ARKANSAS WATER RESOURCES: SUPPLY, USE, AND RESEARCH NEEDS

by

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ABSTRACT

ARKANSAS WATER RESOURCES: SUPPLY, USE, AND RESEARCH NEEDS

The purpose of this study is to identify Arkansas' water resources research needs against an economic backdrop of water supply and use conditions existing in the state. In the aggregate Arkansas has an abundance of high quality water relative to present use. There are local conditions that give rise to water problems, but, in general, critical water problems in Arkansas are emergent and potential rather than actual. The causes of these problems are to be found, in large part, in the economic, legal, and social institutions surrounding water use--and particularly in the economic institutions. Research designed to improve economic efficiency criteria and to develop methods of applying such criteria to water resources planning, to water resources allocation, and to quality of water control would do much to mitigate the problems of water management in the future. Research of this nature requires considerably more water data concerning supply, use, and costs associated with water use than are now available. Other promising areas of research include basic research on the nature of water and the water cycle, and applied research in areas of flood control, artificial recharge, the measurement of pollution damage and costs, the identification and treatment of pollution, the limnology of artificial lakes, and the role of water resources in industry location.

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CHAPTER I

INTRODUCTION

At the turn of the century, there was little evidence in the literature of hydrology and, indeed, only isolated cases of physical evidence that a water problem was building. Water, for the most part, was looked upon as a free resource in all of its uses including waste disposal. Legally, water use was subject to the riparian or appropriation doctrines and *ad hoc* litigation in cases arising from supply and pollution damage.

Since 1900 the physical situation has changed markedly. A number of factors related to the growth of the United States economy are responsible. Rapid population growth and the conversion of rural lands to densely populated industrial, urban and suburban communities have intensified both water supply and waste disposal problems. Moreover, population density has had a hydrologic impact on natural drainage, ground water, sediment, and water quality.[1] Growth and technological change in all facets of American industry have greatly increased the use of water and introduced new and increasingly difficult problems in the qualitative, quantitative, and waste disposal aspects of water use. The rise in per capita income and leisure have greatly

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[1]J. Savini and J. C. Kammerer, *Urban Growth and the Water Regimen*, Geological Survey Water Supply Paper 1591-A (Washington: U. S. Government Printing Office, 1961), p. A 3.

structure of use of Arkansas' water resources and show changes in the use of water through time; and (3) to identify water resources research needs in conformity with the major hydrologic problems and the developmental needs of the state.

the amount diverted and used, only about one-third is consumed (i.e., used up in the sense that it is no longer available). About 90 percent of the consumptive use is for agriculture.

Table 1

National Water Use

Total Precipitation (Continental U.S.)	100% or 4750 maf[1]
Used where it falls	39% or 1850 maf[2]
Diverted and consumed	2% or 100 maf[2]
Discharged into oceans	27% or 1280 maf
Returned to atmosphere without beneficial use	32% or 1530 maf

[1]Million acre feet. One maf = 327 billion gallons.

[2]Excludes navigation, generation of hydropower, recreation, and other major stream flow uses.

Source: Reproduced from Federal Council for Science and Technology Committee on Water Resources Research, A Ten Year Program of Federal Water Resources Research (Washington: U. S. Government Printing Office, 1966), p. 4.

In the aggregate, then, less than half of the annual precipitation is used, and an amount constituting less than one percent of annual precipitation is withdrawn from water-bearing strata in the ground. Aggregative data, however, conceal a great deal of information. In some areas of the nation, there is an abundance of water, while in the arid and semi-arid regions, capacity utilization is being approached.

As indicated in Figure 1, the area of critical supply is limited to the southwestern region of the United States. Arkansas is well to the east of this region. Annual precipitation in Arkansas exceeds the national average by approximately 20 inches.

Distribution

Problems of water distribution arise because water does not appear with geographic uniformity over a given area. As shown in Figure 2, the uneven distribution of existing water supplies characterizes the entire western half of the United States with the exception of a strip along the northern Pacific coast. A recent water study in Oklahoma concluded that the solution of the distribution problem was essential for continued growth and development of the state. "In a sense, the water problem in Oklahoma is one of capturing the water in areas where surplus amounts are generated and transporting it to areas that are perennially in short supply."[1]

Water is distributed much more evenly in Arkansas than in much of the western portion of the nation. Yet, as the state continues to develop, the distribution problem may increase in intensity. The emergence of water distribution as a problem area in Arkansas can be seen in the Interior Highlands (the northwestern half of the state) and in certain sections of the Gulf Coastal Plain (the southeastern half of the state) where the mining of water from aquifers has resulted in substantial cones of depression in the ground water level.

Variability

The problem of the variability of rainfall through time is at least as old as recorded history and is experienced by almost every area in the United States. As shown in Figure 3, it is a chronic problem in the Midwest and Southwest. In the past, Arkansas has not often been subjected to general

[1]Bureau of Business Research, Oklahoma's Long Range Water Requirements (Norman: University of Oklahoma, 1965), p. i.

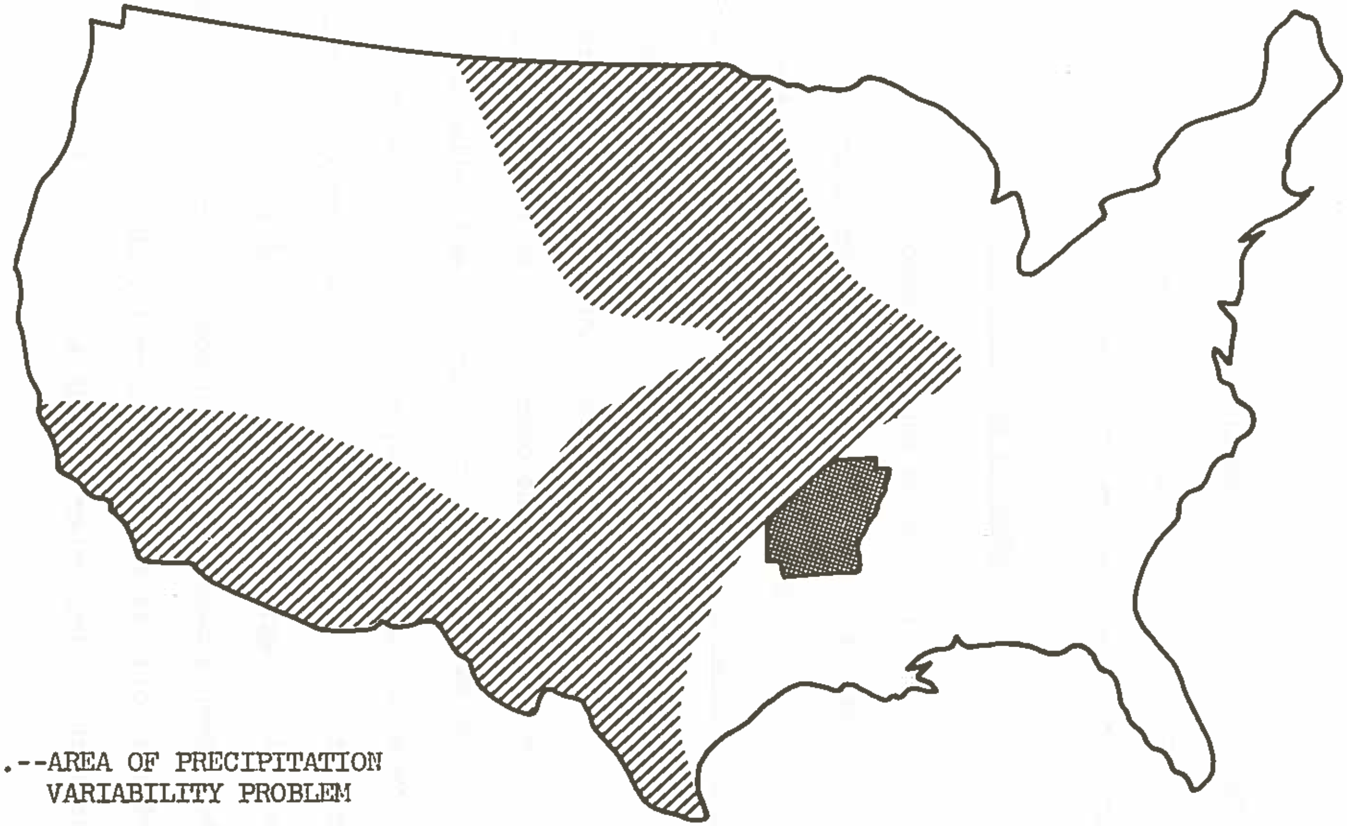

Fig. 3.--AREA OF PRECIPITATION VARIABILITY PROBLEM

Source: Arkansas Pollution Control Commission

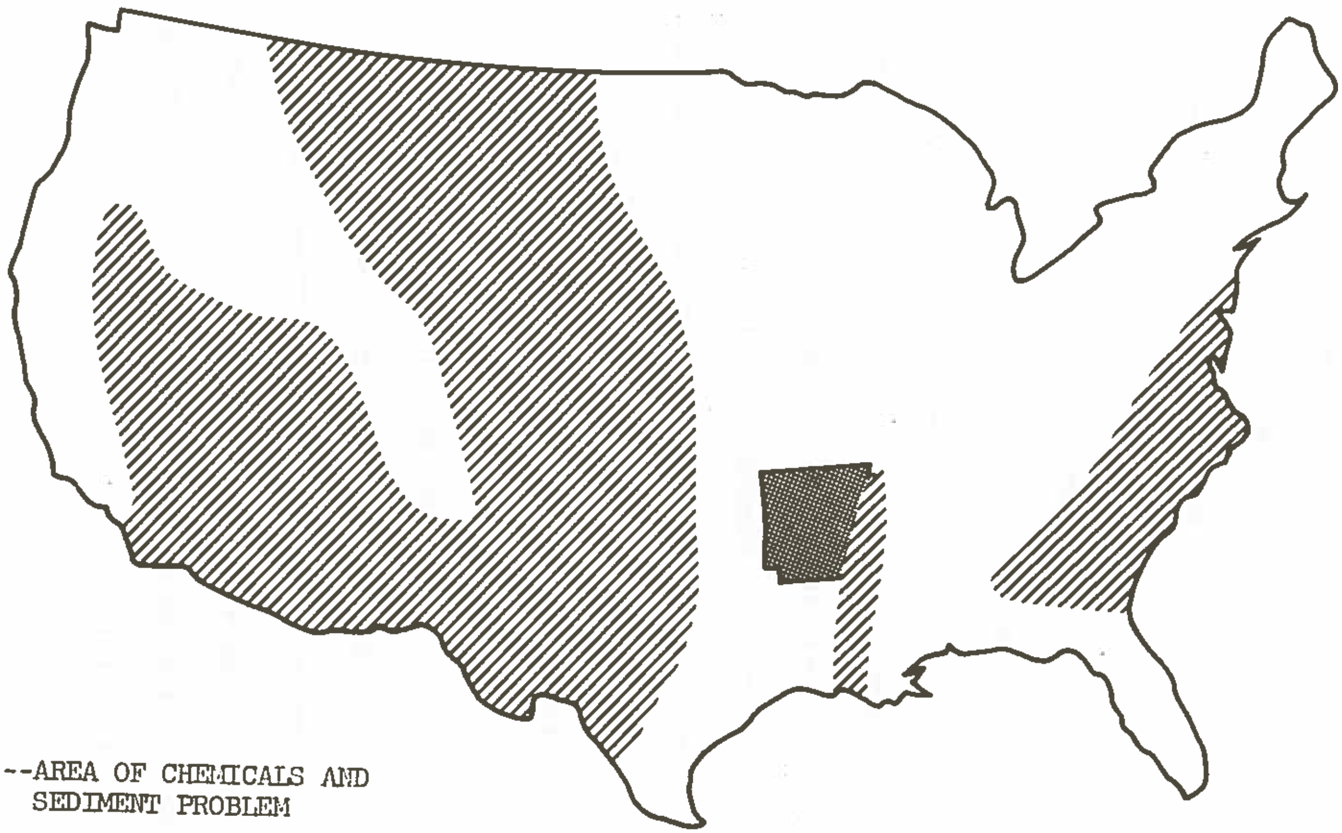

Fig. 4.--AREA OF CHEMICALS AND SEDIMENT PROBLEM

Source: Arkansas Pollution Control Commission

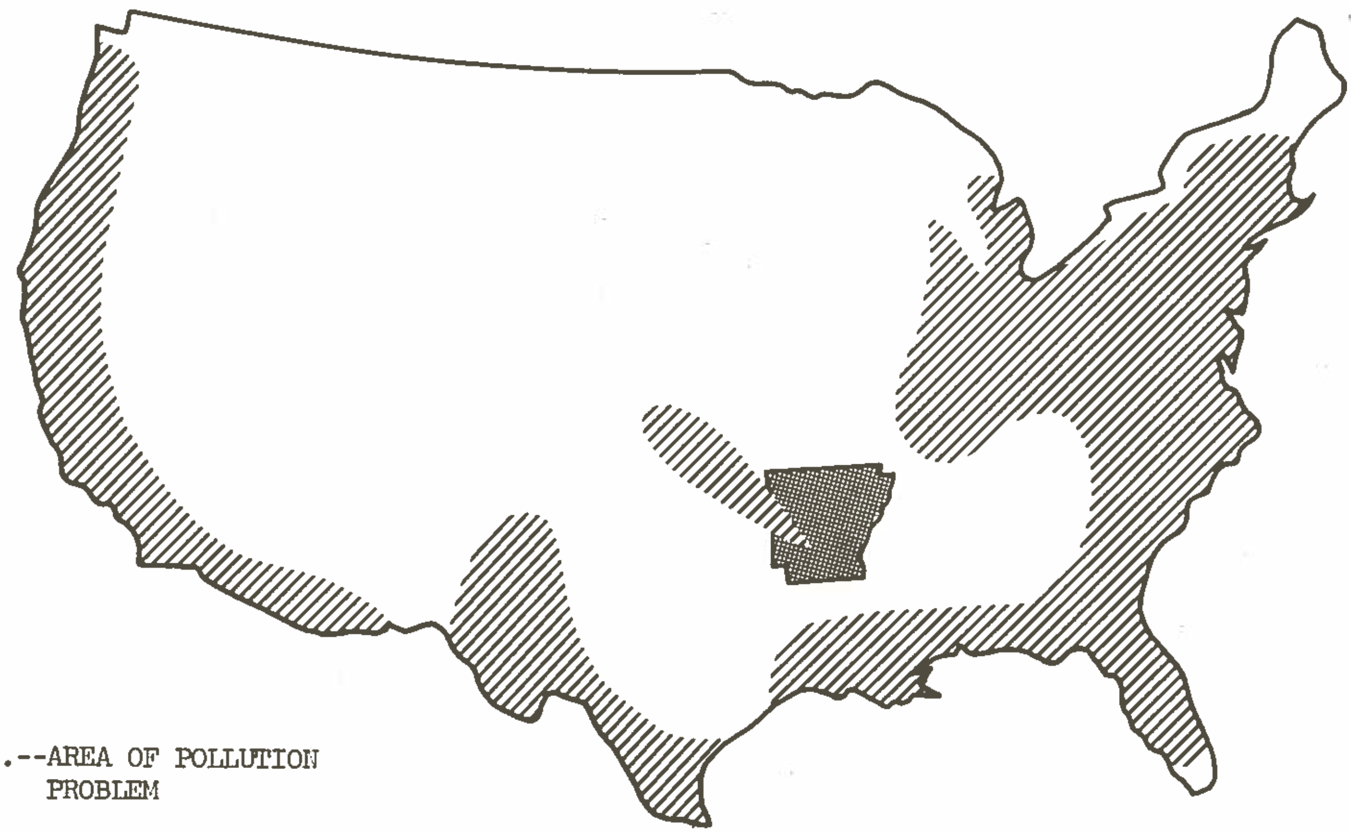

Fig. 5.--AREA OF POLLUTION
PROBLEM

Source: Arkansas Pollution
Control Commission

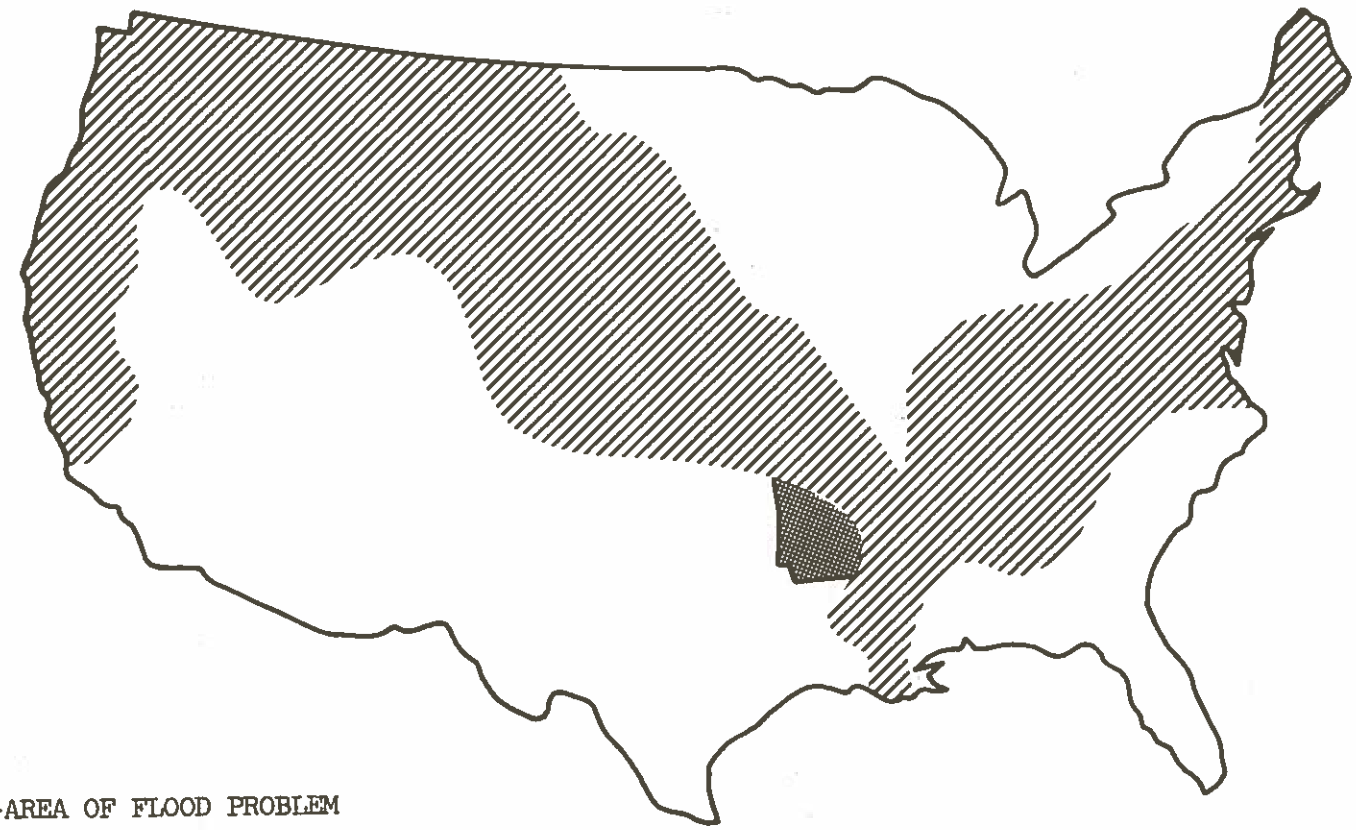

Fig. 6.--AREA OF FLOOD PROBLEM

Source: Arkansas Water Pollution
Control Commission

Annual average precipitation over Arkansas is about 49 inches. Of this amount, 31 inches is returned to the atmosphere by evapotranspiration, and 18 inches flows through rivers toward the oceans. About 18 inches is evaporated from the oceans and carried over the state by air currents.[2] The 18 inches of runoff combined with the water stored in the ground and an equivalent of 12 inches of river inflow to the state constitute the effective water supply in Arkansas over which man has some control.

Topography and Climate

The total area of Arkansas is 53,100 square miles. The state is divided by a line, roughly, from the southwest corner of the state to the northeast corner into two physiographic regions--the Interior Highlands and the Gulf Coastal Plain (Figure 7). The Interior Highlands, which constitute the northwest half of the state, are further divided into three sub-regions: the Ozark Plateau, the Arkansas Valley, and the Ouachita Mountains. The Gulf Coastal Plain consists of the Mississippi Alluvial Plain and the West Gulf Coastal Plain.

The Interior Highlands range in altitude from 250 to 2800 feet above sea level. Elevations of from 1000 to 1400 feet are common. The land surface is generally rough. Mountains of the Ozark Plateau have been formed in large part by erosion of the valleys. Maximum elevation is above 2400 feet, and elevations of over 1000 feet are common.

The Arkansas Valley divides the Ozark Plateau and the Ouachita Mountains. The Arkansas Valley is characterized by a relatively low relief with isolated

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[2] U. S. Geological Survey, in cooperation with Arkansas Geological Commission, Water Facts (1964).

Table 2

Mean Monthly Temperature Fahrenheit, Little Rock
1951--1960

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
42.3	46.1	51.3	62.5	71.4	79.4	82.5	82.3	75.2	63.5	50.6	44.1

Source: U. S. Department of Commerce: Decennial Census of United States Climate (Washington: U. S. Government Printing Office, 1965), p. 40.

Precipitation in Arkansas occurs for the most part in showers. There are occasional periods of general rainfall during winter, early spring, and late fall. Rainfall is abundant and fairly evenly distributed throughout the year. The early spring is the wettest season, and late summer and early fall are the driest. Protracted general droughts seldom occur, but local dry periods are fairly common. The number of days with measurable precipitation ranges, on the average, from 100 to the west to 112 in the east.[4] Figure 8 shows by means of contours the average annual precipitation over the state.

Surface Water

The major rivers in Arkansas flow in a southeasterly direction, and all eventually flow into the Mississippi River. There are five major river basins in Arkansas. From southwest to northeast, they are: the Red, Ouachita, Arkansas, White, and St. Francis. The United States Geological Survey in cooperation with the Arkansas Geological Commission collects information

[4]U. S. Department of Commerce, Weather Bureau, Climates of the States (Washington: U. S. Government Printing Office, 1959), pp. 1-2.

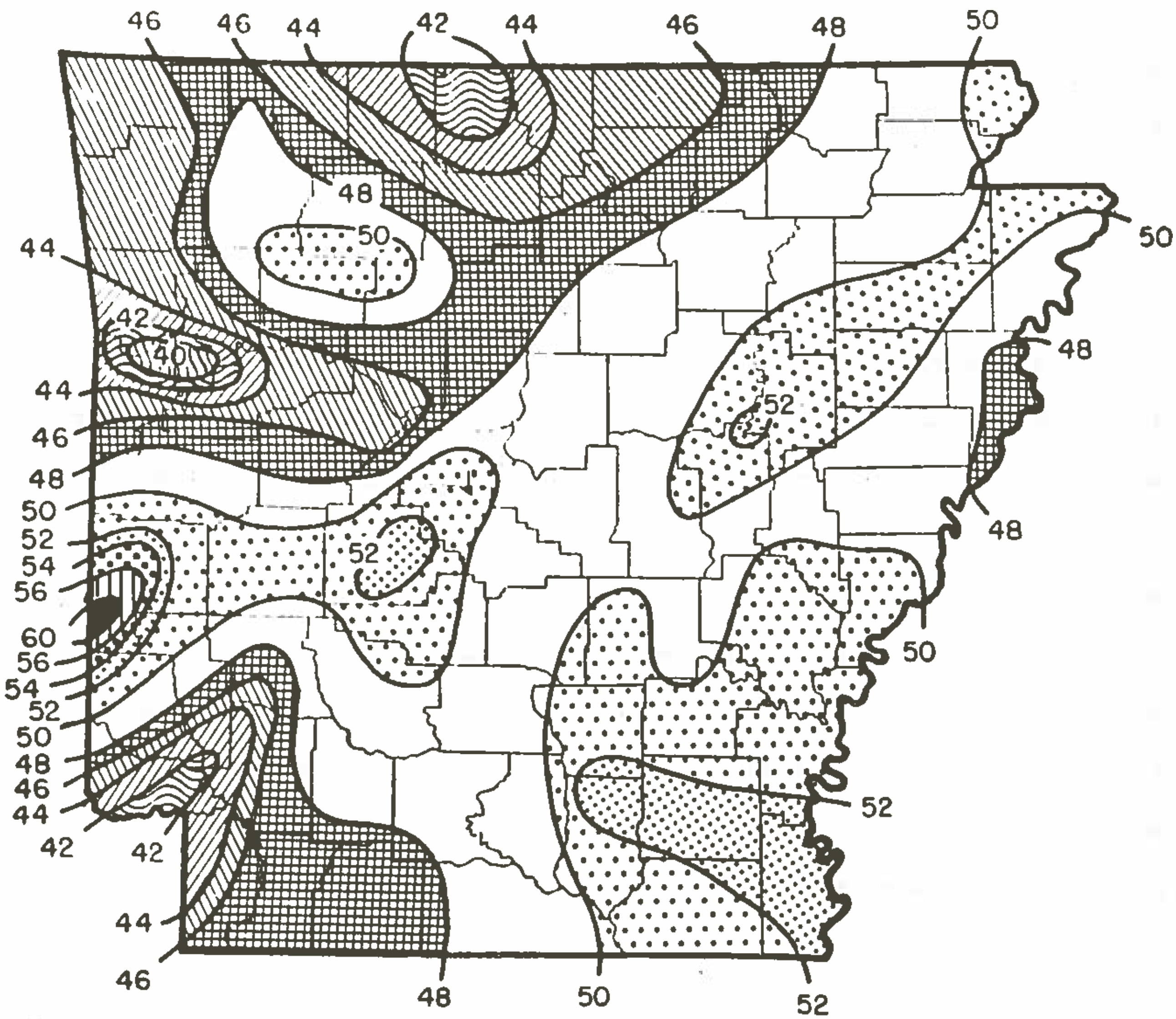

Fig. 8.--AVERAGE ANNUAL PRECIPITATION (INCHES)

Source: Reproduced from Noel H. Wood, <u>Arkansas Water Resources</u>, by permission.

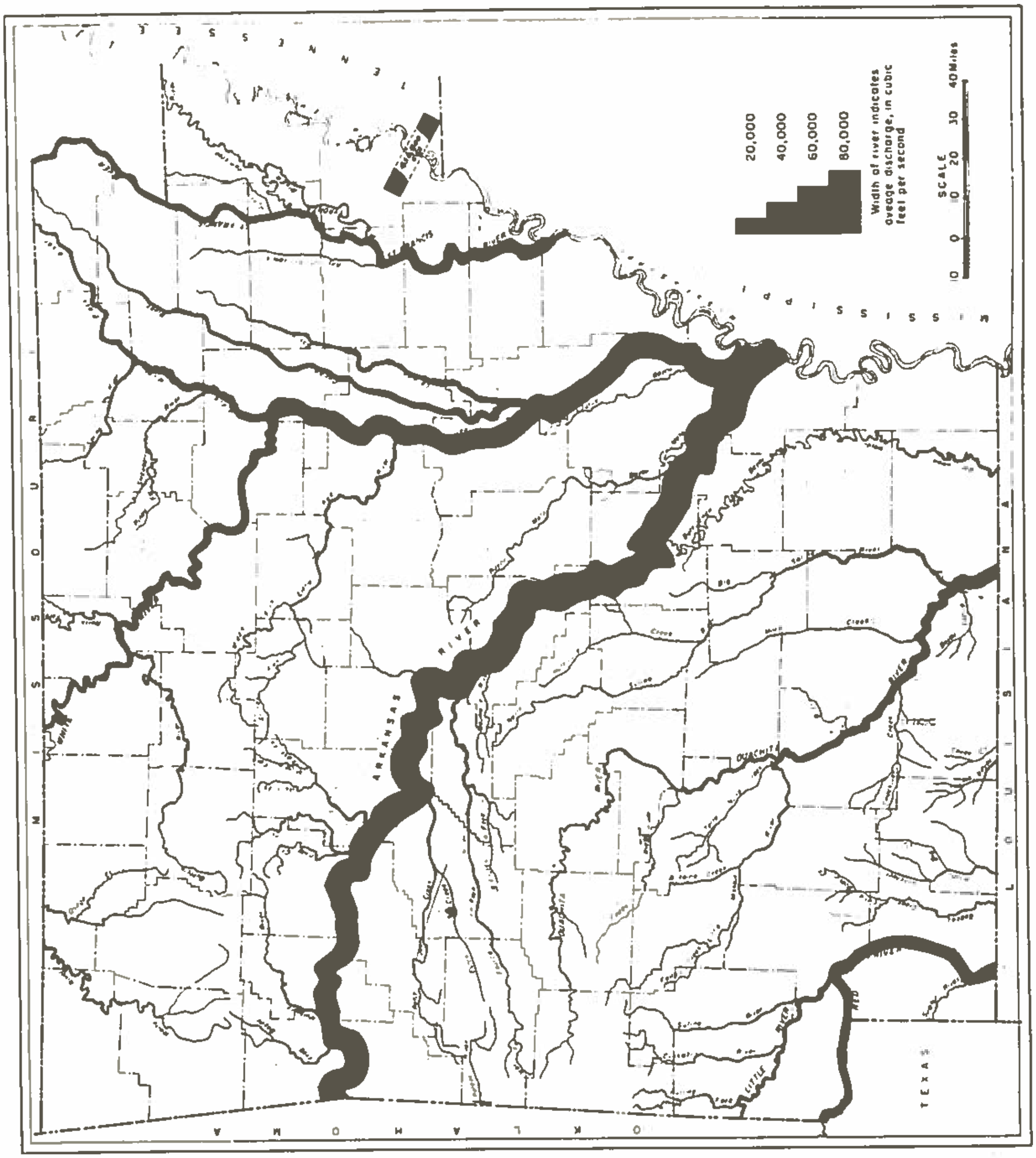

Fig. 9.--ARKANSAS RIVERS
(AVERAGE DISCHARGE)

Source: U. S. Geological Survey

contains and transmits water). Wells in aquifers that are composed of coarse unconsolidated material yield much more water than wells in aquifers composed of consolidated materials that have compacted or cemented.

The Interior Highlands

Rock formations of the Interior Highlands consist primarily of interbedded sandstone, limestone and shale. The formations are geologically very old and have been compacted and cemented. Ground water occurs in fissures and cracks in the formations. Wells nearly everywhere in the Highlands will yield sufficient water for domestic use, but wells yielding in excess of 50 gallons per minute are limited to the northern tier of counties and the alluvium of the Arkansas Valley (see Figure 10).

The alluvium underlying the flood plain of the Arkansas River between Little Rock and Fort Smith is the most important water-bearing aquifer in the Interior Highlands. The aquifer ranges in thickness from 40 feet near Fort Smith to 80 feet near Little Rock and is capable of yielding 300 to 700 gallons per minute to wells.[7]

There is a great deal of ground water stored in the Highlands. Using fairly conservative assumptions, Mr. G. M. Hogenson of the U. S. Geological Survey, in a talk to the Arkansas Academy of Science in April, 1966, estimated ground water storage in the Highlands to exceed 5200 billion gallons. At 1960 water use rates, and if the estimate is correct, there is sufficient water in the ground to supply the area for 370 years without recharge. Two major problems stand in the way of the development of ground water resources in the Highlands--the first is the unequal distribution of water throughout

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[7]See Robert M. Cordova, Reconnaissance of the Ground Water Resources of the Arkansas Valley Region Arkansas, Geological Survey Water-Supply Paper 1669-BB (Washington: U. S. Government Printing Office, 1963).

the area, and the second is the lack of permeability of the water-bearing rocks.

The Gulf Coastal Plain

The Gulf Coastal Plain is underlaid by deposits of clay, silt, sand, and some calcareous material. The deposits are shallow near the Highlands, but further west and south, they increase in thickness to about 4500 feet in the southeast corner of the state. They are of relatively recent geologic origin and are not cemented or compacted to any appreciable degree. The water-bearing formations in the Gulf Coastal Plain include deposits of Cretaceous, Tertiary and Quaternary Ages. These deposits will yield an abundance of high quality water to wells over most of the area.[8] Figure 10 shows the well yields in gallons per minute over the state.

Cretaceous Formations

Formations of Cretaceous Age occur in southwestern Arkansas. While the yields in wells in this area are less than 500 gallons per minute, they are sufficient for domestic use and for small industry. Where the formation is close to the surface, the formation yields water of acceptable quality; but further south it dips, and the water is too mineralized for most uses.[9]

Tertiary Formations

A water-bearing formation of Tertiary Age, known locally as the "1400 Foot Sand," occurs in northeastern Arkansas at a depth of about 1000 feet and extends to the east central portion of the state where it reaches a depth

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[8] R. C. Baker, *op. cit.*, pp. 1-4.

[9] *Ibid.*, p. 4.

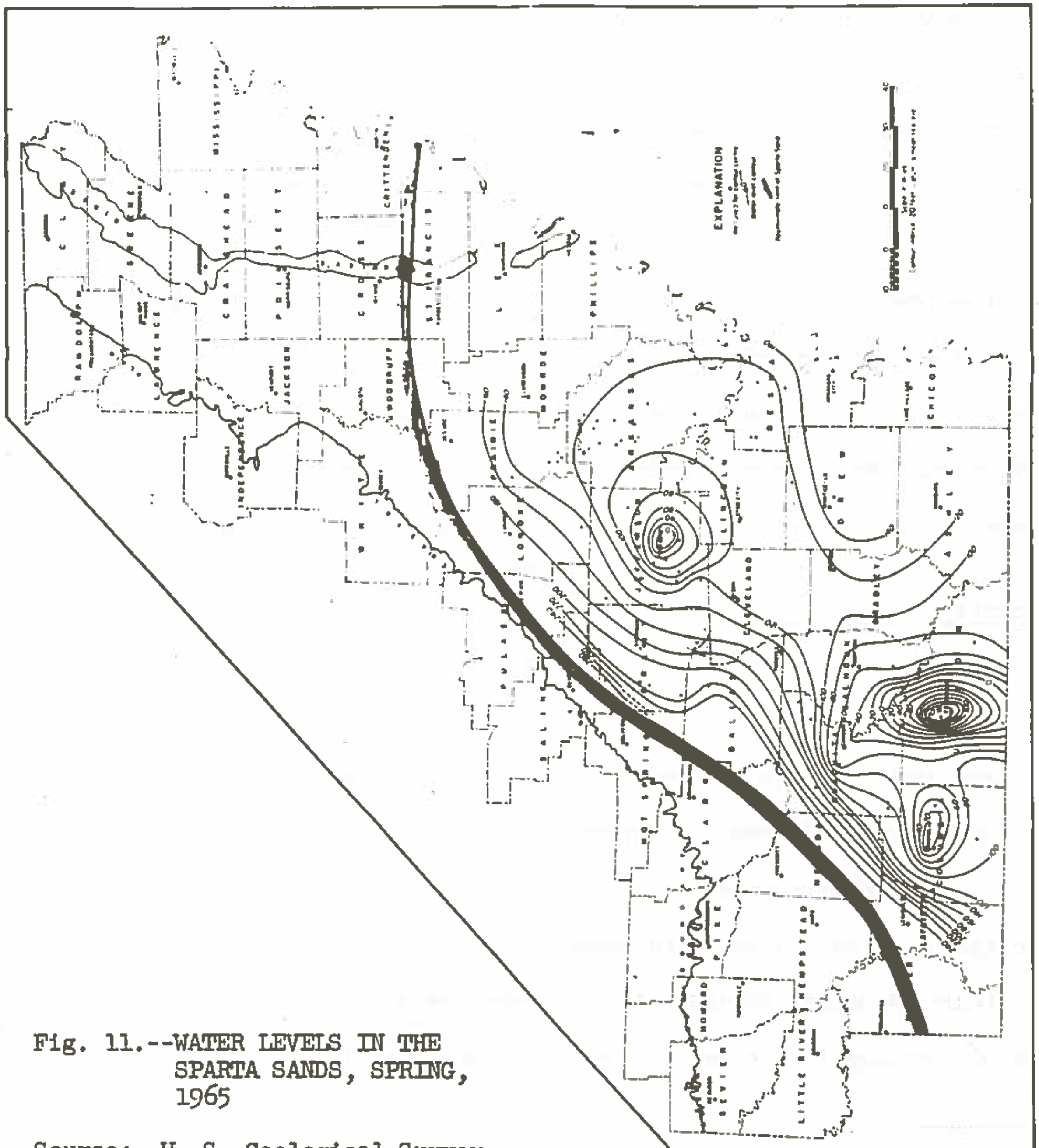

Fig. 11.--WATER LEVELS IN THE SPARTA SANDS, SPRING, 1965

Source: U. S. Geological Survey and Arkansas Geological Commission slopes from about 280 feet above sea level in Clay and Randolph counties in the north to about 100 feet above sea level in Chicot and Ashley counties in the south. The most significant feature of Figure 12, however, is the large cone of depression that has developed in the water table beneath Lonoke, Prairie, and Arkansas counties in what is known as the Grand Prairie area.

The Grand Prairie cone of depression has resulted primarily from the withdrawal of ground water for irrigation purposes. The draw-down of the water level is sufficiently serious to categorize the Grand Prairie as a water problem area. The crescive Grand Prairie cone of depression has been a subject of continuing observation and study for a number of years. Since 1951 a series of studies has been undertaken by the U. S. Geological Survey, the Corps of Engineers, and the University of Arkansas to " . . . determine the feasibility of relieving ground water shortages by injecting surface water through wells."[15]

Between 1953 and 1961 the Grand Prairie cone of depression enlarged in a northwesterly direction as ground water flowed into the cone.[16] There was little or no deepening in the cone between 1961 and 1965, but some widening again occurred, and minor cones of depression became evident in Lincoln county, and to the north, in Cross and Poinsett counties.[17] In general,

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[15]K. Engler, F. H. Bayley, and R. T. Sniegocki, _Studies of Artificial Recharge in the Grand Prairie Region, Arkansas_, Geological Survey Water-Supply Paper 1615-A (Washington: U. S. Government Printing Office, 1963), p. A 1.

[16]Raymond O. Plebuck, _Changes in Ground Water Levels in Deposits of Quaternary Age in Northeastern Arkansas_, U. S. Geological Survey in cooperation with Arkansas Geological Commission (Little Rock: 1962).

[17]D. R. Albin, _et al_, _op. cit_.

however, there was little change in the water stored in deposits of Quaternary Age between 1961 and 1965.

Water Quality

Water is an effective solvent and a vehicle for chemicals in solution and small insoluble particles. It also constitutes the most important method of disposing of domestic and industrial waste. The quality of water is then determined by its environment--by the purity of the air through which precipitation falls, by the nature of the soil with which surface and ground water comes in contact, and, more important, by what man dumps in lakes, rivers, streams, and on exposed surfaces of the land.

The term pollution includes any activity or material, organic or inorganic, natural or man made, that degrades the quality of water. There are a number of ways of classifying or grouping impurities that enter water courses. The following classification is in terms of the source of pollutants and is similar to that used by the United States Senate Committee on Public Works.[18]

1. Domestic sewage.
2. Industrial wastes of plant and animal origin.
3. Infectious bacteria and viruses from domestic sewage and organic industrial waste.
4. Plant nutrients--nitrogen, phosphorous, carbon--the residual products of organic waste decomposition.
5. Synthetic organic chemicals (e.g., detergents and pesticides).
6. Inorganic chemicals both natural and man made.
7. Sediment.
8. Radioactive pollutants.
9. Temperature increases arising from industrial use of water as a coolant.

The impurities enumerated above may be further divided into those which are degradable and those which are non-degradable. Degradable wastes are subject

[18] A Study of Pollution-Water (Washington: U. S. Government Printing Office, 1963), pp. 3-5.

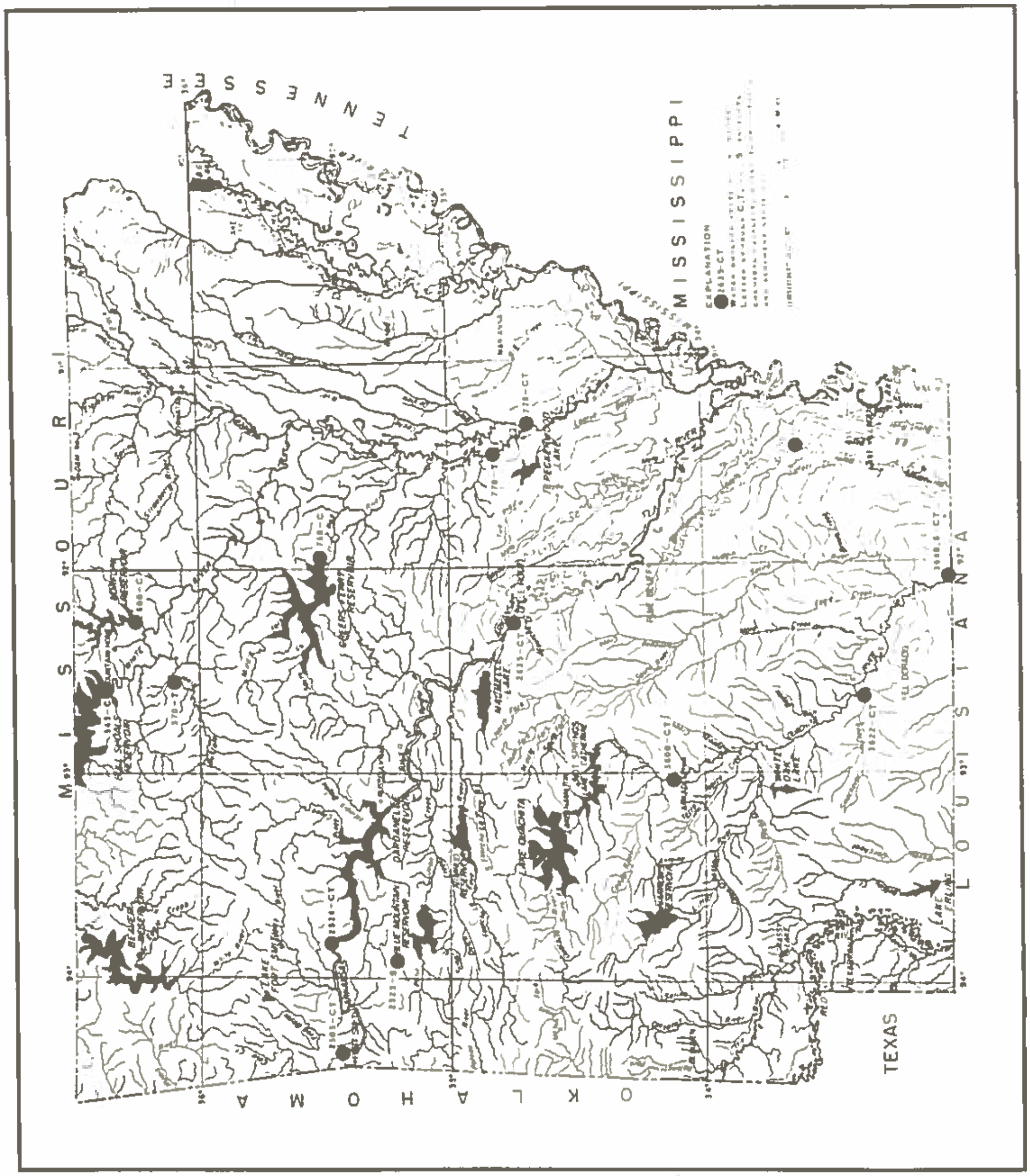

Fig. 13.--LOCATION OF CHEMICAL, TEMPERATURE AND SEDIMENT MONITORING STATIONS

Source: U. S. Geological Survey

7-600. NORTH FORK RIVER AT NORFORK DAM, NEAR NORFORK, ARK.

LOCATION.--At gaging station at Norfork Dam, 4.3 miles northeast of Norfork, Baxter County.
DRAINAGE AREA.--1,806 square miles.
RECORDS AVAILABLE.--Chemical analyses: October 1946 to September 1964.
REMARKS.--Flow completely regulated by Norfork Reservoir. Records of discharge for water year October 1963 to September 1964 furnished by Corps of Engineers, and reviewed by Geological Survey.

Chemical analyses, in parts per million, water year October 1963 to September 1964

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$		Total acidity as H^{+1}	Specific conductance (micromhos at 25°C)	pH	Color
																Calcium, magnesium	Noncarbonate				
Jan. 15, 1964..	1300	5.0			0.00	32	22	1.5	1.2	197	4.6	3.5	0.0	1.0	168	171	9		319	7.8	5
Feb. 14........	233	4.1			.00	32	22	1.4	1.4	199	4.4	--	.0	.8	164	171	8		315	8.0	5
Mar. 13........	306	3.3			.00	32	23	1.5	1.4	203	6.2	3.0	.0	1.3	174	175	8		332	7.9	5
Apr. 14........	1750	3.9			.00	33	20	1.5	1.4	194	4.2	1.6	.1	.8	168	165	6		312	8.2	1
May 18.........	2600	3.3			.00	33	20	1.4	1.4	194	4.4	1.4	.1	1.0	167	165	6		314	7.9	3
June 12........	1680	3.6			.00	32	20	1.4	1.5	192	4.8	1.7	.1	1.5	168	162	4		316	7.7	5
July 16........	1610	3.4			.00	32	20	1.5	1.5	190	4.6	1.8	.2	1.3	166	162	6		316	7.7	8
Aug. 20........	1460	5.6			.00	32	20	1.3	1.1	198	5.6	1.6	.0	1.8	175	162	0		308	7.5	3
Sept. 15.......	400	5.2			.00	32	19	1.3	1.1	194	5.6	1.7	.0	1.8	167	158	0		307	7.4	4

7-760. LITTLE RED RIVER NEAR HEBER SPRINGS, ARK.

LOCATION.--At gaging station on right bank, 1,600 feet downstream from Greers Ferry Dam and 3 miles northeast of Heber Springs, Cleburne County.
DRAINAGE AREA.--1,146 square miles.
RECORDS AVAILABLE.--Chemical analyses: November 1949 to September 1952, October 1954 to September 1964.
Water temperatures: November 1949 to September 1952.
REMARKS.--Flow completely regulated since Mar. 30, 1962 by Greers Ferry Reservoir. Some regulation October 1960 to February 1962 by construction of Greers Ferry Dam. Records of discharge for water year October 1963 to September 1964 furnished by Corps of Engineers and reviewed by Geological Survey.

Chemical analyses, in parts per million, water year October 1963 to September 1964

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$		Total acidity as H^{+1}	Specific conductance (micromhos at 25°C)	pH	Color
																Calcium, magnesium	Noncarbonate				
Oct. 4, 1963...	64	6.4		--	0.00	7.3	1.6	1.2	1.1	26	5.2	3.0	0.0	0.2	39	24	3		65	6.9	5
Dec. 3.........	97	4.2		0.30	.40	8.3	1.2	2.0	1.2	32	2.6	3.0	.0	.1	46	26	0		62	6.4	5
Apr. 15, 1964..	188	2.2		.04	.00	7.3	1.4	1.5	1.5	29	3.2	2.0	.1	.2	37	24	0		63	7.1	5
June 1.........	21	2.6		.05	.00	8.4	1.5	3.3	1.5	37	3.4	1.6	.1	.1	44	27	0		75	7.1	5
July 8.........	61	3.1		1.3	.00	8.1	1.6	2.2	1.4	32	3.8	1.1	.1	.4	42	26	0		69	7.4	28
Aug. 3.........	2960	1.9		.17	.10	7.2	1.9	2.6	1.4	31	3.6	1.5	.2	.4	36	26	1		63	7.0	5
Sept. 16.......	43	2.4		--	.00	8.6	1.3	2.0	1.2	36	3.9	1.7	.0	.1	42	27	0		69	7.3	3

Fig. 14.--Cont'd

7-2635. ARKANSAS RIVER AT LITTLE ROCK, ARK.

LOCATION (revised).--At gaging station on right bank, 130 feet downstream from Main Street Bridge in Little Rock, Pulaski County, and at mile 165.5.
DRAINAGE AREA.--158,201 square miles, of which 22,241 square miles is probably noncontributing.
RECORDS AVAILABLE.--Chemical analyses: October 1945 to September 1964.
Water temperatures: October 1945 to September 1964.
EXTREMES, 1963-64.--Dissolved solids: Maximum, 1,300 ppm Jan. 13 to Feb. 7; minimum, 154 ppm Apr. 6-9.
Hardness: Maximum, 325 ppm Oct. 31 to Nov. 5; minimum, 46 ppm Mar. 9-26.
Specific conductance: Maximum daily, 2,760 micromhos Feb. 4; minimum daily, 205 micromhos Apr. 8.
Water temperatures: Maximum, 92°F Aug. 4; minimum, freezing point Dec. 21, 23, Jan. 13.
EXTREMES, 1945-64.--Dissolved solids (1945-61, 1963-64): Maximum, 2,400 ppm Nov. 28-29, 1953; minimum, 105 ppm Mar. 3, 1957.
Hardness (1945-61, 1963-64): Maximum, 556 ppm Nov. 28-29, 1953; minimum, 46 ppm Feb. 2-4, 9, 12-18, 1957, Mar. 9-26, 1964.
Specific conductance: Maximum daily, 5,050 micromhos Apr. 8, 1954; minimum daily, 173 micromhos Feb. 4, 1957, Nov. 20, 1958.
Water temperatures: Maximum, 98°F Aug. 16, 1954, July 5, 1956; minimum, freezing point on several days during December to February most years.
REMARKS.--Records of specific conductance of daily samples available in district office at Little Rock, Ark.

Chemical analyses, in parts per million, water year October 1963 to September 1964

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids (residue at 180°C): Parts per million	Dissolved solids: Tons per acre-foot	Dissolved solids: Tons per day	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Noncarbonate	Sodium adsorption ratio	Specific conductance (micromhos at 25°C)	pH
Oct. 1-15, 1963..	4869	14	0.00	63	13	143	5.0	155	4	68	220	0.7	2.3		611	0.83	8030	211	77	4.3	1120	8.5
Oct. 16-30.......	2739	11	.00	81	18	228	5.8	195	12	94	345	.9	3.6		893	1.21	6600	277	97	6.0	1640	8.6
Oct. 31-Nov. 5...	4963	12	.00	94	22	331	6.7	203	8	127	508	1.4	4.8		1220	1.66	16350	325	145	8.0	2210	8.5
Nov. 6-9.........	4125	14	.00	67	15	260	5.8	151	4	113	395	.8	6.2		973	1.32	10840	229	98	7.5	1770	8.4
Nov. 10-21.......	2668	17	.00	67	14	175	5.3	169	6	81	268	1.0	3.4		733	1.00	5280	225	76	5.1	1330	8.5
Nov. 22-28.......	5604	13	.00	46	14	128	4.3	135	0	54	200	.7	2.1		555	.75	8400	173	62	4.2	1000	8.2
Nov. 29-Dec. 14..	3266	12	.00	82	15	255	5.6	185	4	95	402	.9	1.5		988	1.34	8710	266	103	6.8	1770	8.4
Dec. 15-Jan. 12, 1964...........	2884	10	.00	76	16	228	4.6	191	0	78	358	1.0	1.4		899	1.22	7000	256	99	6.2	1600	7.5
Jan. 13-Feb. 7...	2593	7.8	.00	90	23	354	5.8	209	0	120	555	1.0	1.2		1300	1.77	9100	319	148	8.6	2290	8.2
Feb. 8-23........	8075	6.4	.00	44	5.2	180	3.5	100	0	61	275	.4	1.5		644	.88	14040	132	50	6.8	1200	7.9
Feb. 24-Mar. 4...	4657	6.0	.00	52	14	230	3.7	129	0	75	355	.4	1.1		809	1.10	10170	187	82	7.3	1520	8.2
Mar. 5-8.........	9462	4.6	.00	29	7.7	144	2.8	80	0	34	222	.3	1.3		486	.66	12420	104	38	6.1	930	6.7
Mar. 9-26........	37380	9.2	.00	13	3.4	37	2.2	38	0	18	56	.0	2.0		171	.23	17260	46	16	2.4	301	7.5
Mar. 27-28.......	22350	--	.00	21	4.9	77	2.4	58	0	32	106	.3	--		288	.39	17380	72	25	3.9	533	8.1
Mar. 29-Apr. 2...	13000	8.6	.00	17	4.7	52	2.4	50	0	24	81	.2	1.3		222	.30	7790	62	21	2.9	411	7.2
Apr. 3-5.........	13480	11	.00	25	6.1	80	1.6	62	0	33	125	.2	1.4		332	.45	12080	88	36	3.7	613	7.4
Apr. 6-9.........	88650	12	.00	17	2.7	28	1.8	48	0	15	42	.1	2.6		154	.21	36860	54	15	1.7	267	6.9
Apr. 10-May 4....	30870	9.5	.00	23	5.4	49	2.5	66	0	27	77	.1	1.8		239	.33	19920	80	26	2.4	429	7.5
May 5............	17300	--	--	26	6.9	--	--	73	0	--	120	--	--		339	.46	15830	94	34	--	606	8.0
May 6............	16800	--	--	31	7.9	--	--	78	0	--	180	--	--		455	.62	20640	110	46	--	827	7.9
May 7-11.........	11380	9.2	.00	28	7.7	76	2.9	82	0	38	121	.2	1.2		339	.46	10420	102	34	3.3	620	7.5
May 12...........	22100	--	--	37	8.8	--	--	97	0	--	150	--	--		426	.58	25420	129	49	--	760	8.1
May 13-17........	68380	12	.00	18	3.9	27	2.2	60	0	17	39	.0	2.0		159	.22	29360	61	12	1.5	268	8.0
May 18...........	46800	--	--	26	5.5	--	--	74	0	--	78	--	--		254	.35	32100	88	27	--	453	7.9
May 19-21........	33630	14	.00	33	6.7	86	3.0	94	0	38	132	.3	2.9		387	.53	35140	110	33	3.6	688	7.6
May 22-30........	11150	14	.00	31	6.4	58	3.2	98	2	31	86	.3	2.3		303	.41	9120	104	20	2.5	525	8.3
May 31-June 2....	5127	14	.00	46	8.6	82	4.0	138	2	44	113	.2	1.3		397	.54	5500	151	34	2.9	713	8.4
June 3-4.........	4765	20	.00	55	11	112	3.9	154	5	53	168	.3	.8		525	.71	6750	182	46	3.6	897	8.6
June 5-8.........	4062	11	.00	59	12	146	4.3	166	6	58	213	.3	.8		621	.84	6810	197	51	4.5	1110	8.6
June 9...........	5500	--	--	63	16	--	--	165	0	--	270	--	--		739	1.01	10970	223	88	--	1320	8.1
June 10-12.......	4700	8.2	.00	76	17	282	4.6	168	8	98	428	.5	2.2		1060	1.44	13450	260	109	7.6	1890	8.7
June 13-14.......	3950	10	.00	67	14	205	4.0	154	8	86	316	.5	1.2		829	1.13	8840	225	85	5.9	1480	8.6

Fig. 14.--Cont'd

7-778. WHITE RIVER AT CLARENDON, ARK.

LOCATION.--At gaging station on Cottonbelt Railroad bridge at Clarendon, Monroe County.
DRAINAGE AREA.--25,497 square miles.
RECORDS AVAILABLE.--Chemical analyses: October 1947 to September 1964.
Water temperatures: October 1948 to September 1964.
EXTREMES, 1963-64.--Dissolved solids: Maximum, 182 ppm June 1-30; minimum, 78 ppm Apr. 1-30.
Hardness: Maximum, 162 ppm Oct. 1-31, Jan. 1-31; minimum, 47 ppm Apr. 1-30.
Specific conductance: Maximum daily, 361 micromhos Oct. 30; minimum daily, 85 micromhos Mar. 26.
Water temperatures: Maximum, 89°F July 7; minimum, 35°F Dec. 22-24, 30-31.
EXTREMES, 1947-64.--Dissolved solids: Maximum, 349 ppm Nov. 12, 1955; minimum, 38 ppm Feb. 1-9, 1950.
Hardness: Maximum, 202 ppm Apr. 25, 1956; minimum, 28 ppm Dec. 1-10, 1957.
Specific conductance: Maximum daily, 544 micromhos Nov. 12, 1955; minimum daily, 61 micromhos Feb. 3, 1950.
Water temperatures (1948-64): Maximum, 90°F on several days during June and July 1954; minimum, freezing point Jan. 15, 1962, Jan. 26-28, 1963.
REMARKS.--Values reported for iron are in solution when analyzed. Records of specific conductance of daily samples available in district office at Little Rock, Ark. Records of discharge for water year October 1963 to September 1964 furnished by District Office, Corps of Engineers, Memphis, Tenn.

Chemical analyses, in parts per million, water year October 1963 to September 1964

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Total acidity as H^{+1}	Specific conductance (micromhos at 25°C)	pH	Color
Oct. 1-31, 1963.......	7000	7.8		0.00	0.00	35	18	5.3	1.6		200	0	4.6	7.0	0.0	1.2		179	162	0		325	6.8	3
Nov. 1-30....	7280	7.1		.00	.00	34	18	4.2	1.6		191	0	4.8	6.4	.0	1.4		172	159	2		314	6.8	3
Dec. 1-31....	8070	13		.00	.00	35	16	3.7	1.3		190	0	4.4	4.4	.0	1.1		172	154	0		303	6.9	3
Jan. 1-31, 1964.......	6200	5.5		.00	.00	35	18	4.2	1.1		200	0	4.4	6.0	.0	.9		181	162	0		323	7.1	3
Feb. 1-29....	8800	12		--	.00	29	15	5.0	1.2		142	8	6.4	6.0	.0	.9		153	134	4		280	8.5	7
Mar. 1-31....	50500	7.6		--	.00	15	6.1	2.5	2.2		65	0	7.8	5.0	.1	1.1		97	62	9		142	8.1	10
Apr. 1-30....	59100	5.7		--	.00	11	4.7	2.6	2.5		56	0	3.6	3.5	.1	.9		78	47	1		110	7.7	50
May 1-6......	35500	10		--	.00	17	6.4	2.9	2.9		83	0	3.4	1.8	.3	1.9		106	69	1		151	8.2	48
May 7-31.....	21600	11		--	.00	28	10	3.1	1.9		128	2	4.4	2.0	.3	2.2		131	111	3		228	8.4	12
June 1-30....	10600	17		--	.00	36	16	4.1	1.6		168	8	5.0	3.3	.3	1.5		182	156	5		308	8.6	6
July 1-31....	10200	8.5		--	.00	34	15	4.7	1.6		164	4	5.0	3.9	.3	1.4		163	147	6		293	8.6	6
Aug 1-31.....	11200	9.4		--	.00	33	14	4.5	1.4		162	4	6.0	3.4	.0	1.4		156	140	0		278	8.5	3
Sept. 1-30...	9700	10		--	.00	31	14	4.9	1.6		158	6	4.8	3.8	.0	1.1		155	135	0		280	8.6	4
Weighted average..	--	8.5		--	0.00	22	9.7	3.3	2.0		108	2	5.2	4.1	0.1	1.2		121	94	3		198	7.5	20
Time-weighted average	17800	9.5		--	0.00	30	14	4.0	1.6		151	3	5.1	4.6	0.1	1.3		151	130	2		264	7.3	9
Tons per day	--	405		--	0.00	1050	463	159	96		5180	74	251	197	6.0	58		5790	--	--		--	--	--

Fig. 14.--Cont'd

7-3640.8. OUACHITA RIVER NEAR FELSENTHAL, ARK.

LOCATION.--At. U.S. Engineers Lock No. 6, 3 miles south of Felsenthal, Union County.
DRAINAGE AREA.--10,787 square miles.
RECORDS AVAILABLE.--Chemical analyses: October 1949 to September 1964.
Water temperatures: October 1949 to September 1964.
EXTREMES, 1963-64.--Specific conductance: Maximum daily, 1,710 micromhos Oct. 20; minimum daily, 63 micromhos May 7.
Water temperatures: Maximum, 92°F July 25; minimum, freezing point Dec. 22.
EXTREMES, 1949-64.--Specific conductance: Maximum daily, 7,610 micromhos Oct. 7, 1954; minimum daily, 44 micromhos May 19, 1958.
Water temperatures: Maximum, 96°F June 9, 1953, Aug. 29, 1954; minimum, freezing point Feb. 8, 12, 13, 1958, Dec. 22, 1963.
REMARKS.--Records of specific conductance of daily samples available in district office at Little Rock, Ark. Records of discharge are given for Ouachita River near Arkansas-Louisiana state line for stages below bankfull, about 19 feet.

Chemical analyses, in parts per million, water year October 1963 to September 1964

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Total acidity as H^+	Specific conductance (micromhos at 25°C)	pH	Color
Oct. 17-22, 1963	1040	6.4		0.04	0.04	49	12	243	3.5	16	10	480	0.1	17	894	172	158		1630	6.3	5
Nov. 1-5	1314	6.0		.09	.54	40	13	212	3.1	2	15	400	.3	19	802	154	152		1470	5.0	10
Dec. 22-26	3462	6.8		.15	.00	12	3.3	34	2.0	24	9.4	64	.1	3.0	172	44	24		292	7.2	30
Jan. 4-7, 1964	1792	5.3		.14	.08	21	7.5	84	1.8	4	21	160	.1	18.	356	84	80		638	5.2	10
Feb. 15-18	5835	7.9		--	.00	15	2.6	39	2.0	21	16	68	.3	4.0	187	48	31		329	7.3	27
Mar. 15-18	--	7.3		--	.00	7.6	.9	13	2.0	16	8.8	22	.2	1.1	94	22	10		127	7.2	48
Apr. 27-30	--	5.8		--	.00	6.0	1.3	11	2.0	15	5.4	20	.2	1.6	88	20	8		108	6.9	80
May 5-14	--	6.9		--	.00	6.0	1.0	5.5	2.0	19	4.6	9.5	.2	.9	72	19	4		72	7.1	70
June 25-29	1302	6.3		--	.00	14	4.8	46	1.7	14	26	78	.3	11	238	54	43		366	7.0	25
July 15-18	1372	6.2		--	.00	16	3.8	55	2.0	4	11	103	.4	24	242	56	52		432	6.5	16
Aug. 18-21	1372	8.6		--	.00	8.9	2.3	21	1.0	26	9.0	30	.1	6.0	111	32	10		180	7.7	10
Sept. 25-30	3085	5.9		--	.00	9.8	2.3	25	1.2	18	7.6	42	.0	6.4	128	34	19		214	7.5	11

Fig. 14.--Cont'd

7-3622. SMACKOVER CREEK NEAR NORPHLET, ARK.

LOCATION.--At bridge on county road, 3.5 miles north of Norphlet, Union County.
DRAINAGE AREA.--500 square miles, approximately.
RECORDS AVAILABLE.--Chemical analyses: October 1952 to September 1955, October 1959 to September 1964.
Water temperatures: October 1952 to September 1955, October 1959 to July 1960, October 1961 to September 1964.
EXTREMES, 1963-64.--Specific conductance: Maximum daily, 39,000 micromhos Oct. 27, 28, 30; minimum daily, 253 micromhos Apr. 28.
Chloride: Maximum, 15,100 ppm Oct. 27, 28, 30; minimum, 60 ppm Apr. 28.
Water temperatures: Maximum, 92°F Aug. 4; minimum, 34°F Dec. 30, 31, Jan. 1, 2, 15, 17.
EXTREMES, 1952-55, 1959-64.--Specific conductance: Maximum daily, 96,400 micromhos Sept. 4, 1954; minimum daily, 215 micromhos Dec. 19, 1961.
Chloride (1960-64): Maximum, 17,800 ppm Aug. 28, 1963; minimum, 52 ppm Dec. 18, 1961.
Water temperatures: Maximum, 102°F July 18, 24, 26, Aug. 17, 1954; minimum, freezing point Mar. 2, 1960.

Chemical analyses, in parts per million, water year October 1963 to September 1964

Date of collection	Mean discharge (cfs)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue at 180°C)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Immediate acidity (H)	Specific conductance (micromhos at 25°C)	pH	Color
Oct. 26-30, 1963.........		11			2.4	1370	313	7360	70	4	5.0	14800	0.5	--	23900	4710	4710	--	37800	6.3	2
Jan. 17-22, 1964.........		23			1.6	124	81	675	7.5	0	18	1410	.3	0.1	2470	643	643	0.4	4420	4.0	9
Apr. 27-May 2..		8.8			.00	8.9	2.7	39	2.8	7	5.4	77	.2	.6	150	33	28	--	299	6.7	70
Aug. 14-16.....		6.2			4.4	635	124	3080	14	0	11	6320	.6	--	11000	2100	2100	1.4	17900	3.7	7
Sept. 29.......		--		0.88	--	173	48	--	--	0	--	1840	--	--	--	630	630	--	5720	4.3	--

Fig. 14.--Cont'd

trap sediment. Bank stabilization and the completion of irrigation dams will further reduce the silt load of the Arkansas.

Red River Basin

The Red River, like the Arkansas, is polluted primarily with silt and salt and also with sewage and industrial waste when it enters the state. Ten major sources and six minor sources of natural mineral pollution have been identified in the Red River Basin. Oil and gas production also contribute to the salt pollution.

As a result of the salt content, water quality is degraded to the extent that it is unsuitable for industrial, agricultural or municipal use in either the Arkansas or Red Rivers. During 1961 and 1962 a combined total of 27,000 tons of salt per day was detected in the Arkansas and Red Rivers near points where these rivers enter Arkansas.[22]

Ouachita River

The principal pollutants in the Ouachita River consist of sewage, industrial wastes and oil field brines. From its headwaters in the Ouachita Mountains south to Camden, water quality varies from excellent to good. South of Camden the influx primarily of oil field brines and also of industrial wastes degrades the water to the extent that, by the time it leaves the state, it is not suitable for most uses. For example, at Arkadelphia, north of Camden, during the period from October, 1963, to September, 1964, the time-weighted average chloride content was 4.5 parts per million; the time-weighted average

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[22] *Ibid.*, p. 2.

plants. The amount for any one project was not to exceed thirty percent of the total cost or $250,000, whichever was smaller. The Federal Water Pollution Control Act Amendments (Public Law 87-88) of 1961 increased the federal grant total from $50 million to $80 million in 1962, $90 million in 1963, and $100 million for the next four years. The single project limitation was raised from $250,000 to $600,000. The amended act allowed single grants of up to $2.4 million for joint sewage plants between communities. The Water Quality Act of 1965 (Public Law 89-234) doubled the maximum dollar limitation on grants for both single and joint projects to $1.2 and $4.8 million, respectively. Again the grant could not exceed 30 percent of the project cost.

The enactment of federal pollution control legislation in 1956 combined with the establishment of an effective water pollution control commission in Arkansas in the same year has done much to abate domestic sewage pollution in Arkansas.[23] Since 1956 the population of cities and towns served by sewers has increased by 21.5 percent. During the same period, the raw sewage discharge in terms of population equivalent has decreased by 10.8 percent.[24]

As of the end of 1965, over $13 million in federal grants on 190 sewage treatment projects, of which total costs were $44.5 million, had been authorized. Prior to 1956, 167 cities and incorporated towns had inadequate sewage treatment or none at all. Every city or town as of 1966 has sewage treatment of

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[23]The Arkansas Pollution Control Commission was established in 1949, but it did not function effectively until 1956.

[24]Arkansas Pollution Control Commission.

CHAPTER IV

ARKANSAS WATER RESOURCES: USE

A difficulty inherent in any discussion of water use arises from the consideration that a given quantity of water may satisfy a number of wants concomitantly or through time, before it disappears from a given area. The following use concepts have been developed in the literature of hydrology.[1]

Withdrawal use refers to water diverted from any natural source such as a lake, river or aquifer for any use whatever. Withdrawal use is a gross concept in that it does not consider water discharged after use for possible re-use.

Consumption use refers to water that is used up in the sense that it is lost to the area. Consumption of water may result from water being incorporated into a product or yielded to the atmosphere by evapotranspiration.

Two other use concepts may be distinguished--flow use and on-site use. Flow use refers to water used in stream channels. Examples are hydroelectric power, navigation and sports. On-site use refers to the use of water for wild life habitat and programs of soil erosion abatement. The term is sometimes used with reference to the maintenance of soil moisture and the recharge of aquifers.

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[1]Ackerman, et. al., op. cit., pp. 47-55. See also Select Committee on Natural Water Resources, United States Senate, Water Resources Activities in the United States (Washington: U. S. Government Printing Office, 1960), p. 15.

Table 4

NUMBER OF EMPLOYEES AND VALUE ADDED
MANUFACTURING ESTABLISHMENTS
ARKANSAS

Industry Group	1963 No. Empl.	1963 Value Added ($1,000)	1958 No. Empl.	1958 Value Added ($1,000)
Food and kindred products	17,821	149,642	15,119	101,022
Textile mill products	2,920	17,483	2,081	10,985
Apparel and related products	10,661	43,998	7,715	24,454
Lumber and wood products	21,311	119,687	21,260	78,603
Furniture and fixtures	8,167	47,244	6,876	31,127
Paper and allied products	7,152	118,164	5,190	65,565
Printing and publishing	3,802	31,051	2,981	20,368
Chemicals and allied products	3,310	69,779	3,229	49,411
Petroleum and coal products	1,453	25,596	1,582	18,777
Leather and leather products	6,510	35,995	3,947	20,663
Stone, clay and glass products	4,022	46,865	3,377	31,238
Primary metals industries	3,121	37,665	2,450	36,297
Fabricated metal products	4,187	34,419	2,709	19,377
Machinery except electrical	3,075	35,256	1,279	11,172
Electrical machinery	7,599	72,655	2,914	29,214
Transportation equipment	2,146	15,714	1,076	6,092
Miscellaneous including ordnance[a]	3,027	23,647	1,810	12,023
All industries[b]	113,694	958,687	88,655	591,745

[a]Government owned and operated plants are excluded.

[b]Includes figures for industry groups not included above.

Source: U. S. Bureau of the Census, 1963 Census of Manufactures, Preliminary Report (Washington: 1965), p. 6.

Table 5.--Continued

County	Public Supply GW	Public Supply SW	Private Supply GW	Private Supply SW	TOTAL
*Madison	00	00	00	00	00
*Marion	00	00	.07	00	.07
Miller	00	.71	.08	.11	.90
Mississippi	1.18	00	2.88	00	4.06
Monroe	.25	00	.01	00	.26
*Montgomery	00	00	.05	00	.05
Nevada	00	00	00	.01	.01
*Newton	00	00	00	00	00
Ouachita	00	.20	1.75	13.81	15.76
*Perry	00	00	00	00	00
Phillips	.85	00	1.19	00	2.04
Pike	.25	00	.07	.03	.35
Poinsett	.30	00	00	00	.30
*Polk	00	.10	.33	00	.43
*Pope	.11	.82	.05	.01	.99
Prairie	.01	00	00	00	.01
*Pulaski	1.81	9.01	00	1.19	12.01
*Randolph	00	.12	.02	00	.14
St. Francis	.48	00	.68	00	1.16
*Saline	00	.54	.01	4.88	5.43
*Scott	00	.36	00	.01	.37
*Searcy	00	00	00	00	00
*Sebastian	00	7.51	00	.03	7.54
Sevier	.57	00	00	00	.57
*Sharp	00	00	00	00	00
*Stone	00	00	.01	00	.01
Union	.82	00	15.12	.16	16.10
*Van Buren	00	.17	00	00	.17
*Washington	.15	3.43	00	.16	3.74
*White	.01	.58	.04	.03	.66
Woodruff	.06	00	.02	00	.08
*Yell	.50	.28	.03	00	.81
TOTAL	14.22	29.37	73.90	55.80	173.29
Interior Highlands Total	4.84	28.18	1.23	7.83	42.08
Gulf Coastal Plain Total	9.38	1.19	72.67	47.97	131.21

*Counties located in the Interior Highlands.

Source: See Table 10.

Table 6.--Continued

County	Public Supply GW	Public Supply SW	Rural GW	TOTAL	1960 County Pop'n
Lonoke	.74	00	.59	1.33	24,551
*Madison	00	.09	.33	.42	9,068
*Marion	.08	00	.19	.27	6,041
Miller	00	.92	.43	1.35	31,686
Mississippi	2.67	00	1.42	4.09	70,174
Monroe	.49	00	.39	.88	17,327
*Montgomery	.03	.04	.18	.25	5,370
Nevada	.32	00	.23	.55	10,700
*Newton	00	00	.24	.24	5,963
Ouachita	.23	1.16	.44	1.83	31,641
*Perry	.03	.05	.16	.24	4,927
Phillips	1.75	00	.71	2.46	43,997
Pike	.11	.09	.20	.40	7,864
Poinsett	.99	00	.75	1.74	30,834
*Polk	00	.33	.29	.62	11,981
*Pope	.10	.88	.41	1.39	21,177
Prairie	.32	00	.27	.59	10,515
*Pulaski	1.36	19.78	.18	21.32	242,980
*Randolph	00	.33	.32	.65	12,520
St. Francis	.94	00	.70	1.64	33,303
*Saline	.07	.62	.61	1.30	28,956
*Scott	00	.13	.24	.37	7,297
*Searcy	.11	00	.27	.38	8,124
*Sebastian	.08	3.72	.41	4.21	66,685
Sevier	.38	00	.22	.60	10,156
*Sharp	.09	.05	.17	.31	6,319
*Stone	.09	00	.19	.28	6,294
Union	2.97	00	.65	3.62	49,518
*Van Buren	00	.06	.26	.32	7,228
*Washington	.10	4.00	.78	4.88	55,797
*White	.32	1.41	.74	2.47	32,745
Woodruff	.42	00	.34	.76	13,954
*Yell	.24	.06	.31	.61	11,940
TOTAL	39.72	43.50	31.34	114.56	1,786,272
Interior Highlands Total	5.65	39.47	12.19	57.31	807,150
Gulf Coastal Plain Total	34.07	4.03	19.15	57.25	979,122

*Counties located in the Interior Highlands.

Source: For water use data see Table 10. Population data are from the Decennial Population Census, U. S. Bureau of the Census.

Table 7.--Continued

County	Rice GW	Rice SW	Rice Total	Row Crops GW	Row Crops SW	Row Crops Total
Marion	00	00	00	00	00	00
Miller	1.00	.16	1.16	.50	.12	.62
Mississippi	2.18	.32	2.50	1.57	.11	1.68
Monroe	20.96	2.33	23.29	31.32	5.13	36.45
Montgomery	00	00	00	00	.01	.01
Nevada	00	00	00	00	.04	.04
Newton	00	00	00	00	00	00
Ouachita	00	00	00	00	00	00
Perry	00	1.65	1.65	00	.15	.15
Phillips	8.19	00	8.19	5.14	.28	5.42
Pike	00	00	00	00	00	00
Poinsett	58.50	3.08	61.58	26.68	1.40	28.08
Polk	00	00	00	00	.01	.01
Pope	00	00	00	.41	00	.41
Prairie	47.17	17.68	64.85	20.35	2.18	22.53
Pulaski	2.56	.45	3.01	3.01	.53	3.54
Randolph	2.65	1.13	3.78	.32	.05	.37
St. Francis	24.06	6.01	30.07	6.11	1.50	7.61
Saline	00	00	00	00	.01	.01
Scott	00	00	00	00	.13	.13
Searcy	00	00	00	00	00	00
Sebastian	00	00	00	00	.06	.06
Sevier	00	00	00	00	.02	.02
Sharp	00	00	00	00	00	00
Stone	00	00	00	00	00	00
Union	00	00	00	00	.04	.04
Van Buren	00	00	00	00	.02	.02
Washington	00	00	00	00	.33	.33
White	1.03	.81	1.84	.80	.11	.91
Woodruff	31.08	1.29	32.37	21.22	1.53	22.75
Yell	00	00	00	.40	.10	.50
TOTAL	577.16	126.97	704.13	372.21	83.87	456.08

Source: See Table 10.

Table 8.--Continued

County	Livestock GW	Livestock SW	Livestock Total	Fish Farms GW	Fish Farms SW	Fish Farms Total
*Madison	.27	.50	.77	.21	00	.21
*Marion	.06	.28	.34	.03	00	.03
Miller	.21	.31	.52	00	00	00
Mississippi	.12	.03	.15	00	00	00
Monroe	.03	.05	.08	2.87	8.10	10.97
*Montgomery	.13	.14	.27	00	.11	.11
Nevada	.16	.16	.32	00	00	00
*Newton	.04	.23	.27	.03	00	.03
Ouachita	.07	.08	.15	00	00	00
*Perry	.10	.12	.22	00	.03	.03
Phillips	.08	.11	.19	.41	00	.41
Pike	.16	.11	.27	00	00	00
Poinsett	.06	.04	.10	.35	.55	.90
*Polk	.16	.16	.32	.21	00	.21
*Pope	.29	.24	.53	00	.16	.16
Prairie	.09	.13	.22	8.44	16.39	24.83
*Pulaski	.17	.25	.42	.92	1.65	2.57
*Randolph	.05	.29	.34	00	00	00
St. Francis	.20	.05	.25	.42	1.32	1.74
*Saline	.10	.14	.24	1.07	00	1.07
*Scott	.18	.22	.40	00	00	00
*Searcy	.06	.32	.38	00	00	00
*Sebastian	.21	.28	.49	.21	00	.21
Sevier	.17	.19	.36	.04	00	.04
*Sharp	.04	.24	.28	00	00	00
*Stone	.08	.20	.28	00	00	00
Union	.11	.11	.22	00	.01	.01
*Van Buren	.06	.24	.30	00	00	00
*Washington	1.15	.77	1.92	.26	00	.26
*White	.34	.42	.76	1.05	.71	1.76
Woodruff	.05	.08	.13	4.94	00	4.94
*Yell	.38	.27	.65	00	.28	.28
TOTAL	12.56	16.48	29.04	103.53	75.60	179.13
Interior Highlands Total	7.36	10.77	18.13	5.94	4.86	10.80
Gulf Coastal Plain Total	5.20	5.71	10.91	97.59	70.74	168.33

*Counties located in Interior Highlands.

Source: See Table 10.

Table 10
TOTAL WATER USE BY COUNTY AND SOURCE (GROUND AND SURFACE WATER), ARKANSAS, 1965 AND 1960
(millions of gallons per day

County	1965 GW	1965 SW	1965 Total	1960 GW	1960 SW	1960 Total
Arkansas	130.77	107.62	238.39	119.09	54.35	173.44
Ashley	23.63	34.75	58.38	39.56	1.59	41.15
*Baxter	.73	.27	1.00	.59	5.96	6.55
*Benton	5.11	3.38	8.49	5.10	2.08	7.18
*Boone	.54	1.28	1.82	1.06	.70	1.76
Bradley	1.40	.85	2.25	.94	.13	1.07
Calhoun	.35	.53	.88	.34	.09	.43
*Carroll	1.06	1.11	2.17	.69	1.59	2.28
Chicot	13.04	14.85	27.89	14.79	6.97	21.76
Clark	.79	3.54	4.33	.72	2.69	3.41
Clay	22.69	10.63	33.32	19.44	1.27	20.71
*Cleburne	.48	.44	.92	.36	.50	.86
Cleveland	.44	.16	.60	.84	.20	1.04
Columbia	3.25	.87	4.12	1.82	.26	2.08
*Conway	2.65	.28	2.93	1.43	.37	1.80
Craighead	52.46	1.88	54.34	32.03	3.78	35.81
*Crawford	2.46	2.91	5.37	1.38	.39	1.77
Crittenden	28.02	4.10	32.12	13.98	2.71	16.69
Cross	68.72	8.04	76.76	55.61	5.82	61.43
Dallas	.75	.36	1.11	.74	.22	.96
Desha	46.35	5.74	52.09	27.47	5.44	32.91
Drew	9.87	4.55	14.42	7.45	2.50	9.95
*Faulkner	.90	2.89	3.79	1.73	1.80	3.53
*Franklin	1.25	30.79	32.04	.65	.49	1.14
*Fulton	.38	.56	.94	1.65	.54	2.19
*Garland	1.06	5.54	6.60	1.15	6.70	7.85
Grant	.98	.08	1.06	.90	.13	1.03
Greene	17.17	1.54	18.71	9.40	1.20	10.60
Hempstead	2.04	.66	2.70	1.61	.47	2.08
Hot Spring	.82	217.61	218.43	.93	262.54	263.47
Howard	1.08	.74	1.82	.68	.93	1.61
*Independence	2.80	1.93	4.73	2.91	1.94	4.85
*Izard	.38	1.29	1.67	.47	.86	1.33
Jackson	56.93	3.94	60.87	55.22	2.03	57.25
Jefferson	86.89	5.59	92.48	--	--	109.30
*Johnson	1.00	.99	1.99	.77	.63	1.40
Lafayette	7.56	.55	8.11	5.37	.84	6.21
Lawrence	17.89	3.69	21.58	21.45	.57	22.02
Lee	25.55	2.26	27.81	13.79	1.38	15.17
Lincoln	26.57	3.37	29.94	18.58	7.85	26.43
Little River	1.62	.31	1.93	1.22	.40	1.62
*Logan	.96	1.26	2.22	.77	1.13	1.90
Lonoke	155.87	14.94	170.81	99.69	5.04	104.73
*Madison	.81	.61	1.42	.87	.66	1.53
*Marion	.43	.28	.71	.32	.35	.67

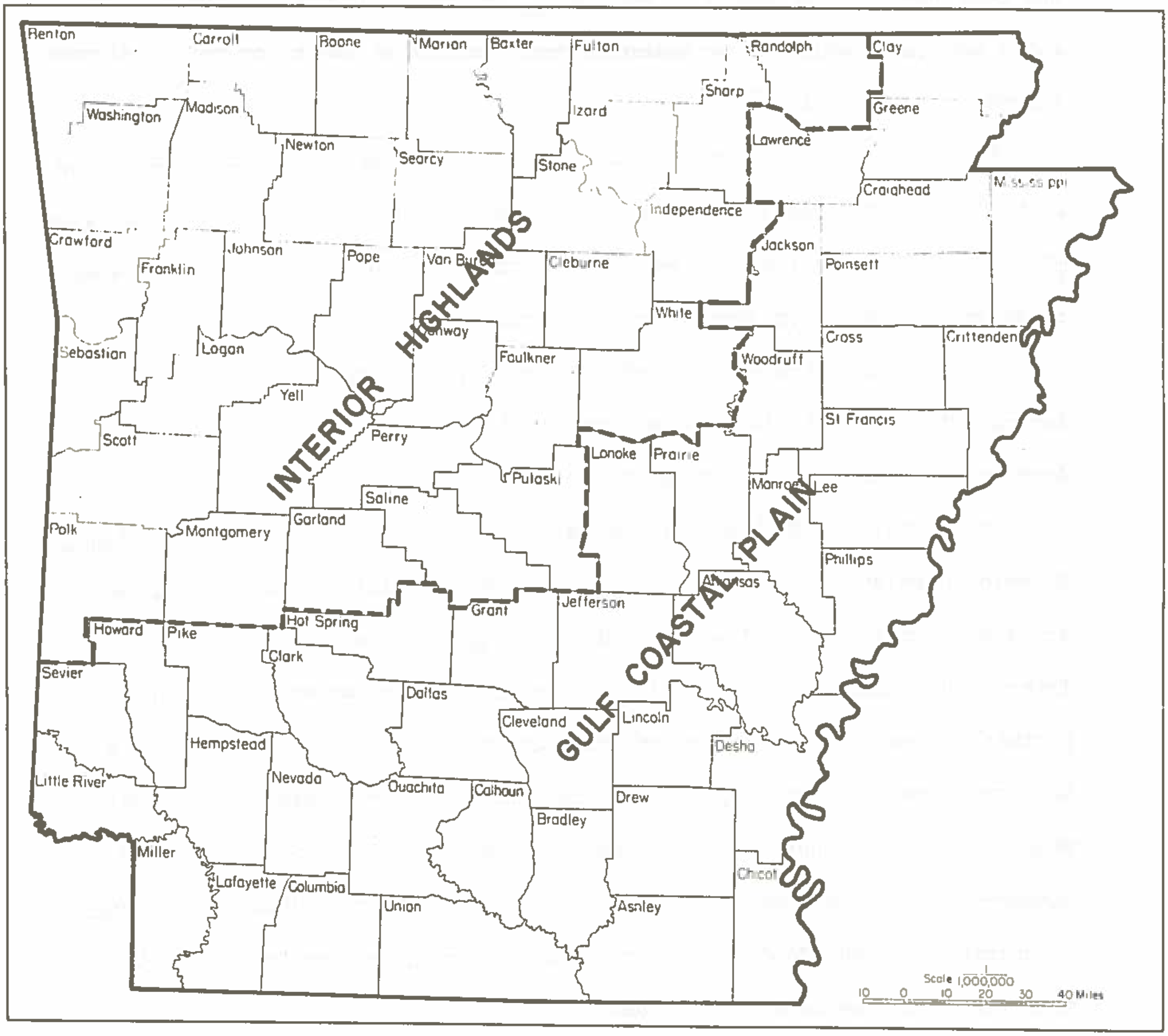

Fig. 15.--COUNTIES IN INTERIOR HIGHLANDS AND GULF COASTAL PLAINS .

daily life and its purity requirements, domestic water withdrawal is an extremely important component of total water use. It has been estimated that an individual could exist on about a gallon of water per day for cooking and drinking.[3] Actual use, however, is much greater, and it is increasing as the amenities of life are introduced into more and more homes. Per capita water use in Arkansas averaged about 60 gallons per day in 1965. The per county Arkansas domestic use by source is given in Table 6.

Irrigation Water Use

Agriculture is Arkansas' principal industry. In 1965 total value of field crop production was about $547 million. Of this amount the three major field crops--soybeans, cotton and rice--contributed $467 million or about 85 percent. Each of these crops uses substantial amounts of irrigation water.

The first commercial rice crop in Arkansas was planted in 1904 in the Prairie area. The venture yielded 5,225 bushels on 70 acres and established what is now Arkansas' third largest field crop in terms of value added.[4] After 1904 acreage planted in rice grew rapidly to 60,000 in 1910, 104,700 in 1913 and 690,000 in 1954. In 1965, 434,000 acres of rice were harvested. Rice has been grown at one time or another in every country in the state, but the lowlands of eastern Arkansas are by far the largest producers. In 1965 an average of 704 million gallons of irrigation water per day was used in rice production.

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[3]E. A. Ackerman, et al., op. cit., p. 48.

[4]K. Engler, F. H. Bayley, and R. T. Sniegocki, Studies of Artificial Recharge in the Grand Prairie Region, Arkansas, p. A 8.

techniques for the intensive production of channel or blue catfish. In 1965 an estimated 30,000 acres of land and 168 million gallons of water per day were used for fish farming. About 57 percent of the water was ground water (see Table 8).

Fuel Electric Water Use

Steam power plants utilize water for two purposes. Through the use of fossil fuels, water is converted into steam, and water is used as a coolant to condense the exhaust steam from turbines. In terms of volume, the latter is by far the most important use. In modern plants the conversion of one gallon of water into steam is sufficient to generate one kilowatt hour of electricity, but the steam is condensed and re-used. The amount of water necessary as a coolant depends upon the extent of re-circulation. Thus, a modern 150,000 kilowatt plant may use from 3 million to 300 million gallons per day.[7] In 1965 total withdrawal for steam electric was slightly over 423 million gallons per day (see Table 9).

Total Arkansas Water Use

Total Arkansas water use by county and source (the summation of all use categories discussed above) for 1965 is given in Table 10. For purposes of comparison through time, comparable data for 1960 are included in Table 10. Average daily water use has increased steadily from 522 million gallons per day in 1940 to 1519 million gallons per day in 1960 and 2079 million gallons per day in 1965. In 1960, 59 percent of water used was withdrawn from ground water sources and 33 percent from surface water sources. The remaining 8

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[7] E. A. Ackerman, et al., op. cit., pp. 309-310.

returned to the atmosphere by evapotranspiration.[9] The remaining 18 inches flows through rivers toward the oceans. The 18 inches of runoff is equivalent to about 51 million acre feet. In addition about 34 million acre feet flow through rivers into the state. About 85 million acre feet are then available to the state if the level of ground water remains unchanged. Use in Arkansas during 1965 was slightly over 2 million acre feet. The above figures, however, should be interpreted with care. Arkansas use figures exclude important flow uses such as hydroelectric and recreation use. Also the use figures are withdrawal use only. Steam electric use, for example, consumes very little water relative to intake. In addition, the supply figures do not consider quality of water. Much of the 34 million acre feet of water which flows into the state annually is too polluted with silt and chemicals for many uses. In general, however, the water balance data do indicate that, in the aggregate, there is an abundance of water in Arkansas relative to use.

Recreational Use

An important water use category not included in the Arkansas water use data is water based recreation. The exclusion of recreational use was based on a number of considerations. In the first place, such use is either flow or on-site use. Second, in multiple purpose water impoundments, it is, given the present state of knowledge, difficult if not impossible to allocate water to recreational use. Third, there are unresolved conceptual difficulties in defining recreational use. Finally, there is too little factual information concerning water based recreation.

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[9] Water vapor equivalent to about 18 inches is evaporated from oceans and carried over the state by air currents.

CHAPTER FIVE

WATER RESEARCH NEEDS IN ARKANSAS

Even a cursory perusal of the literature of hydrology is sufficient to emphasize the ubiquitous nature of water problems that have arisen in man's relation with both his physical and social environment. Solutions or, more accurately, partial solutions to water problems, of course, require research; and it is to water research needs in Arkansas that this chapter is directed. No attempt will be made to catalogue completely water problems and related research needs. While such a classification is a necessary first step to a conceptual grasp of all of the dimensions and interrelations of the aggregative water problem, it is beyond the scope of this study. The focus of this chapter is rather on the research needs which appear to have a high priority in terms of Arkansas' present water use practices and the developmental needs of the state. Also, the focus of the chapter is almost entirely upon problem-oriented, or applied research projects.

Economics of Water Resources Management

Water is a scarce resource in much the same sense that oil, or silver, or the services of a carpenter are scarce resources. It is true that water is unique in terms of supply characteristics, but it is scarce relative to the needs for it. And water is becoming relatively more scarce as population increases and as water uses multiply. The net result is that the cost of additional water is increasing almost everywhere. Yet, water is still widely regarded as a free resource. It is subject to treatment and distribution roots predate the Industrial Revolution and whose focus has continued to be on redistributive aspects rather than efficiency aspects of water utilization. But more important, water is almost unique among economic resources because it has not been subject, for the most part, to regulation by the free market process.

Efficiency Conditions

This section examines the methods by which scarce economic resources are allocated and utilized by the interaction of free market processes under conditions of perfect competition.[1] Perfect competition is at best an imperfect representation of the contemporary economic system, but the perfectly competitive model does provide useful insights into the contemporary system; and, more important for the problem at hand, it establishes criteria for the allocation and utilization of resources which are optimum in terms of consumer preferences and a given distribution of income.[2]

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[1]Perfect competition is a term used in the literature of economics to describe a particular type of competitive structure. In general, perfect competition requires that both buyer and seller of both goods and productive resources regard price as a parameter--determined by the interaction of supply and demand--over which they have no control. The conditions necessary for perfect competition to exist are: (1) perfect knowledge of price and economic opportunity; (2) large numbers of buyers and sellers in both resources and goods markets; (3) homogeneity of the units of each good and resource; (4) no collusion; and (5) divisibility of goods and resources. Several excellent discussions of the various types of competitive structures are available. See G. J. Stigler, The Theory of Price (New York: The Macmillan Company, 1966), Chap. 10; and J. F. Due and R. W. Clower, Intermediate Economic Analysis (Homewood, Ill.: Richard D. Irwin, Inc., 1966), Chap. 8.

[2]No attempt will be made here to develop the underlying theory in detail. For a more complete treatment, see H. R. Bowen, Toward Social Economy (New York: Rinehart and Company, Inc., 1948); and William J. Baumol, Economic Theory and Operations Analysis (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1965), Chap. 14.

organize production so as to maximize profits. The second is the technical assumption of diminishing returns applied to any single resource used in production.[5] Under the assumed conditions, each producer will purchase productive resources to the point where the cost of the last unit of each resource is equal to that resource's contribution to total revenue.[6] Since under competitive conditions there is a uniform price on all units of a productive resource, it follows that the dollar price of each resource reflects the value in production of that resource as well as the opportunity cost of using that resource in any particular use. Free market institutions, then, channel each resource into its most productive use and remunerate each resource according to its productivity.

In a competitive economic system the pricing mechanism serves two important functions. First, it functions as a rationing device. If demand for a particular good (or productive resource) is increased relative to the supply, competitiion among consumers for the good (or among producers for the resource) pushes up the price of the good (or resource) and excludes marginal buyers from the market. In the same way an increase in supply relative to demand exerts downward pressures on price and brings previously submarginal buyers into the market. Price then equates supply and demand by rationing the amount of a good (or resource) that suppliers are willing to provide at a particular price to those consumers (or resource users) who are willing to pay that price. Second, the pricing mechanism functions as a control and coordinating

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[5]As additional units of any productive resource are used in production, the other productive resources held constant, the addition to total output added by the last unit (marginal product) will decline.

[6]In common sense terms, this means that a producer will employ, say, labor as long as the last unit employed continues to pay for itself.

water for purposes of waste disposal as long as the productivity of water in that use were positive. In other words, there would be no incentive on the part of the user to economize in his use of water as a vehicle for waste disposal. Nor would there be any incentive for the water user, because of pollution costs, to economize on the use of water in processes which give rise to pollution.

The efficiency criteria developed by the perfectly competitive market for the allocation and utilization of a scarce resource are then not conceptually complex. They require that a uniform price--which equates supply and demand--be placed on all units of a given resource, that the value of the marginal product of the resource be equal in all of its uses, and the value of the marginal product be equal to its price. It is important to note that the above criteria apply strictly only under the conditions stipulated--i.e., perfect competition and its corollaries. To the extent, however, that the real world conforms to the stipulated conditions, the criteria constitute valid guide lines.[7]

As indicated above, water use has not been subjected to regulation by free market processes. In part this has resulted from the legal institutions surrounding water use. There are, for example, legal barriers to the transfer of property rights. Also, the free market is not, for the most part, capable of dealing effectively with production processes which involve large external diseconomies. Downstream water pollution is a classical example of an external diseconomy. Yet, the application of efficiency criteria to water use is necessary if society is to receive maximum benefit from the utilization of water resources. An example will serve to emphasize this point.

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[7]For a discussion of this point, see Otto Eckstein, Water Resources Development (Cambridge: Harvard University Press, 1961), Chap. 2. Also see A. V. Kneese, The Economics of Regional Water Quality Management (Baltimore: The Johns Hopkins Press, 1964), Chap. 3.

probably is not able) to effect unilateral waste treatment because of competition.

2. To the extent that legal institutions act as barriers to the transfer of water rights, they may preclude the transfer of water from low to high productivity use.

3. Free use of rivers as waste vehicles will tend to limit research conducted by industry on water saving techniques. Thus, wasteful practices and de facto subsidies (in the form of external diseconomies borne by society) will tend to perpetuate themselves.

4. De facto subsidies to industry may attract manufacturers who are large water users and large scale polluters into an area. It may be that some could exist competitively only with the subsidy.

Future Supplies

A great deal of uncertainty with respect to future benefits and costs is inherent in any investment project with a life span extending into the remote and indefinite future. Futurity of benefits and costs has made it difficult to formulate efficiency criteria or guide lines for optimum investment practices, and existing guide lines reflect this difficulty. The problem is, of course, not a new one. Investment decisions have always constituted an essential part of the management of both public and private funds. In recent years there has been a growing interest in the development of objective criteria to assist in investment decision making, and, while there are still many unresolved issues, progress has been made. Current investment in water projects has an important bearing on future water supplies, and it is essential that intelligent use be made of those guide lines that are available.

Private Investment

It is instructive to consider how investment decisions are made by the management of a firm operating in a free market. Ideally, the following three categories of information are necessary: (1) alternative investment possibilities available to the firm in question; (2) the anticipated future not be consistent.[9] If, however, the objective is to maximize the present value of the firm, and, if the firm's ability to borrow is not limited (i.e., the interest rate paid by the firm on borrowed funds measures the opportunity cost of money to the firm), then the present value approach is straightforward and unambiguous. The investment alternative with the largest difference between discounted costs and discounted receipts makes the largest contribution to the present value of the firm.

Public Investment

Public investment decisions differ from private domestic decisions primarily in terms of objectives. It is generally assumed in the case of a firm operating in a free market that the investment objective of management is to maximize the firm's present value. In the case of public investment--because of the social nature of government--private maximizing assumptions are not relevant. The assumption most usually substituted in the discussions of public investment in water projects is the maximization of area income.[10] If the income maximization assumption holds, defensible public investment decisions require the same categories of information as private investment decisions. It is necessary for government decision makers to have information regarding alternative investment needs, anticipated income generated by each alternative, and costs attached to each alternative. It should be noted that, in the case of public investment, the income categories are often inclusive of components

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[9] J. H. Lorie and L. J. Savage, "Three Problems in Capital Rationing," Journal of Business (October, 1955), reproduced in Ezra Solomon (ed), The Management of Corporate Capital (New York: The Free Press of Glencoe, 1959). See in the same volume: Ezra Solomon, "The Arithmetic of Capital Budgeting Decisions," pp. 74-79; and Ed Renshaw, "A Note on the Arithmetic of Capital Budgeting," pp. 80-88.

[10] See R. H. Haveman, Water Resources Investment and the Public Interest (Nashville: Vanderbilt University Press, 1965), p. 96.

indivisible, if alternative projects are mutually exclusive, or if investment projects are complementary in the sense that one requires the other, then more sophisticated techniques are necessary.[11]

There are, however, very real advantages to be realized from using the techniques outlined above or similar techniques in investment decision making. Their use would certainly help to avoid hasty and unwise decisions, since alternative ways of achieving a given end, or goal, necessarily and objectively would be weighed one against the other. Too, their use would require that some scrutiny be given to the relative merits of investment projects serving different ends.

It is important to note that the incidence of the cost of failure of an investment project differs between the private and the public sections of the economy. In the private sector, the cost of failure is borne by the private owners of equity in the firm. In the public sphere, the cost of failure, or of inefficient operation, is an obligation of society. In many municipalities, water costs reflect the cost of current services plus a legacy of debt from inefficient investment projects undertaken in the past.

Research Needs

On the basis of the preceding section, the following observations can be made: (1) The economic institutions (behavior patterns) of a free and competitive market are reasonably efficient in the allocation and utilization of scarce resources. The institutions both identify and employ the necessary resource-use efficiency criteria. (2) Water is unique among productive resources used in the United States economic system in that it is subject to

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[11]See W. J. Baumol, Economic Theory and Operations Analysis (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1965), pp. 448-449.

Any system of water management must perform at least the following functions: (1) water resources planning, (2) the allocation of water to various users, and (3) quality of water control. Each of these functions may be performed in different ways under different administrative organizations.

Water resources planning has been described by the Committee on Water Resources Research of the Federal Council of Science and Technology as ". . . the most promising area of research and . . . the most neglected area in the present federal research program . . . ."[13] The planning function encompasses the institutional structure of the management program itself, and decisions pertaining to the institutional structure involve political as well as economic judgments. According to the Committee on Water Resources Research, research involving the institutional structure ". . . should be directed to understanding existing water laws and institutions and their social, economic and engineering implications. It should endeavor to identify the best features of the current situation with a view to formulating model water laws and institutional frameworks for the future."[14] Another important aspect of water resources planning is the making of investment decisions. There is a critical need for research on improved evaluation techniques. Closely related to investment, in terms of function, are the non-structural alternatives to investment. For example, more efficient use of existing supplies, including the curtailment of waste, may obviate the need for structural investment projects designed to increase supply. Reduction of the amount of waste discharged into municipal sewers and/or rivers, perhaps by a system of charges, may substitute for increased water

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[13] A Ten-Year Program of Federal Water Research, op. cit., p. 9.

[14] Ibid., p. 63.

systems has merits and disadvantages. The system employed need not necessarily be restricted to one or the other of the three methods, but it may entail some combination.

It should be noted in passing that the Federal Walter Pollution Control Act of 1965 (Public Law 89-234) may have some influence on the method actually employed. Public Law 89-234, among other things, requires that each state establish standards of water quality. The law does not specify how such standards are to be financed. If one state adopts the payments system, other states may feel compelled to because of competition for industry. The same consideration applies, although to a smaller degree, to direct regulation as opposed to a system of charges.

As a subtopic in the general area of water management, there is a need for research in the area of municipal pricing for water and sewer service. Such research should examine the various practices used in the state from the point of view of both economic efficiency and conformity with overall objectives of water management.

Water Resources and Industry Location

The importance of water for most industrial processes suggests that water availability and water costs are important determinants in the location of industry. Yet, too little is known about the impact of water on industry location. Since industrial development is a high priority objective in Arkansas, research should be undertaken to ascertain how availability and costs of water influence the location decision of different industries.

Data Requirements

The paucity of water data constitutes one of the major problems in research which focuses on the economics of water management. Data may not pollutants. Present technology is sufficient to provide--on a sampling basis--much more information regarding the content of water than is available. Such information is expensive. It is, however, necessary for pollution control and the maintenance of water quality standards.

Water Use Data

Information pertaining to water use in Arkansas is subject to two major limitations. First, it is highly aggregative. For example, data are available relative to total water use in manufacturing, but not by manufacturing industry. Such information is necessary for projections of water use which are in turn essential to long-range planning. Too, water use data by industry may point up inefficiency in water use and, when combined with production function studies, may suggest significant water saving measures. Second, although water-based recreation is an important and a growing industry in Arkansas, accurate data pertaining to the economic importance of the industry are almost non-existent. Water-based recreation and benefits attached thereto constitute significant by-products of many multiple purpose water projects. Yet, in the absence of relevant data, such benefits cannot be considered in investment decision making.

Cost Data

Information about the amount of external costs involved in different types of waste discharge under varying flow conditions is essential to any of the three water quality control methods discussed above. Yet, existing data are fragmentary. Research on methods of estimating damage costs arising from different types of pollutants as well as the costs of removing pollutants from water courses is urgently needed. In the absence of such data it will be extremely difficult for states to establish water quality standards or for established standards to be judged satisfactory or unsatisfactory.

Precipitation is variable in terms of both frequency and location. A better understanding of this phase of the water cycle may, among other things, lead to more accurate methods of forecasting. The need for improved forecasting techniques for water resources development and management is evident.[18]

The surface and ground water phase of the water cycle is, of course, the phase which constitutes the supply of water available to man. Surface water, including lakes, is an important source of water in Arkansas, and it will almost certainly become more important as the state continues to develop. More information is needed with respect to stream flow variations and the chemical reaction between water and the environment through which it passes. As the importance of surface water increases in Arkansas, the importance of water supplied from lakes--and particularly the man-made reservoirs--may be expected to increase. For this reason it is essential that the limnology of man-made reservoirs in Arkansas be understood.[19] Physical, chemical, meteorological and biological processes may seriously alter the character and usefulness of a lake.

Ground water constitutes the principal source of water in eastern Arkansas for municipal supplies, agriculture, and industry. Research is needed on movements of ground water, rates of recharge of aquifers, and possible pollution from surface sources or from other aquifers. There is too little information available with respect to the location of recharge areas and the effect of surface condition on rates of recharge.

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[18] A Ten-Year Program of Federal Water Research, op. cit., p. 34.

[19] Ibid., p. 39.

needed as to the feasibility of flood plain zoning as a non-structural method of reducing flood losses.

Artificial Recharge

The United States Geological Survey in cooperation with the University of Arkansas and other government agencies has conducted research to determine the feasibility of recharging acquifers by the injection of surface water through wells. It was found that injected water recovered for use would cost about thirty dollars per acre foot and that the major cost factor was water treatment costs prior to injection.[20] It is important that research on artificial recharge be continued for two reasons. First is the importance of ground water to the Arkansas economy. This is attested to by the consideration that almost 60 percent of the water used in 1965--exclusive of flow uses--was pumped from the ground. In some areas of eastern and southern Arkansas uncontrolled withdrawal in excess of natural recharge has threatened to exhaust local underground supplies. Second, underground storage of water has a number of advantages over surface storage. It is not subject to evaporation, and for the most part, it is free from pollution. Too, underground storage does not compete for land use.[21]

Quality of Water

This section is concerned with research needs associated with (1) detection and identification of pollutants; (2) the effects of pollutants on

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[20] See R. T. Sniegocki, F. H. Bayley, Kyle Engler, and J. W. Stephens, Testing Procedures and Results of Studies of Artificial Recharge in the Grand Prairie Region Arkansas, Geological Survey Water-Supply Paper 1615-G (Washington: U. S. Government Printing Office, 1965), p. G 1.

[21] A Ten-Year Program of Federal Water Research, op. cit., p. 51.

Effects of Pollutants on Receiving Waters

Once pollutants have entered into water courses, they affect the quality of water to some (largely unknown) degree in all of its uses. On the one hand, pollution makes necessary the treatment of water prior to municipal use and prior to many industrial and agricultural uses. On the other hand, pollution causes physical damage in cases where treatment is incomplete or nonexistent. The latter is evident in the case of on-site and flow uses. Too little is known about the effect of pollutants, particularly the synthetic organics, on fish and fish food organisms in the variety of stream and lake conditions in Arkansas. Pollution affects the flavor and even the smell of fish. Evidence suggests that a substantial number of fish kills in the state have resulted from agricultural insecticides and herbicides. Too little is known with respect to the effect of water temperature and water temperature changes on fish. This is a problem in Corps of Engineer lakes and where warm water tributaries flow into cold water rivers below lakes. Too little is known about the effects of oxidation pond effluents on the biota of receiving streams, the causes of death of oxidation ponds, and methods of reactivating oxidation ponds. The introduction of coliform into water courses gives rise to a number of problems. Coliform distribution in lakes--i.e., whether they float, sink, remain in lakes, or move out with water currents, is an area where research is needed. Too, more information is needed with respect to the length of life of coliform under varying conditions as well as the possibility of their reproduction. In the Arkansas River, a substantial increase in the coliform count occurred below an inflow of sterile industrial waste. A related problem is the survival of virus through sewage treatment plants. In general, research designed to improve knowledge in the entire area of the effects of pollution damage is urgently needed. Such knowledge concerning physical damage and

Arkansas is ground water, more information with respect to the possibility of polluting fresh water supplies is needed. Also, there is a need for the development of inexpensive pit linings, or sealers, for salt water pits where brine is stored prior to its injection into the ground. The food processing industry is an important industry in Arkansas. A large number of the plants make use of municipal water supplies and sewage facilities. It has been found that organic wastes from food processing plants are not too responsive to conventional sewage treatment techniques. Further study is needed in this area. The importance of water-based recreation to the Arkansas economy was mentioned in a previous section. A large and growing number of boats with sleeping and cooking facilities are causing a pollution problem in lakes. Since these lakes are now a source of municipal water and will probably become a more important source in the future, research on methods of limiting pollution from boats is needed. Also with respect to lakes, research is needed on methods of controlling rough fish and on the development of non-toxic chemicals for the control of aquatic plants.

As in the case of detection and identification of pollutants, the development of new compounds and industrial processes as well as the influx of new industry into the state makes pollution treatment a continuing problem. New problems will replace present problems in the treatment of, for example, rug mill wastes and pulp paper mill wastes. Each industry which uses water as a waste vehicle will continue to have its own particular treatment problems.

Recreation: Lake Fishing

Exclusive of the Great Lakes and Alaska, there are more acres of man-made than of natural lakes in the United States. About 1,200 large man-made reservoirs constitute one-third of the fresh water acreage (including rivers)