GPM. Yields of this amount from the Nacatoch Sand and (or) Tokio Formation are not adequate to satisfy the needs of large public supply systems. The city of Prescott which previously withdrew water from these geologic units currently uses the Little Missouri River as a water supply source. The city of Hope has reduced groundwater withdrawals and is currently using water from Millwood Reservoir to supplement the water supply for the city. Several small towns still rely on these formations today, however, low yields will remain a problem in the Cretaceous outcrop area and surface water will have to be developed if economic growth continues along the transportation corridor marked by the Fall line.

Quality

The quality of water from Paleozoic rocks is highly variable. The most common water-quality problem is excessive iron, but it can usually be removed by aeration.

The quality of water from the Cretaceous units is a limiting factor in water availability in the Cretaceous portion of the basin. Overall the quality of water from the Nacatoch and Tokio Formation is highly variable, mainly depending on the distance from the outcrop areas. Suitable water quality for most purposes in the outcrop zone becomes too mineralized and salty as little as two miles downdip from the outcrop.

Concentrations of nitrate that exceed the limit established for drinking water standards have been detected in water from several wells in the Upper Ouachita Basin. (See Figure 4-23) Nitrate contamination is probably a problem in other parts of the study area, however, only limited water quality data from this area were available for evaluation.

Nitrate contamination is often due to poor well construction practices. When there is no seal between the bore hole and the casing, water containing high concentrations of nitrate from septic systems, barnyards, outdoor toilets, and waste disposal on pastures can enter the well. The problem, therefore, is partially a legal and institutional problem. The authority to regulate the construction of water wells is vested in the Water Well Construction Committee. The Committee licenses water well contractors, provides drilling rig permits, and tests and registers water well drillers. The Committee also establishes rules and regulations regarding proper construction methods and holds hearings regarding violations of the rules. The problems center around enforcement of existing legislation concerning proper construction techniques and changing the law to address and alleviate current and potential problems. All well contractors are required to submit a construction report within 30 days after the completion of a well. It has been estimated that approximately 1/2 of all wells drilled in certain areas of the state do not have construction reports on file. The Committee has a staff of two people to maintain files, investigate complaints, inspect or enforce regulations, and perform necessary administrative functions required of a state committee. Lack of time and funds hinder enforcement of well construction regulations.

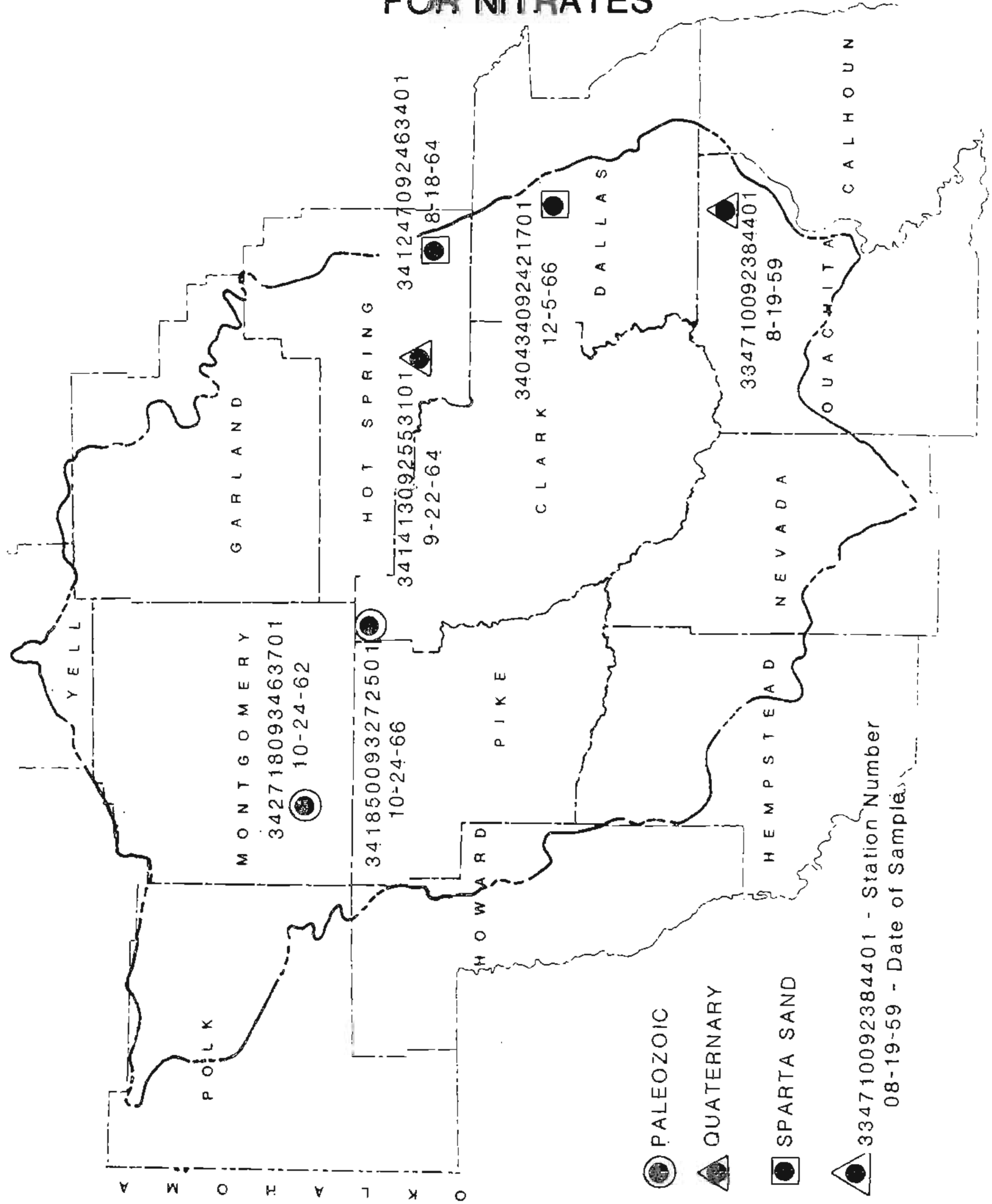
Critical Use Areas

Critical groundwater use areas have been defined by the Arkansas Soil and Water Conservation Commission as an aquifer in which at least one of the following criteria applies: (Water table aquifer only) (A) 50% of the thickness of the formation or less is saturated, and (or) (B) average annual declines of one foot or more have occurred for the preceding five year period, and(or) (C) groundwater quality has been degraded or trends indicate probable future degradation that would render the water unusable as a drinking water source or for the primary use of the aquifer.

The criteria for critical groundwater use areas in artesian aquifers are as follows: (A) potentiometric surface is below the top of the formation, and(or) (B) average annual declines of one foot or more have occurred for the preceding five years, and(or) (C) groundwater quality has been degraded or trends indicate probable future degradation that would

figure 4-23

GROUNDWATER PROBLEMS
WELLS EXCEEDING PRIMARY DRINKING WATER STANDARD FOR NITRATES



SOURCES: Bryant and Others ⟨15⟩
USGS File Data

render the water unusable as a drinking water source or for the primary use of the aquifer.

Paleozoic Rocks are essentially under water table conditions in the basin. Usually the depth to water is less than 20 feet below land surface. Quality problems are often isolated cases of contamination such as excessive nitrates. High iron concentrations are common throughout the Ouachita Mountains but can be reduced with minimal treatment. Based on the limited data available, no areas in the Interior Highland Province of the basin are critical. The quantity and quality problems of available ground water are natural constraints that have and will always limit development unless surface water sources are developed.

The Cretaceous units of the Nacatoch Sand and the Tokio Formation are under water table conditions in the outcrop areas and are under artesian pressure downdip. Water-level data for wells in both formations are insufficient to delineate critical areas. However, several public supply systems which previously withdrew water from the Nacatoch and Tokio Formation have partially or totally converted to surface water to supply their water needs. And wells that showed declines in the past are now showing rebound. Therefore, even though quantity and quality problems exist in the Nacatoch Sand and the Tokio Formation, these geologic units are probably not critical areas.

The Sparta Sand is under water table conditions in the outcrop area within the basin. Water levels during the period of 1980 to 1985 showed 0.4 foot of average annual decline. While these delcines are reason for concern, the rate is not high enough to fit the criteria for a critical use area.

In summary, the problem of declining water levels is not severe enough to be critical. Water users that could have caused significant cones of depression in Cretaceous units now depend on surface water supplies to meet their needs. Quality problems are either isolated problems in individual wells or are naturally occurring with increased distance from the outcrop area. Therefore, no areas in the Upper Ouachita Basin were designated as critical use areas.

POTENTIAL GROUNDWATER PROBLEMS

Potential hazards to groundwater in the basin include surface impoundments, landfills, surface impoundments (waste holding), hazardous and non-hazardous wastes, salt water intrusion, and pollution of the Sparta Sand recharge zone. (See Figure 4-24)

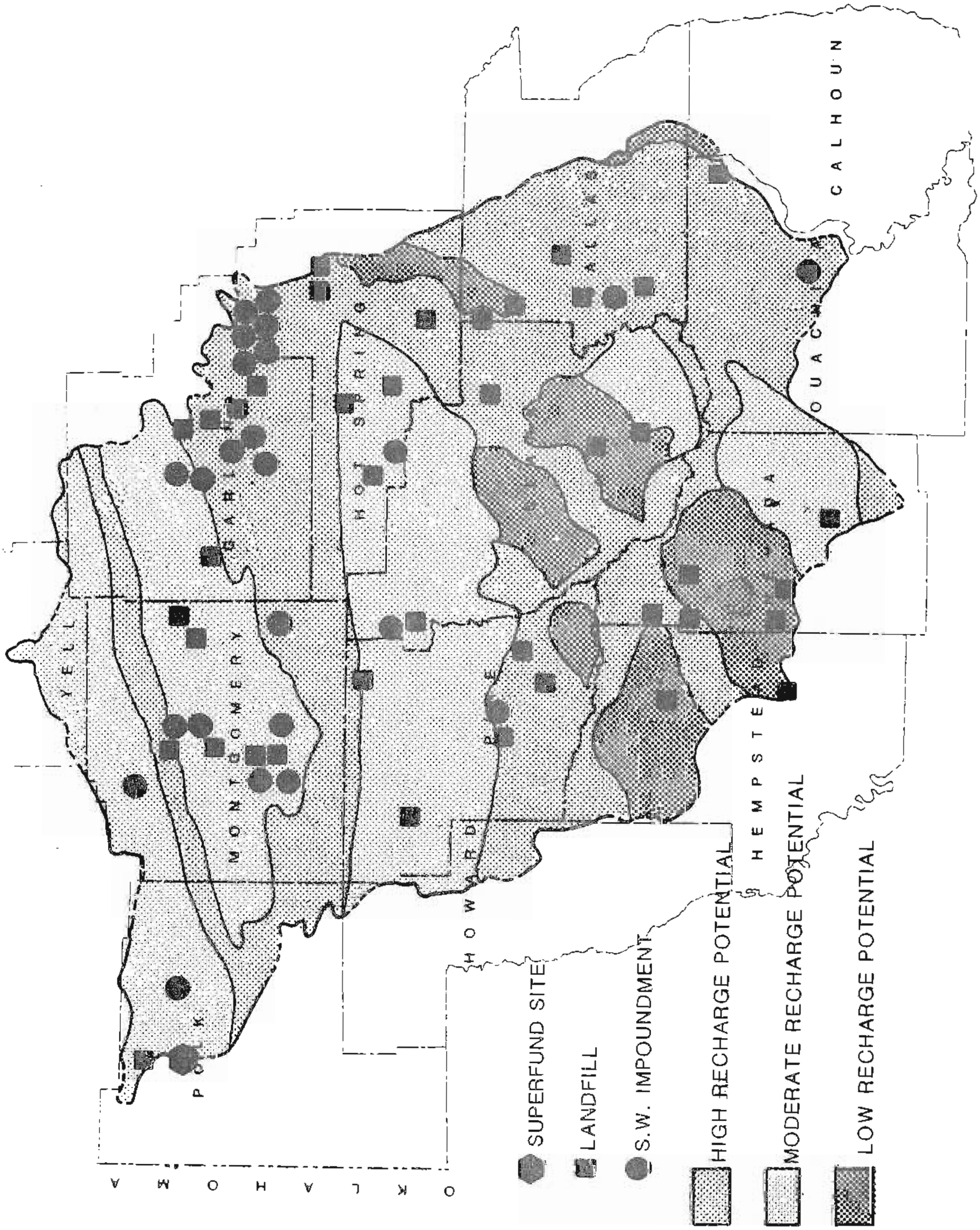
The potential for groundwater pollution exists practically anywhere in the state. However, the probability of contamination is highly variable from area to area depending on the permeability of surface materials or the ease at which water can percolate down to the water table and the existence of a pollution source.

Figure 4-24 shows the areas in the basin with high, medium, and low recharge potential along with some sources of potential contaminants. Recharge occurs at various rates over the basin dependent upon precipitation, depth to the water table, and the permeability of surface materials. Zones delineated on Figure 4-24 are designated as having either high, moderate, or low recharge potential depending on the general nature of the surficial materials within a given area. Surface materials with high potential include the following: the outcrop zones of the Bigfork Chert and Arkansas Novaculite of Paleozoic age, the Nacatoch and Tokio Formation of Cretaceous age, the Sparta Sand of Tertiary age, and upland terraces of the Quaternary System. Areas designated as having medium potential are outcrops of Paleozoic sandstone and shale, and the Cane River, Carrizo and Wilcox Group of Tertiary age. The least permeable units in the basin on the surface are the heavy clays of the Midway Group (Tertiary) and the relatively impermeable marls of the Cretaceous system.

Many open land fills and dumps exist in the basin. Forty-two sites are illustrated on Figure 4-24. The basin also contains many roadside dumps but the locations are numerous and are not inventoried. Some of the landfills have remained as open dumps while others are called sanitary land fills. The contents of these dumps are basically unknown. Hazardous materials may be stored in these areas and could eventually percolate into the surface aquifer. According to data supplied by the Arkansas Department of Pollution Control and Ecology (personal communication, 1987), approximately 2100 tons of hazardous waste was generated in the seven-county study area in 1986. Officially there are no RCRA (Resource Conservation and Recovery Act) sites in this basin. However, there is one superfund site located at Mena around a wood treating (creosote) plant that has contaminated the shallow aquifers with pentachlorophenol.

figure 4-24

POTENTIAL GROUNDWATER PROBLEMS



SOURCE: Modified from Bryant and others ⟨15⟩

A recent study by the Central Interstate Low-Level Radioactive Waste Compact Commission listed 17 counties in southern Arkansas as possible locations for a multi-state waste disposal site. The counties listed were: Lincoln, Drew, Grant, Bradley, Cleveland, Dallas, Calhoun, Clark, Columbia, Hempstead, Howard, Little River, Nevada, Ouachita, Pike, Sevier, and Union. Under Federal law, states are responsible for disposal of their own low-level radioactive wastes. Arkansas has signed a compact with Louisiana, Oklahoma, Nebraska, and Kansas to rotate the location of the site from state to state every thirty years.

The best available source of information on pits, ponds, and lagoons is the Surface Impoundment Assessment (SIA). The assessment was funded by ADPC&E and conducted in Arkansas in 1978 and 1979 by the Arkansas Soil and Water Conservation Commission and the U.S. Soil Conservation Service. The study found 7,640 impoundments at 872 sites in the state. Five hundred and six impoundments were then selected for assessment of pollution potential. <16>

The assessment included describing the characteristics of the impoundments such as size in acres, age, amount of influent and effluent, type of liner, presence of monitoring needs, purpose of impoundment, and nature of the wastes. The geology underlying the impoundments was determined to the extent possible. Then the impoundments were assessed for ground-water contamination potential which is expressed as a numerical score on a scale ranging from a low of 1 to a high of 29. The numerical ratings were based on four separate scores related to: "(1) the ease with which pollutants can penetrate surface layers and reach the ground water, (2) the ability of the ground water to move easily underground and the amount of ground water present, (3) the quality of the naturally occurring ground water at the location, and (4) how hazardous is the waste in the impoundment." The impoundments shown on Figure 4-24 had scores exceeding 15. <18>

The Surface Impoundment Assessment discovered that surface impoundments are distributed throughout localities where little or no protection of groundwater is afforded by an impermeable surface layer. Some unlined ponds have been constructed at these sites which may be potentially hazardous because of the lack of natural protection. A more detailed investigation at each site would be required to quantify the validity of this concern. <16>

The assessment of surface impoundments determined that 78% of the impoundments surveyed reported no liner, and 32% were within one mile of a well used for drinking water. Only about 10% of the industrial sites have monitoring wells and less than 2% of the municipal sites assessed have monitoring wells. The fact that 95% of the sites (on which information was available) had no monitoring wells attests to the need for a statewide monitoring system. <16>

Underground storage tanks containing hazardous materials are sources for potential aquifer contamination. Gasoline storage tanks are perhaps the most prevalent example. In 1983, there were 31 reports of gasoline leaking from underground storage tanks in the State. Considering the number of automobile service stations with underground gasoline storage tanks, the potential is fairly significant for further leaks from such tanks.

Septic tanks placed in a soil zone comprised of sand over an unconfined aquifer or over bedrock comprised of secondary openings such as the Paleozoic Rocks are potential sources of contamination of aquifers. Contaminants from septic tanks include nitrate nitrogen, bacteria, and certain viruses.

The potential for salt water intrusion exists as a result of the overdraft of Cretaceous aquifers in the basin. With large users shifting to surface water sources, however, the probability of this occurring may be low.

The recharge area for the Sparta Sand that is directly up gradient for the large use area around El Dorado is in Ouachita County within this basin. While the use from the Sparta in this basin is minimal, the water percolating into the recharge zone supplies wells used by approximately 50,000 persons in Union, Bradley and Calhoun Counties. The recharge zone must be protected from contamination.

SOLUTIONS AND RECOMMENDATIONS

The two most common problems with water from Paleozoic Rocks are low yields and excessive iron concentrations. Low yields are characteristic of shales and sandstones. Movement to wells is limited by the fracture density, size and interconnection of individual cracks. Commonly, wells yielding in excess of 10 GPM are considered to be "large producers". The east-west orientation of geologic structures can be utilized to obtain higher yields. Locating new wells east or west of large yielding wells will generally tap the same geologic structure and have a similar yield. Because of the large drawdowns that occur with larger yields, well spacing should be greater than 1000 feet. Commonly, two areas related to structure have the highest yields: (A) flanks of anticlines and (B) along the axis of a plunging anticline. Bedding plane separations during deformation expose fractures to recharge along the flanks of anticlines. The axis of a plunging anticline will commonly be highly fractured from distortion and will provide high yields. <2>

Research is needed to study the feasibility of utilizing Landsat imagery to locate favorable structural zones of higher yields. It is possible that additional small municipalities and industries could obtain sufficient yields from Paleozoic rocks if proper planning and research were conducted; however, low yields will remain an impediment to economic growth and development in the Ouachita Highlands.

Water in Paleozoic Rocks commonly contains excessive iron. Treatment for iron removal is necessary over most of the highlands and no changes or alternatives can be expected in the near future.

Many areas in the basin have marginal water quality and limited groundwater yields. Two incentives were contained in Act 417 of 1985 to assist groundwater users in building impoundments and/or converting to surface water sources. The act was entitled "Water Resource Conservation and Development Incentives Act of 1985". This Act stated that existing water use patterns were depleting underground water supplies at an unacceptable rate because alternative surface water supplies in sufficient quantity and quality were not available at the time of demand. The Act provides groundwater conservation incentives in the form of tax credits to encourage construction and restoration of surface water impoundments and conversion from groundwater to surface water withdrawal and delivery systems.

Many of the problems associated with nitrate contamination could be lessened with proper sealing of well casings to prevent the descent of pollutants alongside the casing. Improper sealing provides an avenue of travel for nitrates as well as other contaminants. Septic tanks and leacheate lines placed too close to a well or installed in soils that do not percolate well, cause quality problems. Improper waste disposal on pastures is another source of nitrates, along with barnyards and toilets. None of these sources should be close to a well, or the potential for contamination is significant.

The importance of protecting the recharge area for the Sparta Sand cannot be over emphasized. However, protection of such an aquifer requires knowledge of the groundwater system. Many characteristics of the Sparta Sand aquifer are still unknown. A recent cost-sharing agreement between the Arkansas Soil and Water Conservation Commission and the USGS (Arkansas District), for three (3) years at a cost of $40,000 per year will result in a groundwater model of the Sparta Sand in Arkansas and Louisiana. The investigation will develop a method for evaluating the impact of present and proposed aquifer development on water-level declines and ultimately, groundwater availability. The objectives of the study are as follows: (1) Evaluate the hydrogeologic characteristics of major units that control flow in the Sparta Sand formation within the project area, including recharge, vertical leakage, nature of the flow system, and hydraulic characteristics; (2) Evaluate areas of major withdrawal in Arkansas and adjacent states with regard to their potential impact on water level declines in this aquifer; (3) Construct and calibrate a groundwater flow model, in coordination with the Louisiana District (USGS), to be used in assessing the feasibility of proposed withdrawals from the Sparta Sand aquifer in Louisiana and Arkansas. The Regional Aquifer Systems Analysis (RASA) will be utilized during model development and calibration for estimating initial boundary conditions. A report will be prepared that will describe the hydrogeology of the study area, flow system within the aquifer, the digital model, and will provide examples of how the model will run. The report will be part of the cooperators technical report series in Arkansas and Louisiana and will be submitted for Directors' approval prior to the end of FY 1987.

Currently, additional work is being conducted in Ouachita County on the recharge zone for the Sparta Sand. The study consists of water-quality data collection and analysis to determine the presence of contamination. If contamination has occurred, the study will determine the nature and significance of the contamination and provide recommendations to solve the problem. This program is one of six (6) monitoring prototypes developed by ADPC&E in the state. Monitoring objectives and constituents vary with each prototype. Preliminary results of the water-quality analyses for samples collected in Ouachita County showed that only three (3) out of 26 samples contained coliform bacteria.

The potential for pollution from surface impoundments may be significant. Legislation is already in place for controlling or denying construction of liquid waste holding impoundments and for requiring an extensive monitoring system to ensure that any leakage from the impoundments is detected at an early stage and prompt action is taken to prevent further contamination. Both the Water and Air Pollution Control Act and the Hazardous Waste Management Act provide procedures for enforcement by holding hearings on cases of alleged violations and taking action through civil and criminal courts. Both acts provide for immediate action by the Arkansas Department of Pollution Control and Ecology in case of emergency and specifies penalties up to $10,000 for each day of violation or a maximum prison sentence of one year. In the past, court-imposed penalties for violation have been in amounts of only a few hundred dollars for each case.

In 1982, a report was published by the Wright-Pierce Engineering Firm of Topsham, Maine. The report established criteria for siting impoundments and landfills of hazardous and non-hazardous waste and indicated areas that posed a significant threat to groundwater quality. The report outlines in detail, the siting criteria that should be required by ADPC&E. Each site should be physically inspected to be adequately evaluated. Adequate staffing to inspect these sites would prevent ADPC&E from relying on reports supplied by firms applying for the permits. Volume II of the Wright-Pierce Report has recently been adopted as the official criteria for siting hazardous and non-hazardous landfills, but Volumes I and III for land application of waste and surface lagoons have not.

Under the RCRA (Resource Conservation and Recovery Act) program, all open dumps should be upgraded to sanitary landfills. This upgrading would provide a data base for further control. Impoundments holding hazardous waste could be controlled by the permit process of site evaluation. If the program was properly administered, the danger of groundwater contamination from hazardous wastes should no longer be a significant threat in the State. Although it will be several years before the program is fully implemented, the "interim status" requirements for permit applicants will provide some control on the impoundments as the program progresses.

For impoundments containing non-hazardous materials, the states still must exercise some initiative in developing programs of control but can request funds in support of such projects through the Solid Waste Management Program of RCRA or the Water Quality Management Program under the Clean Water Act. All such impoundments should be permitted. This program could be used to contribute to the overall protection of groundwater by limiting the quantities of brine held in surface impoundments in the Lower Ouachita Basin. ADPC&E is currently updating information on the location and nature of surface holding impoundments.

Many of the problems associated with the execution of programs that indirectly apply to groundwater and could result in increased groundwater protection are hindered by inadequate funding and staffing of state offices. The addition of any new committments to groundwater protection will require increased staffing and considerable financial, legislative, and public support.

The major emphasis in the past has been on surface water contamination and the result has been Federal legislation to control the nature and extent of same. Commonly, groundwater protection has occurred as a spinoff of surface water pollution regulations. This approach, as evidenced by groundwater pollution problems in the State, is inadequate to protect the groundwater resource. The requirements for groundwater protection that do exist are too easily ignored and under-funded when they are secondary components of larger programs. Accountability for groundwater protection is too easily hidden among plans for protection of surface waters.

In summary, groundwater is not used much in the Upper Ouachita Basin due to the natural problems of low yields and variable quality. Man-induced problems are rather limited in the basin because the resource has never been available to develop, or to deteriorate. If economic development is going to occur in the area, it will continue to be dependent on the development of surface-water resources which are relatively abundant compared to groundwater resources.

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DEFINITIONS

ALKALINITY: A measure of the buffering capacity of water. Alkalinity is used as an index of sensitivity because it expresses the acid neutralizing capacity of water and the water's relative sensitivity or tolerance to acid inputs.

ALLUVIUM: Debris from erosion, consisting of some mixture of clay particles, sand, pebbles, or larger rocks. Usually a good, porous storage medium for ground water.

AQUIFER: A water-bearing layer of rock that will yield water in a usable quantity to a well or spring.

BEDROCK: A general term for the consolidated (solid) rock that underlies soils or other unconsolidated surficial material.

BEST MANAGEMENT PRACTICE (BMP): A practice or practices that have been determined to be the most effective, practical means of preventing or reducing pollution from nonpoint sources.

CONE OF DEPRESSION (Or drawdown cone): A conical concavity (or dimple) in the potentiometric surface around a pumping well caused by the withdrawal of water.

CONFINED (or artesian) AQUIFER: An aquifer that is under pressure significantly greater than atmospheric, and its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the material in which the confined water occurs.

CONFINING BED: A body of "impermeable" material stratigraphically adjacent to one or more aquifers, the hydraulic conductivity of which may range from nearly zero to some value distinctly lower than that of the aquifer. Synonyms: aquitard; aquiclude; and aquifuge.

CONSUMPTIVE USE: Use of water in a manner that makes it unavailable for use by others because of absorption, evaporation, transpiration or incorporation in a manufactured product. In some instances, when water is returned to a stream at a distance downstream from the point of diversion, the use may be consumptive as to users immediately below the point of diversion but nonconsumptive as to users below the point where the water is returned.

CRITICAL GROUND WATER AREAS:

Water Table Condition: Water levels have been reduced such that 50% of the thickness of the formation, or less, is saturated; and/or average annual declines of one foot or more have occurred for the preceding five years; and/or groundwater quality has been degraded or trends indicate probable future degradation that would render the water unusable as a drinking water source or for the primary use of the aquifer.

Artesian Condition: Potentiometric surface has declined below the top of the formation; and/or average annual declines of one foot or more have occurred for the preceding five years; and/or groundwater quality has been degraded or trends indicate probable future degradation that would render the water unusable as a drinking water source or for the primary use of the aquifer.

CRITICAL SURFACE WATER AREA: Any area where current water use, projected water use, and (or) quality degradation have caused, or will cause, a shortage of useful water for a period of time so as to cause prolonged social, economic, or environmental problems.

DATUM PLANE: An arbitrary surface (or plane) used in the measurement of ground-water heads. The datum most commonly used is the National Geodetic Vertical Datum of 1929, which closely approximates sea level.

DEPENDABLE WATER SUPPLY: The amount of water of desired quality that can be expected to be available at a given point a stated percentage of the time.

DISCHARGE: Outflow of water from a drainage basin, reservoir or other facility through a channel, pipe or other outlet, including the release of polluted water into a stream or waterbody. Also, the rate of discharge measured in units of volume per unit of time, either for an entire outlet or for a specified cross-sectional area of the outlet.

DRAWDOWN IN A WELL: The vertical drop of the water level in a well caused by pumping.

EPILIMNION: The upper stratum of a lake characterized by uniformly warm, circulating, and fairly turbulent water.

EROSION: The wearing away of the land surface by the detachment and transport of soil materials through the action of moving water, wind or other geological agent.

EVAPOTRANSPIRATION: Evaporation from water surfaces, plus transpiration from plants.

EXCESS STREAMFLOW: Twenty-five percent of that amount of water available on an average annual basis above the amount required to satisfy the existing and projected water needs of the basin.

FAULT: A fracture in the Earth's crust accompanied by displacement of one side of the fracture with respect to the other.

FRACTURE: A break in rock that may be caused by compressional or tensional forces.

GROUND WATER: Water in the saturated zone that is under a pressure equal to or greater than atmospheric pressure.

GROUNDWATER, CONFINED: Groundwater which is under pressure significantly greater than atmospheric, and its upper limit is the bottom of a bed of distinctly lower hydraulic conductivity than that of the material in which the confined water occurs.

GROUNDWATER, PERCHED: Unconfined groundwater separated from an underlying body of groundwater by an unsaturated zone. Its water table is a perched water table.

GROUNDWATER, UNCONFINED: Water in an aquifer under atmospheric pressure that has a water table and is free to rise and fall.

HEAD (or static head): The height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point.

HYDRAULIC CONDUCTIVITY: The capacity of a rock to transmit water. It is expressed as the volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

HYDRAULIC GRADIENT: The change in static head per unit of distance in a given direction. If not specified, the direction generally is understood to be that of the maximum rate of decrease in head.

HYDROLOGIC CYCLE: The constant movement of water in the atmosphere and on and beneath the earth's surface.

HYPOLIMNION: The bottom region of a lake characterized by cold, relatively undisturbed water.

INFILTRATION: The movement of water from the earth's surface into the soil zone.

INSTREAM FLOW REQUIREMENTS: The flow regime which will best meet the individual and collective instream uses and off-stream withdrawals of water. Instream uses of water include uses of water in the stream channel for navigation, recreation, fisheries, riparian vegetation, aesthetics, and hydropower. Off-stream water withdrawals include uses such as irrigation, municipal and industrial water supply, and cooling water.

INTERBASIN TRANSFER: The physical conveyance of water from one watershed to another.

IRRIGATION SCHEDULING: The process that enables an irrigator to apply irrigation water in the proper amounts and at the proper time to efficiently alleviate moisture shortages.

METALIMNION: An intermediate zone between the epilimnion and the hypolimnion where temperature in the lake drops rapidly with increasing depth.

MINIMUM STREAMFLOW: The lowest daily mean discharge that will satisfy minimum instream flow requirements. The minimum streamflow represents the discharge at which all withdrawals from the stream will cease.

NONCONSUMPTIVE USE: Use of water with return to the stream or waterbody of substantially the same amount of water as withdrawn. A use in which only insignificant amounts of water are lost by evapotranspiration or incorporation in a manufactured product.

NONPOINT SOURCE: The entry of a pollutant into a body of water in a diffuse manner with no definite point of entry and where the source is not readily discernible.

PERCOLATION: Movement under hydrostatic pressure of water through the openings of rock or soil, except movement through large openings such as caves.

PERMEABILITY: A measure of the relative ease with which a porous medium can transmit a liquid under a potential gradient.

pH: A measure of the relative acidity of water. Below 7 is increasingly acid, 7.0 is neutral, and above 7 is increasingly alkaline (basic).

POINT SOURCE: The release of a pollutant from a pipe or discrete conveyance into a body of water or a watercourse leading to a body of water.

POROSITY: The voids or openings in a rock. Porosity may be expressed quantitatively as the ratio of the volume of openings in a rock to the total volume of the rock.

POTENTIOMETRIC SURFACE: A surface that represents the total head in an aquifer; that is, it represents the height above a datum plane at which the water level stands in tightly cased wells that penetrate the aquifer.

PRIME FARMLAND: Land well suited to the production of food and fiber. Prime farmland has the soil quality, growing season, and moisture supply needed to economically produce sustained high yields of crops when managed according to acceptable farming methods.

RCRA SITES: Resource Conservation and Recovery Act sites where hazardous wastes are treated under authorization of regulatory agencies.

RECHARGE: The entry into the saturated zone of water made available at the water table surface, together with the associated flow away from the water table within the saturated zone.

RECHARGE AREA OR ZONE: That portion of a drainage basin in which the net saturated flow of groundwater is directed away from the water table.

RECHARGE, ARTIFICIAL: The addition of water to the groundwater by activities of man at a recharge rate greater than normal.

RIPARIAN DOCTRINE: The system of law in which owners of lands along the banks of a stream or waterbody have the right to reasonable use of the waters and a correlative right protecting against unreasonable use by others that substantially diminishes the quantity or quality of water. The right is appurtenant to the land and does not depend upon prior use.

RIPARIAN RIGHTS: The rights accompanying ownership of land along the bank of a stream or lake under the riparian doctrine.

RUNOFF: (1) That portion of precipitation which does not return to the atmosphere through evapotranspiration nor infiltrate the soil to recharge groundwater, but leaves the hydrologic system as streamflow; also (2) that portion of precipitation delivered to streams as overland flow to tributary channels.

ROCK: Any naturally formed, consolidated or unconsolidated material (but not soil) consisting of two or more minerals.

SALTWATER INTRUSION (Seawater intrusion): The migration of saltwater into freshwater aquifers under the influence of groundwater development (pumping).

SATURATED ZONE: The subsurface zone occurring below the water table where the soil pores are filled with water, and the moisture content equals the porosity.

SAFE YIELD:

SURFACE WATER: The safe yield of a stream or river is the amount of water that is available on a dependable basis which could be used as surface-water supply. The safe yield is the discharge which can be expected 95 percent of the time minus the discharge necessary to maintain the minimum flow in the stream during the low-flow season (July-October).

GROUNDWATER: The safe yield of an aquifer is roughly equal to the recharge rate to the system. Due to the temporal and spatial variability of recharge, the safe yield can most easily be expressed as the quantity of groundwater that can be withdrawn while maintaining static water levels over the long term.

SHEET AND RILL EROSION: A combined process caused by runoff water, that removes a fairly uniform layer of soil from the land surface and forms many small channels in the land surface.

SOIL: The layer of material at the land surface that supports plant growth.

SPECIFIC CAPACITY: The discharge from a pumping well (the pumping rate) divided by the drawdown in the well; it is a measure of the productivity of a well.

SPECIFIC RETENTION: The ratio of (1) the volume of water which the rock or soil, after being saturated, will retain against the pull of gravity to (2) the volume of rock or salt.

SPECIFIC YIELD: The ratio of (1) the volume of water which the rock or soil, after being saturated, will yield by gravity to (2) the volume of the rock or soil.

STORAGE COEFFICIENT: The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer, the storage coefficient is equal to the specific yield.

STRATIFICATION: The layered structure of sedimentary rocks.

THERMOCLINE: In a lake, the plane of maximum rate of decrease of temperature with respect to depth.

TRANSMISSIVITY: The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It equals the hydraulic conductivity multiplied by the aquifer thickness.

UNCONFINED AQUIFER: An aquifer in which the upper surface of the saturated zone is free to rise and fall.

UNSATURATED ZONE: The subsurface zone, usually starting at the land surface, that contains both water and air.

WATER TABLE: The level in the saturated zone at which the pressure is equal to the atmospheric pressure.

APPENDIX A

COMMENTS ON THE DRAFT REPORT

Additional comments were received from the U.S. Geological Survey, but they were provided to the Arkansas Soil and Water Conservation Commission as notations in the margins of the draft report and cannot be included here.

BILL CLINTON
GOVERNOR

Arkansas **DEPARTMENT OF HEALTH**

4815 WEST MARKHAM STREET • LITTLE ROCK, ARKANSAS 72205-3867
TELEPHONE AC 501 661-2000

BEN N. SALTZMAN, M.D.
DIRECTOR

RECEIVED
JUL 6 1987
SOIL AND WATER
CONSERVATION COMMISSION

June 30, 1987

Mr. J. Randy Young,P.E.
Director
Arkansas Soil and Water Commission
One Capitol Mall, Suite 2D
Little Rock, AR 72201

RE: Upper Ouachita Basin
Draft Report
Arkansas State Water Plan

Dear Mr. Young:

The draft report referenced above has been reviewed by this office and we have the following comments.

1. Figure 4-9 on Page 293 should be revised as follows:

Blakely Waterworks:	Maximum Capacity = 0.144 MG Storage = 0.005 MG
Oden-Pencil Bluff Waterworks:	Storage = 0.2 MG
Harbor East Inc. Waterworks:	Storage = 0.007 MG
Remmel Dam Landing Waterworks:	Maximum Demand = 0.01 MG Maximum Capacity = 0.05 MG

2. References on Pages 305, 311, 362, and 367 to the Hope Municipal Water System abandoning thier well supply are incorrect. Our records indicate that from January through May, 1987 the Hope utility had an average daily groundwater withdrawal of 1.3 MG with a maximum of 3.5 MGD. Surface water withdrawals during this same time period averaged 1.3 MGD with a maximum of 2.1 MGD. So slightly more than 50% of their water still comes form their well field.

If you have any questions concerning this matter please contact this office.

Sincerely,

Harold R Seifert

Harold R. Seifert,P.E.
Director
Division of Engineering

HRS:UP:BM:PS:ps

United States Department of Agriculture

Soil Conservation Service

Room 5423 Federal Office Building
700 West Capitol Avenue
Little Rock, Arkansas 72201

AUG 4 1987

Mr. J. Randy Young, Director
Arkansas Soil and Water Conservation Commission
One Capitol Mall, Suite 2D
Little Rock, Arkansas 72201

Dear Randy:

We have reviewed the draft copy of the Upper Ouachita River Basin Draft Report and offer the following comments and suggestions:

1. (p. 18) (Third paragraph) Groundwater storage in the Ouachita Mountains is limited to the cracks and fissures of the underlying consolidated formations.

2. (p. 18) (Last sentence) Quaternary deposits in the principal stream floodplains yield adequate quantities for domestic supplies.

3. (p. 156) Figures 3-17, 3-18, 3-19 need the word elevation added to streambed, mean valley, etc., to better explain to the reader.

4. (p.158) MSL has been dropped for NGVD.

5. (p. 227) First paragrah is not understandable.

6. (p. 227) Change suitable alternative to feasible alternative.

7. (p. 274) (Second paragraph) Since saltwater is in the lower sections of most of the fresh water aquifers in the area, there is the possibility that saltwater contamination can be induced by overpumping.

8. (p. 288) Increases from 1965 to 1970 amounted to approximately 1.5 MGD with 0.5 MGD increases from 1970 to 1975 and 1975 to 1980.

9. (p. 355) Change high transmissivity values to high conductivity values...

10. (p. 364) The dates of sampling need to be added to the figure or in the text to quantify when these concentrations occurred.

We appreciate the opportunity to comment on this document.

Sincerely,

Acting for
GENE SULLIVAN
State Conservationist

3398G

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

REPLY TO
ATTENTION OF:

September 18, 1987

Planning Division
Western Tributaries

SEP 21 1987
SOIL AND WATER
CONSERVATION COMMISSION

Mr. J. Randy Young
Director, Arkansas Soil and
Water Conservation Service
One Capitol Mall, Suite 2D
Little Rock, Arkansas 72201

Dear Mr. Young:

Thank you for the opportunity to comment on the Arkansas State Water Plan for the Upper Ouachita Basin. The following comments are offered for your consideration in compiling the final report.

a. Instream Flow Requirements. The report addresses water quality, fish and wildlife, and interstate compact requirements, but states that there are no instream flow requirements on the streams in the Upper Ouachita Basin (page 98). It should be recognized that the Corps of Engineers operates and maintains the Ouachita-Black navigation project. A minimum release of 100 cubic feet per second (cfs) from Lake Ouachita is maintained for the Ouachita-Black navigation project.

b. Impoundments. As noted and recognized on page 124, large impoundments presently exist in the Upper Ouachita Basin. Three impoundments, DeGray Lake, near Arkadelphia; Lake Greeson, near Murfreesboro; and Lake Ouachita, near Hot Springs, are Corps of Engineers lakes with the primary purpose of flood control. Additional purposes include hydropower and recreation with water supply at DeGray Lake alone. The report has placed a high value on streamflows as calculated to meet fish and wildlife instream requirements (page 130, "The instream flow requirements for fish and wildlife were previously identified as the governing instream need for all streams. . ."). Additionally, the report on page 228 suggests consideration of reduction of flood control benefits to ensure maintenance of lake levels for recreation benefits. The benefits and specific operational procedures required to provide flood control and hydropower production should be recognized as a part of the state plan.

c. Flow Duration. The duration curves used to analyze the water supply potential were based on short and very short periods of records. Because of the limited data used in development of the duration curves, decisions and alternatives that use these curves could be in error. To increase the accuracy and reliability of the hydrologic data presented, the historical flows of the basin should be routed through the existing system. This routing could also be valuable in determining the alternatives to meet water quality deficiencies.

d. Ground Water.

(1) The Cockfield Formation is a potential aquifer in western Dallas County, Arkansas, which should be considered as a source of ground water.

(2) The Trinity Group (Lower Cretaceous) aquifers, including the Paluxy Sand, Ultima Thule Gravel, and Pike Gravel, should be considered as a source of ground water.

(3) Figure 4-2, page 264, shows geologic formations used as sources of ground water. The Midway Group is included in the figure, although it is not an aquifer. Also, a legend would be helpful on this figure to clearly define the area of Quaternary aquifers.

(4) The addition of a base freshwater map to the ground-water section of the report would be helpful. This map would show the distance below the outcrop area that the zone of fresh water would be expected to be found.

e. Water Supply. The report states on page 28 that 250 million gallons per day (mgd) for the city of Little Rock are assumed to come from DeGray Lake. The DeGray Lake project is designed to release 250 mgd for water supply downstream to the reregulating pool. Currently, 98 mgd are released for water quality water supply and a total of 152 mgd are available for release to the reregulating pool for municipal and industrial water supply uses. The sponsor for water supply within the DeGray Lake project is the Ouachita River Water District (ORWD). As the local sponsor, the ORWD has the right to contract with other entities for the sale of water for water supply.

f. Reallocation of Storage. The report recommends reallocation of storage in the Corps of Engineers lakes for water supply and recreation. It should be recognized that the current storage allocation was based on detailed studies to optimize benefits of multipurpose uses. Future conditions were considered. Storage was allocated in accordance with Federal policy, placing primary emphasis on flood control and hydropower. On page 231, a statement of Corps policy is made out of context. The current policy for modification of completed projects does allow some flexibility in reallocation of reservoir storage. The policy allows for reallocation of the lesser of 15 percent of total storage or 50,000 acre-feet by the Office, Chief of Engineers, provided reallocation would not have a significant effect on other authorized purposes. The report references "storage in excess of design purposes." In order to determine the costs as well as the benefits and the optimum sizing of projects, all storage in Corps reservoirs is assigned a purpose (hence, the term "multipurpose reservoir"), and costs and benefits are calculated accordingly. Each reservoir has designed storage by elevation for the project purposes extant within the reservoir pool. Projects are designed to fully utilize available capacity; therefore, there is no storage in excess of the design purposes.

My comments are offered to more fully explain the Federal perspective of our role in wise use of water resources. My staff is available to assist you in resolving questions relating to these comments. Please contact Mrs. Alett Little at (601) 634-5448 if you have any questions.

Sincerely,

for W B Holyood

V. C. Ahlrich, P.E.
Chief, Planning Division

ARKANSAS FORESTRY COMMISSION

P. O. Box 4523, Asher Station ■ Little Rock, Arkansas 72214

Edwin E. Waddell
State Forester

Ph. 501 664-2531

July 9, 1987

Mr. Jon Sweeney
Soil & Water Conservation Commission
One Capitol Mall, Suite 2-D
Little Rock, AR 72201

Dear Mr. Sweeney:

The Arkansas Forestry Commission concurs with the draft Water Plan for the Upper Ouachita Basin. Rather than using ten year old RIDS information for forestry data, you may want to use 1985 data from the U.S. Forest Service mid-cycle survey. We have the 1985 data, and it is available for your study.

Thank you for the opportunity to review the draft.

Sincerely,

Edwin E. Waddell
State Forester

Garner Barnum

By: Garner Barnum
Assistant State Forester
Resource Management

JGB:dr

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SOIL AND WATER
CONSERVATION COMMISSION

ARKANSAS NATURAL HERITAGE COMMISSION
THE HERITAGE CENTER, SUITE 200
225 EAST MARKHAM
LITTLE ROCK, ARKANSAS 72201
Phone: (501) 371-1706

Harold K. Grimmett
Director

Bill Clinton
Governor

Date: July 27, 1987
Subject: Upper Ouachita Basin
ANHC Job #SWCC-8
Dated June 12, 1987
Received June 17, 1987

RECEIVED
JUL 27 1987
SOIL AND WATER
CONSERVATION COMMISSION

Mr. Randy Young
Suite 2-D
#1 Capitol Mall
Little Rock, Arkansas 72201

Dear Mr. Young:

The staff of the Arkansas Natural Heritage Commission has reviewed the draft state water plan for the Upper Ouachita Basin. We note clear improvements over previous draft plans in terms of both clarity and depth. However, some real problems remain. Foremost among these is the selection of "ten percent of the average seasonal flows" as a basis for determining minimum instream flow requirements for fish and wildlife.

Despite a much longer and better-written "argument" concerning the selection of the ten percent standard, we find nothing in that argument to justify or validate the ASWCC method. Lack of justification is the fatal flaw of this document, and of all the other draft basin plans to date, and until this issue is addressed, we have to view the state water plan as inadequate and incomplete.

At best, the relationship of the ASWCC standard to Tennant's findings is superficial. In all likelihood Tennant was concerned, as we are, about low flow conditions. His choice of ten percent of the average **annual** flow as a minimum for short-term survival of fish and wildlife, therefore, was not accidental. Ten percent of the flow during the driest season clearly is something totally different--a horse of a different color--and use of this standard is an extreme and inappropriate kind of extrapolation from the literature. While ten percent of the average annual flow might yield minimums that are inappropriate for certain streams at certain times of the year (i.e., the minimums so established might at times be greater than median monthly flows), there is no justification for taking this same percentage and apply it to the lowest seasonal flows. In other words, ten percent of the average annual flow may well yield figures that are too high in some instances, but the ASWCC method produces minimum streamflow standards that are far too low in many instances. The solution is to work toward something in between, and toward standards that can be justified--justified, at the very least, on the grounds of reasonableness.

The point that allocation of water should begin well before a stream reaches its designated minimum flow (p. 111) is certainly a good one. However, the ASWCC currently has no means to implement and enforce allocation procedures. Why, then, was allocation even mentioned?

As we have pointed out in earlier reviews of basin plans, each river basin harbors certain aquatic species the occurrences of which are of national and/or state significance. In the Upper Ouachita Basin, we have records for 25 special animal species (90+ occurrences in basin streams). Although selection of minimum streamflow standards will affect many different forms of wildlife, we are particularly concerned about those species most vulnerable to extirpation or outright extinction. A listing of these species and the locations in the basin from which they have been collected is attached to this letter.

Sincerely,

Bill Pell

Bill Pell
Stewardship Chief

cc: Kay Arnold
Craig Uyeda
John Giese

DATA FOR ARKANSAS STATE WATER PLAN
UPPER QUACHTTA BASIN

OCC NO.	SITE NAME	USGS TOPOGRAPHIC QUADRANGLE	TOWNSHIP/RANGE	SECTION
** AMMOCRYPTA ASPRELLA		CRYSTAL DARTER		
* FEDERAL STATUS: C2				
003		CAMDEN 7.5	T13S/R17W	SECT.: 10
** ANODONTA SUBORBICULATA		FLAT FLOATER		
* FEDERAL STATUS:				
002		CADDO VALLEY 7.5	T07S/R19W	SECT.: 04
** ARKANSIA WHEELERI		QUACHITA ROCK POCKETBOOK		
* FEDERAL STATUS: C2				
003	OLD RIVER LAKE-OUACHITA RIVER	ARKADELPHIA 7.5	T07S/R19W	SECT.: 27
004	OLD RIVER LAKE-OUACHITA RIVER	CADDO VALLEY 7.5	T07S/R19W	SECT.: 04
** ERIMYZON SUCETTA		LAKE CHUBSUCKER		
* FEDERAL STATUS:				
004		READER 7.5	T11S/R19W	SECT.: 22
** ETHEOSTOMA PALLIDIDORSUM		PALEBACK DARTER		
* FEDERAL STATUS: 3C				
016		NORMAN 7.5	T04S/R25W	SECT.: 06
002		NORMAN 7.5	T04S/R25W	SECT.: 13
017		NORMAN 7.5	T04S/R25W	SECT.: 01
020		NORMAN 7.5	T03S/R25W	SECT.: 30
021		NORMAN 7.5	T04S/R25W	SECT.: 11
022		NORMAN 7.5	T04S/R25W	SECT.: 11
018		POLK CREEK MTN. 7.5	T03S/R27W	SECT.: 25
024		POLK CREEK MTN. 7.5	T03S/R26W	SECT.: 33
003	BRUNT SPRING	NORMAN 7.5	T04S/R25W	SECT.: 15
015	COLLIER CREEK	NORMAN 7.5	T04S/R25W	SECT.: 12
014	FIVE MILE CREEK	GLENWOOD 7.5	T04S/R24W	SECT.: 28
008	GAP CREEK	CADDO GAP 7.5	T04S/R24W	SECT.: 18
023	ROUGH CREEK SPRING	CADDO GAP 7.5	T03S/R24W	SECT.: 27
013	SMITH CREEK	NORMAN 7.5	T04S/R25W	SECT.: 12
004	UPPER CADDO RIVER	CADDO GAP 7.5	T04S/R24W	SECT.: 19
011	UPPER CADDO RIVER	CADDO GAP 7.5	T04S/R24W	SECT.: 19
005	UPPER CADDO RIVER	NORMAN 7.5	T03S/R26W	SECT.: 35
009	UPPER CADDO RIVER	NORMAN 7.5	T03S/R25W	SECT.: 30
007	UPPER CADDO RIVER	POLK CREEK MTN. 7.5	T03S/R27W	SECT.: 25
010	UPPER CADDO RIVER	POLK CREEK MTN. 7.5	T03S/R26W	SECT.: 30
001	UPPER CADDO RIVER	POLK CREEK MTN. 7.5	T03S/R27W	SECT.: 26

DATA FOR ARKANSAS STATE WATER PLAN
UPPER OUACHITA BASIN

OCC NO.	SITE NAME	USGS TOPOGRAPHIC QUADRANGLE	TOWNSHIP/RANGE	SECTION
** FALLICAMBARUS JEANAE		CRAYFISH		
* FEDERAL STATUS:				
001		POINT CEDAR 7.5	T05S/R22W	SECT.: 02
** FALLICAMBARUS SPECTRUM		CRAYFISH		
* FEDERAL STATUS:				
001		AMITY 7.5	T05S/R23W	SECT.: 26
002		NARROWS DAM 7.5	T06S/R25W	SECT.: 07
** GOMPHUS OZARKENSIS		OZARK CLUBTAIL DRAGONFLY		
* FEDERAL STATUS:				
001		ATHENS 7.5	T04S/R27W	SECT.: 27
** HOPERIUS PLANATUS		AQUATIC BEETLE		
* FEDERAL STATUS:				
001		HOPE 7.5	T12S/R24W	SECT.: 29
** LAMPSILIS ORBICULATA		PINK MUCKET		
* FEDERAL STATUS: LE				
010		ARKADELPHIA 7.5	T07S/R19W	SECT.: 27
008		ARKADELPHIA 7.5	T07S/R19W	SECT.: 28
009		CADDO VALLEY 7.5	T07S/R19W	SECT.: 05
** LAMPSILIS ORNATA		SOUTHERN POCKTBOOK		
* FEDERAL STATUS:				
002		CADDO VALLEY 7.5	T06S/R19W	SECT.: 31
** LAMPSILIS POWELLI		ARKANSAS FATMUCKET		
* FEDERAL STATUS:				
005		MOUNT IDA 15	T02S/R25W	SECT.: 19
003	CADDO RIVER BELOW DEGRAY DAM	CADDO VALLEY 7.5	T06S/R19W	SECT.: 31
** MUGIL CEPHALUS		STRIPED MULLET		
* FEDERAL STATUS:				
003		CADDO VALLEY 7.5	T07S/R19W	SECT.: 08
** NERODIA CYCLOPION CYCLOPION		GREEN WATER SNAKE		
* FEDERAL STATUS:				
001		ATHENS 7.5	T05S/R27W	SECT.: 16

DATA FOR ARKANSAS STATE WATER PLAN
UPPER OUACHITA BASIN

OCC NO.	SITE NAME	USGS TOPOGRAPHIC QUADRANGLE	TOWNSHIP/RANGE	SECTION
** NOTROPIS HUBBSI		BLUEHEAD SHINER		
* FEDERAL STATUS:				
015		BRAGG CITY 7.5	T12S/R18W	SECT.: 20
016		HOLLY SPRINGS 7.5	T10S/R16W	SECT.: 16
** NOTROPIS MACULATUS		TAILLIGHT SHINER		
* FEDERAL STATUS:				
007		ARKADELPHIA 7.5	T07S/R19W	SECT.: 14
** NOTROPIS PERPALLIDUS		PEPPERED SHINER		
* FEDERAL STATUS: 3C				
011		ANTOINE 7.5	T08S/R23W	SECT.: 24
013	CADDO RIVER BELOW DEGRAY DAM	CADDO VALLEY 7.5	T06S/R19W	SECT.: 31
014	CADDO RIVER BELOW DEGRAY DAM	CADDO VALLEY 7.5	T06S/R20W	SECT.: 23
015	CADDO RIVER BELOW DEGRAY DAM	CADDO VALLEY 7.5	T06S/R20W	SECT.: 35
009	LITTLE MISSOURI RIVER, LOWER	TATES BLUFF 7.5	T11S/R18W	SECT.: 01
010	LITTLE MISSOURI RIVER, LOWER	TATES BLUFF 7.5	T11S/R18W	SECT.: 03
021	UPPER CADDO RIVER	AMITY 7.5	T05S/R23W	SECT.: 22
023	UPPER CADDO RIVER	AMITY 7.5	T05S/R23W	SECT.: 24
** NOTURUS LACHNERI		OUACHITA MADTOM		
* FEDERAL STATUS: C2				
005	OUACHITA RIVER, UNNAMED TRIBUTARY	LAKE CATHERINE 7.5	T03S/R18W	SECT.: 36
** NOTURUS TAYLORI		CADDO MADTOM		
* FEDERAL STATUS: C2				
001		ATHENS 7.5	T05S/R27W	SECT.: 22
008		LODI 7.5	T04S/R25W	SECT.: 33
010		LODI 7.5	T04S/R26W	SECT.: 32
005	OUACHITA RIVER, UPPER	MOUNT IDA 15	T01S/R24W	SECT.: 29
006	OUACHITA RIVER, SOUTH FORK	MOUNT IDA 15	T02S/R25W	SECT.: 21
007	OUACHITA RIVER, UPPER	MOUNT IDA 15	T01S/R25W	SECT.: 24
018	OUACHITA RIVER, UPPER	ODEN 15	T02S/R27W	SECT.: 09
014	UPPER CADDO RIVER	AMITY 7.5	T05S/R23W	SECT.: 22
017	UPPER CADDO RIVER	AMITY 7.5	T05S/R23W	SECT.: 24
009	UPPER CADDO RIVER	CADDO GAP 7.5	T04S/R24W	SECT.: 19
016	UPPER CADDO RIVER	CADDO VALLEY 7.5	T06S/R19W	SECT.: 31
011	UPPER CADDO RIVER	GLENWOOD 7.5	T05S/R24W	SECT.: 11
012	UPPER CADDO RIVER	NORMAN 7.5	T03S/R24W	SECT.: 26
013	UPPER CADDO RIVER	POINT CEDAR 7.5	T05S/R22W	SECT.: 33
015	UPPER CADDO RIVER	POLK CREEK MTN. 7.5	T03S/R26W	SECT.: 28

DATA FOR ARKANSAS STATE WATER PLAN
UPPER OUACHITA BASIN

OCC NO.	SITE NAME	USGS TOPOGRAPHIC QUADRANGLE	TOWNSHIP/RANGE	SECTION
**** PERCINA NASUTA**		LONGNOSE DARTER		
* FEDERAL STATUS: C2				
003	CADDO RIVER BELOW DEGRAY DAM	CADDO VALLEY 7.5	T06S/R20W	SECT.: 35
002	CADDO RIVER BELOW DEGRAY DAM	CADDO VALLEY 7.5	T06S/R19W	SECT.: 31
020	LITTLE MISSOURI RIVER, LOWER	MURFREESBORO 7.5	T08S/R25W	SECT.: 28
009	LITTLE MISSOURI RIVER, LOWER	OKOLONA SOUTH 7.5	T09S/R22W	SECT.: 28
008	LITTLE MISSOURI RIVER, LOWER	PRESCOTT EAST 7.5	T10S/R21W	SECT.: 19
007	LITTLE MISSOURI RIVER, LOWER	READER 7.5	T11S/R19W	SECT.: 22
006	LITTLE MISSOURI RIVER, LOWER	READER 7.5	T11S/R19W	SECT.: 18
005	LITTLE MISSOURI RIVER, LOWER	TATES BLUFF 7.5	T10S/R18W	SECT.: 36
004	LITTLE MISSOURI RIVER, LOWER	TATES BLUFF 7.5	T11S/R18W	SECT.: 03
013	OUACHITA RIVER, UPPER	MT. IDA 15	T01S/R25W	SECT.: 20
011	OUACHITA RIVER, UPPER	MT. IDA 15	T01S/R24W	SECT.: 33
015	OUACHITA RIVER, UPPER	NATHAN 7.5	T08S/R26W	SECT.: 11
014	OUACHITA RIVER, UPPER	ODEN 15	T01S/R26W	SECT.: 33
012	OUACHITA RIVER, UPPER	ODEN 15	T02S/R28W	SECT.: 16
010	OUACHITA RIVER, UPPER	ODEN 15	T02S/R27W	SECT.: 09
**** PROCAMBARUS REIMERI**		CRAYFISH		
* FEDERAL STATUS:				
004		ACORN 7.5	T01S/R29W	SECT.: 30
001		ACORN 7.5	T01S/R29W	SECT.: 18
002		MENA 7.5	T02S/R30W	SECT.: 13
**** REGINA RIGIDA SINICOLA**		GULF CRAYFISH SNAKE		
* FEDERAL STATUS:				
010		ARKADELPHIA 7.5	T07S/R19W	SECT.: 22
009		HARMONY GROVE 7.5	T12S/R16W	SECT.: 29
**** SOMATOGYRUS AMNICOLOIDES**		OUACHITA PEBBLESNAIL		
* FEDERAL STATUS:				
001		ARKADELPHIA 7.5	T07S/R19W	SECT.: 16
**** SOMATOGYRUS WHEELERI**		CHANNELLED PEBBLESNAIL		
* FEDERAL STATUS:				
001		ARKADELPHIA 7.5	T07S/R19W	SECT.: 16
**** STERNOTHERUS CARINATUS**		RAZORBACK MUSK TURTLE		
* FEDERAL STATUS:				
006		AMITY 7.5	T05S/R23W	SECT.: 22
003		AMITY 7.5	T05S/R23W	SECT.: 24
012		ATHENS 7.5	T05S/R27W	SECT.: 16
002		CADDO VALLEY 7.5	T06S/R19W	SECT.: 31

LEGEND

FEDERAL STATUS CODES

LE - Listed Endangered; the FWS has listed these species as endangered.

C1 - Category 1; the FWS states it currently has substantial information on hand that supports listing these species as Threatened or Endangered.

C2 - Category 2; the FWS states that further biological research and field study will be necessary in order to determine if these species should be listed as Threatened or Endangered.

3C - These species have been reviewed by the FWS and the determination has been made that special designation is not warranted.

OCCURRENCE NUMBER

An Arkansas Natural Heritage Commission Occurrence Number has been included for reference. Please refer to this number when requesting information on a particular occurrence.

STATE OF ARKANSAS
DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY
8001 NATIONAL DRIVE, P.O. BOX 9583
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July 8, 1987

RECEIVED
JUL 1 0 1987
SOIL AND WATER
CONSERVATION COMMISSION

Mr. J. Randy Young, Director
Arkansas Soil and Water Conservation Commission
One Capitol Mall, Suite 2D
Little Rock, Arkansas 72201

Dear Mr. Young:

The following comments comprise the input of the staff of the Department of Pollution Control and Ecology concerning the draft copy of the Arkansas State Water Plan - Upper Ouachita Basin. The seriousness with which we view the long-term directions set out by the State Water Plan and the potential effects of this plan on the water resources of our state cannot be overstated. It is with these concerns that we make these constructive comments.

The following comments concern the groundwater section: (1) The report attempts to discuss and develop a plan based on surface water drainage basins. It is well documented that groundwater aquifers and recharge areas are not congruent with surface drainages. In its recent publication on groundwater problems, USGS abandoned the surface drainage basins as a vehicle for dividing its report and this resulted in a much more logical, concise and comprehendable document. The groundwater section of each basin report of the State Water Plan reflects the confusion between surface water drainage and aquifers. Each of these reports contain repetitive descriptions of overlapping aquifers and reflect the difficulty of dealing with fragments of aquifers that underlie each of the basins. (2) While it is true that aquifer recharge requirements are not known for each aquifer, elaborate models are not needed for entire aquifers to figure recharge requirements as they relate to minimum stream flows. Recharge as a percentage of streamflow can be figured by either physical or chemical means using methods and formulas available in basic hydrology texts. The flow duration curves discussed on page 68 are a useful tool for determining which streams have groundwater-sustained base flow, but more precise evaluations would be needed to establish the actual percentages of groundwater to base flow. For streams in the Upper Ouachita, it is likely that those with sustained base flows are spring fed and do not fit the criteria established on page 103-104. Such information would be needed to determine which measures would work to preserve minimum flow in a threatened stream. (3) It should be made clear to all readers of this document that there is a significant paucity of data on the quantity and quality of groundwater in Arkansas and that much of the available data is self supplied by the users and may be heavily biased by their preconception of the uses of the data.

(4) An additional source of data which is available concerning groundwater quality is the CERCLA industrial monitoring data available through STORET. Tonnage figures for hazardous waste generation are available by county through the ADPC&E Hazardous Waste Division. The figures, as used on page 370, are misleading. There is little hazardous waste generated in the Upper Ouachita Basin. Eighty-two percent of the 700,000 ton figure quoted on page 370 is generated in Union County, mostly in the form of wastewater used in bromine manufacture and injected underground in deep wells.

We are very concerned about the methodology used in the draft document to establish minimum streamflows for surface waters and the negative impact this will have on the biotic uses of the streams. These minimum streamflows are proposed to be only 10 percent of the historical flows for 3 specified seasons of the year, and this is proposed to supply all instream flow needs, including fish and wildlife, during all seasons of the year. In our view, such a plan will drastically alter the designated beneficial uses of the streams in contravention of federal and state statutes and regulations. By definition, minimum streamflows are the point at which "all diversions should cease"; however, there is no effective mechanism to control diversions above the minimum streamflow level. Without such controls, diversions will cause the minimum streamflows to become the average streamflow, and with the proposed plan, "worst case" conditions for instream aquatic life will become the standard.

The Clean Water Act was a mandate from Congress to reverse the trends of degradation of the nation's waters and to restore and maintain the chemical, physical and biological integrity of these waters. Such a mandate is not limited to water quality control and is so recognized in the Act. The biological integrity of an aquatic ecosystem is limited by its energy source, habitat structure, water quality and flow regime. In the goal of the Clean Water Act "...that provides for the protection and propagation of fish, shellfish and wildlife and recreation in and on the water," it further recognizes and mandates the protection of all life stages of the aquatic biota, specifically including the propagation stage. It is intimately clear that maintaining the "biological integrity of the nation's waters" must include maintenance of a flow regime that will be fully protective of all life stages of the aquatic life beneficial uses of these waters.

We feel that an acceptable allocation plan must be a part of the State Water Plan if minimum streamflows are established lower than those of the "Arkansas Plan, and it is imperative that minimum streamflows be established on a seasonal scale since the instream flow needs for fish and wildlife are drastically different in the spring of the year than during the late summer. The streamflow needs are more critical during the reproductive season of the fish than at any other time. To assume that there will always be sufficient water for fish reproduction in the springtime and that removal of water from the streams during this period could not be of significant magnitude to affect the fishery is erroneous. Our studies have shown that higher water quality standards requiring more sophisticated treatment procedures and/or higher background flows are necessary during the springtime when the most sensitive life stages of various aquatic organisms are present. Modifications of stream flow regimes through excessive withdrawals will substantially increase the treatment levels required at municipal and industrial wastewater treatment facilities in order to meet water quality requirements. This will result in a significant cost increase to the public directly for public owned facilities and indirectly at industrial facilities.

Considerations have been given to the development of a stream classification system. The intent of such a system would be to establish minimum flows reflecting a stream's historic flow pattern and recognizing the variation in uses of the state's surface waters. We feel that development of such a system could be a valuable asset to the State Water Plan and to numerous other water resource management activities. Therefore, to establish minimum streamflows before this option is thoroughly investigated would be inappropriate.

Since there appears to be several factors which may influence the establishment of minimum streamflows--e.g., allocation procedures and stream classification--we suggest the establishment of minimum streamflows be delayed until all of the basin plans can be thoroughly reviewed and the factors mentioned above resolved.

Sincerely,

Phyllis Moore

Phyllis Moore, Ph.D.
Director

PM/WEK/sy

ARKANSAS SOIL AND WATER CONSERVATION COMMISSION

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