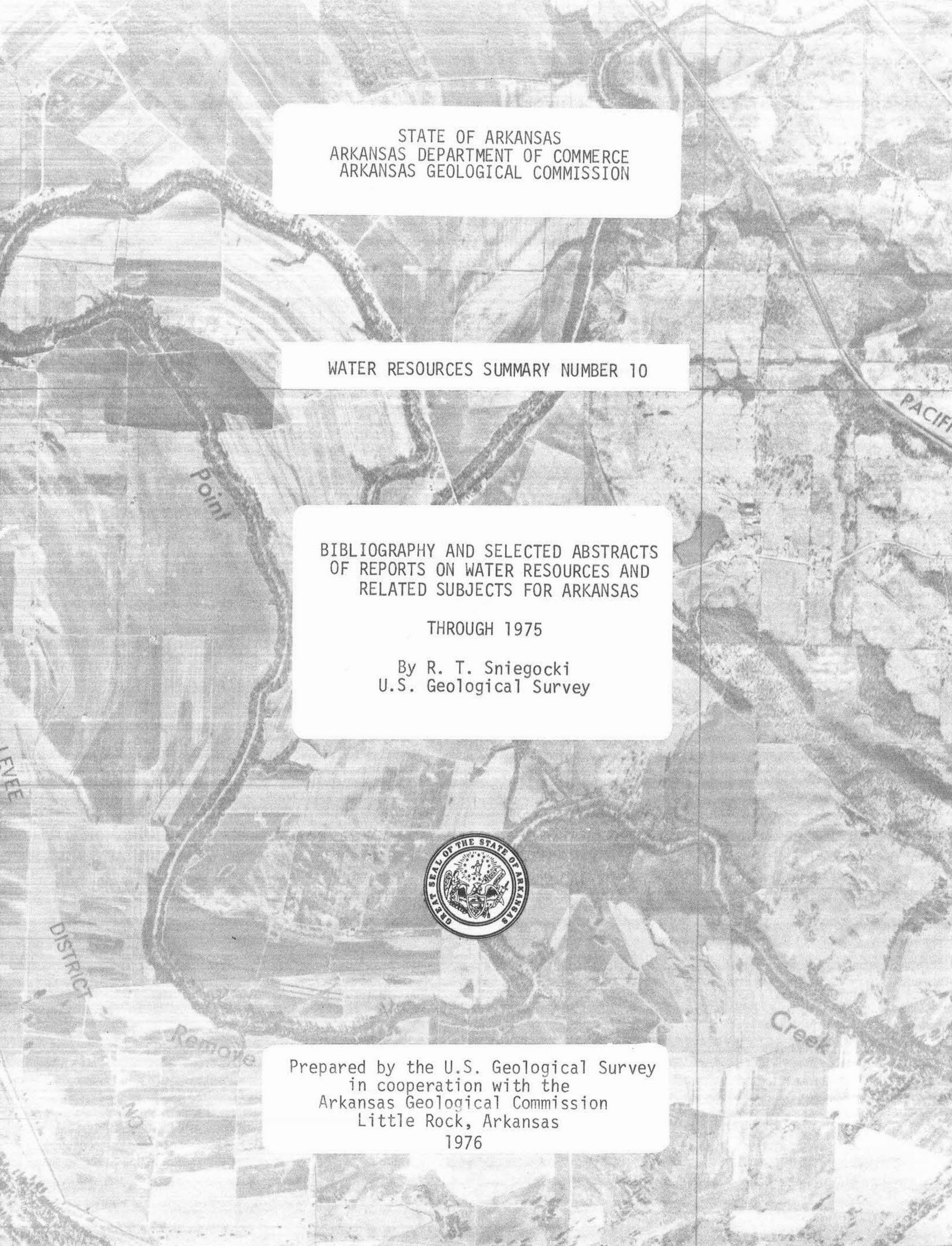

STATE OF ARKANSAS
ARKANSAS DEPARTMENT OF COMMERCE
ARKANSAS GEOLOGICAL COMMISSION

WATER RESOURCES SUMMARY NUMBER 10

BIBLIOGRAPHY AND SELECTED ABSTRACTS OF REPORTS ON WATER RESOURCES AND RELATED SUBJECTS FOR ARKANSAS

THROUGH 1975

By R. T. Sniegocki
U.S. Geological Survey

Prepared by the U.S. Geological Survey
in cooperation with the
Arkansas Geological Commission
Little Rock, Arkansas
1976

STATE OF ARKANSAS

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Norman F. Williams, State Geologist

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BIBLIOGRAPHY AND SELECTED ABSTRACTS OF REPORTS ON WATER RESOURCES AND RELATED SUBJECTS FOR ARKANSAS THROUGH 1975

By R. T. Sniegocki

INTRODUCTION

The reports listed or abstracted in this publication have been placed in broad fields and groups similar to those devised by the Committee on Water Resources Research (CWRR) and as they appear on pages 201 and 202 in the Water Resources Thesaurus, Office of Water Resources Research, November 1966.

Placing the report titles and abstracts in CWRR fields and groups provides an orderly means by which reports can be arranged in this publication as well as any updated compilations that may be prepared. Reference to the CWRR fields and groups will provide a user of this publication a quick, general guide in locating a report of specific interest. A detailed and cross-referenced subject index at the back of this publication used in conjunction with the fields and groups should enable a user to locate those reports containing the specific information desired.

This bibliography does not differentiate between publications purchasable or free from an official source and those out of print and available for examination only from a library or lending source. Inquiry as to availability can be made to:

Arkansas Geological Commission
Vardelle Parham Geology Center
3815 West Roosevelt Road
Little Rock, Arkansas 72204
(501) 371-1646

or the

U.S. Geological Survey
Room 2301 Federal Office Building
Little Rock, Arkansas 72201
(501) 378-5246

Topographic maps may be purchased from the Arkansas Geological Commission.

FIELD 1--NATURE OF WATER

Group 1A--Properties of water

RADIOACTIVITY OF THERMAL WATERS AND ITS RELATIONSHIP TO THE GEOLOGY AND GEOCHEMISTRY OF URANIUM.

For primary bibliographic entry see 2F.

RADIOACTIVITY OF THE SPRING WATER OF HOT SPRINGS NATIONAL PARK AND VICINITY IN ARKANSAS.

For primary bibliographic entry see 2F.

RADIOACTIVITY OF RIVERS AND LAKES IN PARTS OF GARLAND AND HOT SPRING COUNTIES, ARKANSAS.

For primary bibliographic entry see 2F.

THE EQUILIBRIUM BETWEEN RADON AND ITS DECAY PRODUCTS IN THE WATERS OF HOT SPRINGS NATIONAL PARK, HOT SPRINGS, ARKANSAS.

For primary bibliographic entry see 2F.

Group 1B--Aqueous solutions and suspensions

No entries.

FIELD 2--WATER CYCLE

Group 2A--General

CYPRESS BAYOU, GRAND PRARIE REGION, ARKANSAS--AN EXAMPLE OF STREAM ALIENATION.

For primary bibliographic entry see 2E.

A PRIMER ON WATER, U.S. Geological Survey, 1960, by L. B. Leopold and W. B. Langbein.

"Interest in water and related problems is growing as our population increases and the use of water becomes steadily greater.

To help meet this heightened interest in general information about water and its use and control is the reason this primer was written. The primer is in two parts. The first part tells about hydrology, or the science that concerns the relation of water to our earth, and the second part describes the development of water supplies and the use of water. The Geological Survey is publishing this primer in nontechnical language in the hope that it will enable the general reader to understand the facts about water as a part of nature, and that by having this understanding the people can solve their water problems."

A PRIMER ON GROUND WATER, U.S. Geological Survey, by H. L. Baldwin and C. L. McGuinness, 1963.

This popularized report presents, in nontechnical terms, a description of the occurrence, nature, and chemical content of ground water. A map of the United States shows ground-water areas capable of yielding 50 gpm or more to wells. The report is well illustrated with simplified sketches showing how ground water occurs in fractures and pores in the subsurface conditions that create flowing wells. Replenishment of water in the ground through natural and artificial means is briefly covered.

A PRIMER ON WATER QUALITY, U.S. Geological Survey, by H. A. Swenson and H. L. Baldwin, 1965.

This popularized report presents, in nontechnical terms, a description of the structure of water, its unusual properties, and chemical characteristics, and how nature and man affect water quality. A map of the United States shows the hardness range of public water supplies. Nine States have public supplies having a hardness in excess of 180 ppm and nine States have public supplies having a hardness of 60 ppm or less.

WATER FACTS, U.S. Geological Survey Brochure, September 10, 1964.

This brochure was prepared by the U.S. Geological Survey in cooperation with the Arkansas Geological Commission for use at a water-resources information conference held in Little Rock, Ark., September 10, 1964. The brochure shows the locations of 73 sites where streamflow was being measured, 10 sites where water-quality data were being collected, and the locations of 205 sites where water levels were measured. The brochure also indicates that water facts are essential to the optimum development and management of Arkansas' water resources and a 10-point program to collect these facts is suggested.

ARKY AQUIFER SAYS, Arkansas Gazette, May 1, 1960, through December 25, 1960, by R. L. Hosman.

A series of cartoons titled "Arky Aquifer Says," prepared by R. L. Hosman of the U.S. Geological Survey in cooperation with the Arkansas Geological and Conservation Commission, was published in the Arkansas Gazette. The cartoons appeared, one each week, in the magazine section of the Sunday edition, beginning May 1, 1960, and ending December 25, 1960. Each of the 35 cartoons, popularized for the lay reader, covers a basic water fact or principle. As an example, "Arky" in one cartoon is pumping water over his head on a hot sunny day and states that shallow ground water in Arkansas is roughly 65°F the year round, making it seem cool in summer and warm in winter.

ARKY'S AQUAFACTS, Arkansas Geological Commission pamphlet, 1964, reprinted 1967, by R. L. Hosman.

The series of cartoons depicting water facts or principles that were published in the Arkansas Gazette in 1960 proved to be popular with the public and in response to demand were published as a pamphlet in 1964 and reprinted in 1967 and 1975.

Group 2B--Precipitation

NATIONAL WEATHER SERVICE RIVER FORECAST SYSTEM FORECAST PROCEDURES, National Oceanic and Atmospheric Administration, National Weather Service, NOAA Technical Memorandum NWS Hydro-14, December 1972, by Staff, Hydrologic Research Laboratory.

DROUGHTS IN ARKANSAS, Weather Bureau Monthly Weather Review, Volume 61, May 1933, by H. S. Cole.

CLIMATIC SUMMARIES OF RESORT AREAS: HOT SPRINGS NATIONAL PARK, ARKANSAS, U.S. Department of Commerce, Weather Bureau Climatography of the United States, Number 21-3-1, May 1966, by R. O. Rheinhold.

CLIMATES OF THE STATES--ARKANSAS, U.S. Department of Commerce, Weather Bureau, April 1959.

Group 2C--Snow, ice, and frost

No entries.

Group 2D--Evaporation and transpiration

EVAPORATION MAPS FOR THE UNITED STATES, U.S. Department of Commerce, Weather Bureau, Hydrologic Services Division, Technical Paper 37, 1959, by M. A. Kohler, T. J. Nordenson, and D. R. Baker.

Group 2E--Streamflow and runoff

FOREST SPECIES AS INDICATORS OF FLOODING IN THE LOWER WHITE RIVER VALLEY, ARKANSAS.

For primary bibliographic entry see 2I.

STREAM COMPOSITION OF THE COTERMINOUS UNITED STATES.

For primary bibliographic entry see 5A.

TEMPERATURE OF SURFACE WATERS IN THE COTERMINOUS UNITED STATES.

For primary bibliographic entry see 5A.

RECONNAISSANCE OF SELECTED MINOR ELEMENTS IN SURFACE WATERS OF THE UNITED STATES.

For primary bibliographic entry see 5A.

PREIMPOUNDMENT WATER QUALITY SURVEY OF THE CADDO RIVER, ARKANSAS.

For primary bibliographic entry see 5A.

INTERIM REPORT ON WATER QUALITY INVESTIGATION, DEGRAY RESERVOIR, ARKANSAS.

For primary bibliographic entry see 5A.

HARDNESS OF GROUND WATERS IN ARKANSAS.

For primary bibliographic entry see 5A.

PRELIMINARY RECONNAISSANCE, WATER QUALITY SURVEY OF THE BUFFALO NATIONAL RIVER.

For primary bibliographic entry see 5A.

MISSISSIPPI RIVER WATER QUALITY.

For primary bibliographic entry see 5A.

WATER-QUALITY MODELING FOR WASTE-LOAD ALLOCATION STUDIES IN ARKANSAS--STREAM DISSOLVED OXYGEN AND CONSERVATIVE MINERALS.

For primary bibliographic entry see 5G.

FLOW DURATION CURVES.

For primary bibliographic entry see 7B.

SURFACE WATER SUPPLY OF THE UNITED STATES, 1961-65, PART 7. LOWER MISSISSIPPI RIVER BASIN, VOLUME 1. LOWER MISSISSIPPI RIVER BASIN EXCEPT ARKANSAS RIVER BASIN.

For primary bibliographic entry see 7C.

SURFACE WATER SUPPLY OF THE UNITED STATES, 1961-65. PART 7. LOWER MISSISSIPPI RIVER BASIN, VOLUME 2. ARKANSAS RIVER BASIN.

For primary bibliographic entry see 7C.

COMPILATION OF RECORDS OF SURFACE WATERS OF THE UNITED STATES. OCTOBER 1950 TO SEPTEMBER 1960, PART 7. LOWER MISSISSIPPI RIVER BASIN.

For primary bibliographic entry see 7C.

COMPILATION OF RECORDS OF SURFACE WATERS OF THE UNITED STATES THROUGH SEPTEMBER 1950, PART 7. LOWER MISSISSIPPI RIVER BASIN.

For primary bibliographic entry see 7C.

STREAM-GAGING STATIONS AND PUBLICATIONS RELATING TO WATER RESOURCES.

For primary bibliographic entry see 7C.

MAXIMUM DISCHARGES AT STREAM-MEASUREMENT STATIONS, THROUGH DECEMBER 31, 1937, WITH A SUPPLEMENT INCLUDING ADDITIONS AND CHANGES THROUGH SEPTEMBER 30, 1938.

For primary bibliographic entry see 7C.

SURFACE WATER RECORDS OF ARKANSAS, 1961.

For primary bibliographic entry see 7C.

SURFACE WATER SUPPLY OF THE UNITED STATES, 1960, PART 7. LOWER MISSISSIPPI RIVER BASIN.

For primary bibliographic entry see 7C.

ARKANSAS STREAM GAGING REPORT 2, 1929 and 1930.

For primary bibliographic entry see 7C.

STAGES OF THE MISSISSIPPI RIVER AND TRIBUTARIES IN THE MEMPHIS DISTRICT.

For primary bibliographic entry see 7C.

STAGES AND DISCHARGES OF THE MISSISSIPPI RIVER AND TRIBUTARIES IN THE MEMPHIS DISTRICT.

For primary bibliographic entry see 7C.

STAGES AND DISCHARGES OF THE MISSISSIPPI RIVER AND TRIBUTARIES IN THE VICKSBURG DISTRICT.

For primary bibliographic entry see 7C.

RIVER STAGES IN ARKANSAS.

For primary bibliographic entry see 7C.

SURFACE-WATER RESOURCES OF ARKANSAS.

For primary bibliographic entry see 7C.

ARKANSAS STREAM GAGING REPORT II, STREAM GAGING IN ARKANSAS FROM 1929 TO 1930.

For primary bibliographic entry see 7C.

INDEX OF SURFACE-WATER RECORDS TO SEPTEMBER 30, 1955, PART 7, LOWER MISSISSIPPI RIVER BASIN.

For primary bibliographic entry see 7C.

QUALITY OF SURFACE WATERS OF THE UNITED STATES.

For primary bibliographic entry see 7C.

WATER QUALITY RECORDS IN ARKANSAS, 1964

For primary bibliographic entry see 7C.

CHEMICAL COMPOSITION OF ARKANSAS SURFACE WATERS, 1949.

For primary bibliographic entry see 7C.

SUMMARY OF ANNUAL RECORDS OF CHEMICAL QUALITY OF WATER OF THE ARKANSAS RIVER IN OKLAHOMA AND ARKANSAS, 1945-52.

For primary bibliographic entry see 7C.

CHEMICAL QUALITY OF SURFACE WATERS OF ARKANSAS, 1945-55--A SUMMARY.

For primary bibliographic entry see 7C.

CHEMICAL COMPOSITION OF ARKANSAS SURFACE WATERS, 1950.

For primary bibliographic entry see 7C.

A STUDY OF THE CHEMICAL QUALITY OF STREAMFLOW IN ARKANSAS.

For primary bibliographic entry see 7C.

WATER QUALITY STUDIES FOR ARKANSAS STREAMS.

For primary bibliographic entry see 7C.

FLOODS IN ARKANSAS, MAGNITUDE AND FREQUENCY, U.S. Geological Survey open-file report, 1961, by J. L. Patterson.

This report presents methods by which the magnitude and frequency of expected floods for most streams in Arkansas may be determined. Composite frequency curves show the relation of the mean annual flood to floods having recurrence intervals of 1.2 to 50 years. Other curves express the relation of the mean annual flood to drainage basin characteristics. For the northern part of the State, the slope of the composite and frequency curve varies with drainage-area size.

By combining data from the composite and mean annual flood curves, a flood-frequency curve may be drawn for any stream in Arkansas, not materially affected by work of man, within the limits of drainage area and recurrence interval defined by base data.

FLOODS IN ARKANSAS, MAGNITUDE AND FREQUENCY CHARACTERISTICS THROUGH 1968, Arkansas Geological Commission Water Resources Circular Number 11, 1971, by J. L. Patterson.

"Techniques are presented for estimating the magnitude and frequency of floods on Arkansas streams. Modern topographic maps now available and computer techniques facilitate in making a comprehensive analysis in which physical and climatic characteristics of river basins are related to flood characteristics at gaging stations. Equations derived from the analysis make it possible to estimate the magnitude of future floods with recurrence intervals of as much as 50 years on gaged and ungaged streams that have drainage areas of 0.1-3,000 square miles. An estimate of the future flood potential can be used to locate and design flood-control structures, establish flood-insurance rates, and devise flood-zoning plans.

"Appendixes in the report contain data on flood characteristics of gaged drainage basins, a summary of climatic and topographic characteristics of drainage basins, peak stages, and discharges for gaging stations that have 5 or more years of record, and peak-flow data for outstanding floods at miscellaneous sites."

MAGNITUDE AND FREQUENCY OF FLOODS IN THE UNITED STATES, PART 7. LOWER MISSISSIPPI RIVER BASIN, U.S. Geological Survey Water-Supply Paper 1681, 1964, by J. L. Patterson.

"This report describes methods by which the magnitude and frequency of expected floods for most streams in the lower Mississippi River basin may be determined. Flood data were used to define flood-frequency curves applicable to the area. Composite frequency curves were drawn showing the relation of mean annual floods to floods having recurrence intervals from 1.2 to 50 years. In some areas, it was found that the slope of the composite frequency curve varies with drainage area. An adjustment curve was defined for use in conjunction with the composite curve for these areas. Other curves express relation of the mean annual flood to drainage-basin characteristics. By combining data from the composite and mean-annual flood curves, flood-frequency curves may be drawn for streams in the lower Mississippi River basin not materially affected by the works of man. Neither of the two types of curves just mentioned should be extrapolated beyond the range defined by base data. Frequency curves, described in this report, were based on analyses of flood records collected at gaging stations having 5 or more years of record not materially affected by regulation or diversion."

The St. Francis, White, Arkansas, and Red River basins in Arkansas are included in the report.

FLOOD OF JULY 16-17, 1963, IN VICINITY OF HOT SPRINGS, ARKANSAS, U.S. Geological Survey open-file report, 1964, by R. C. Gilstrap and R. C. Christensen.

On July 16, 1963, the city of Hot Springs had severe flooding which, from all reports, was exceeded only by a flood that occurred in May 1923. The storm which caused the flooding was centered in the vicinity of Hot Springs and covered an area including most of Garland County and parts of Hot Spring and Saline Counties. The towns of Owensville, Jessieville, Pleasant Hill, and Malvern were on the outer fringe of the storm area. Flood damage within the storm area exceeded $2 million.

The most intense precipitation was during the early morning of July 16, 1963. At the recording precipitation station at Blakely Mountain Dam, 6.1 inches of rain fell in the 1½-hour period from 5:45 a.m. to 7:15 a.m. A peak discharge of 53,800 cfs at a gage height of 21.03 feet was recorded at a gaging station on the Ouachita River near Malvern.

FLOODS OF MAY 1968 IN SOUTH ARKANSAS, U.S. Geological Survey Water-Supply Paper 1970-A, 1972, by R. C. Gilstrap.

"The floods of May 1968 in south Arkansas produced the greatest peak discharges in the history of recorded streamflow at several gaging stations. Most notable of these floods was on Cossatot River near DeQueen, which has a continuous record since 1938. The peak discharge of 122,000 cubic feet per second was almost twice the previous maximum discharge of 62,000 cubic feet per second in 1961. At Lake Greeson near Murfreesboro, water flowed over the spillway for the first time since construction of the dam in 1949. The lake reached an elevation of 564.60 feet, which is 1.60 feet above the spillway crest. The previous maximum stage of 557.84 feet occurred in 1953. No lives were lost as a result of the flood, but property damage amounted to about $18 million.

"Heavy rains began on May 7 and continued to May 18. The periods of heaviest rainfall were May 9-10, 13, and 16-17. The maximum 24-hour rainfall recorded was 10.1 inches at Gillham Dam near DeQueen on May 13."

FLOODS OF DECEMBER 1971 IN WESTERN ARKANSAS, Arkansas Geological Commission Water Resources Summary Number 8, 1973, by R. C. Gilstrap.

"Heavy rains of December 1971 in western Arkansas caused record-breaking floods on many streams. Heavy rains began on December 8 and continued to December 10. The heaviest rain fell from the afternoon of December 9 to the early morning of December 10. Maximum accumulated rainfall for the 40-hour period exceeded 13 inches at Vandervoort.

"Most notable of the floods was on the Ouachita River near Mount Ida, where there is a continuous record since 1941. The peak stage of 38.62 feet was 6.44 feet higher than the previous known maximum, which occurred in 1960, and the corresponding discharge of 95,500 cubic feet per second was 67 percent greater than the previous known maximum. Lake Ouachita near Hot Springs and Nimrod Lake near Nimrod had the maximum computed peak inflows of 160,000 cubic feet per second and 80,000 cubic feet per second, respectively, for periods of record. No lives were lost as a result of the floods, but property damage was about $2,780,000."

ARKANSAS-LOUISIANA FLOODS, MAY-JUNE 1968, AFTER-ACTION REPORT, U.S. Army Engineer District, Vicksburg Corps of Engineers, September 1968.

"Hail of major proportion fell on three successive evenings on 26, 27, and 28 April in the southern half of Arkansas. Golfball and tennis-ball size hail were common. The hailstorm was followed by severe weather of one variety or another in this same area during the month of May. A period of record breaking heavy rains began on 8 May and continued through 14 May, producing spectacular totals for the month with over 20 inches in the mountain headwaters of the Caddo and Little Missouri Rivers. This storm period was climaxed by extremely heavy rainfall of up to 10 inches on 13-14 May. Record stages were observed on the Caddo and Saline Rivers and on Big Bayou Meto. Near-record stages were observed on the main stem of the Ouachita River near Malvern and at Arkadelphia, Ark. Extensive flooding occurred in parts of 22 counties in Arkansas and three parishes in Louisiana; an excess of one million acres of land was inundated from the rains. Major damages were reported to agricultural crops, agricultural noncrops, roads and bridges, municipalities, public utilities, commercial property and residential areas. Damage estimates contained in the report are limited to those counties within the Ouachita River basin headwater and the Bayou Meto basin and are in excess of 25 million dollars."

FLOODS OF APRIL-MAY 1958, IN LOUISIANA AND ADJACENT STATES, U.S. Geological Survey Water-Supply Paper 1660-A, 1964, by R. P. Smith.

"Heavy rains started on April 24 or 25, continued intermittently through May 3 or 4, and fell on an area 50 miles wide extending from Mt. Pleasant, Tex., eastward to the Mississippi River. The two periods of heaviest rainfall were April 24-26 and April 28-May 1; the maximum 24-hour rainfall recorded was 10.65 inches at El Dorado, Ark., on April 26.

"Many streams reached the maximum discharge for the period of record. The stage or discharge, or both, exceeded the previous maxima at 39 stream-gaging stations. Cornie Bayou and Three Creek near Three Creeks, Ark., reached the highest stage since at least 1880. Boggy Creek near Daingerfield, Tex., reached the highest stage since 1900. Because the second storm period followed the first so closely, many streams had only a single flood peak.

"Three lives were lost in Louisiana. Damage amounted to about $25 million, mostly to crops and agricultural land.

"Flood-frequency studies indicate that at 19 locations the peak discharge during the floods of April-May 1958 had a recurrence interval well in excess of 50 years (2 percent probability of occurring in any one year). The peak discharge of Chemin a Haut Bayou near Beekman, La., was 7.6 times the discharge for a 50-year flood and 12.4 times the discharge of the mean annual flood.

"The present report supplies hydrologic data needed for detailed planning of projects in which studies of flood volumes and discharge rates are essential information; detailed streamflow records at 112 sites; crest stages along the lower Red River, the Ouachita River, and at several other locations; and flood-frequency relationships in parts of the flood area. The area covered in the report includes southern Arkansas, northern Louisiana, southeastern Oklahoma, northeastern Texas, and west-central Mississippi."

FLOODS OF APRIL-JUNE 1957, IN TEXAS AND ADJACENT STATES, U.S. Geological Survey Water-Supply Paper 1652-B, 1963, by I. D. Yost.

"The year 1957 in the Southwest was characterized by rainfall that produced a tremendous volume of flood runoff and brought an abrupt end to the severe drought, which had prevailed for several years.

"The floods of April-June 1957 in Texas and on tributaries to the Red River in Oklahoma and Louisiana were outstanding because of the large extent of the floods and the large volume of runoff produced. All streams in the area, from the Red River to the Rio Grande, were in flood much of the time during this 3-month period. Excluding the Red River and the Rio Grande and considering only the interior streams in Texas, 38 million acre-feet of runoff, adjusted for storage in major reservoirs, was produced over the State during this 3-month period.

"Peak discharges that exceeded previously known maximums occurred on only a few streams. An outstanding peak flow (45,000 cfs), the maximum since at least 1880, occurred on May 26 on Palo Pinto Creek, a tributary to the Brazos River near Santo, Tex. The stage of May 12 on Sulphur Creek at a site about 3 miles downstream from Lampasas, Tex., was only 1.5 feet lower than that of the flood of 1873. Maximum discharge of record occurred on the Salt Fork Red River and the Washita River, tributaries to the Red River in Oklahoma.

"This report has been prepared to furnish hydrologic data for detailed planning. Included are general descriptions of the floods, information concerning rainfall, and detailed streamflow records at selected gaging stations throughout areas in

Arkansas, Oklahoma, Louisiana, and Texas--from the Red River to the Rio Grande."

Mean discharges in cubic feet per second are given for the Red River at Index, Ark., and the Red River at Fulton, Ark.

FLOODFLOW CHARACTERISTICS OF ARKANSAS RIVER AT INTERSTATE HIGHWAY 540 AT VAN BUREN, ARKANSAS, U.S. Geological Survey open-file report, 1965, by R. C. Christensen and R. C. Gilstrap.

"1. The flood potential is being greatly reduced by flood-control storage in upstream reservoirs.

"2. The maximum discharge known since at least 1833 occurred on May 12, 1943, (peak discharge, 850,000 cfs) and reached an elevation of 410.36 feet at the Van Buren gage, or about 409.7 feet in the unrestricted channel at the proposed highway crossing. Under present channel conditions, a flood of equal magnitude would reach an elevation of at least 412.9 feet on the downstream side of the proposed road embankment. The constriction of flow caused by the embankment and bridges would increase the elevation of the water surface at the point of division of flow between the bridge openings at least 414.4 feet.

"3. The maximum stage known since at least 1833 occurred on April 16, 1945, with a peak elevation of 410.46 feet at the Van Buren gage, or about 409.8 feet in the unconstricted channel at the site.

"4. For flows regulated by reservoirs, the 50-year discharge (that which may be expected to be equaled or exceeded on the average of once in 50 years) is 500,000 cfs and would reach an elevation of at least 404.9 feet at the downstream side of the proposed road embankment. The constriction of flow caused by the embankment and bridges would increase the elevation of the water surface at the point of division of flow between the bridge openings to at least 406.2 feet.

"5. The distribution of the 50-year flood (500,000 cfs at 404.9 feet) in the approach channel and through the proposed bridge openings is shown in figure 4. The main-channel opening will discharge 480,000 cfs with a mean velocity of 7.5 feet per second, and the relief opening will discharge 20,000 cfs with a mean velocity of 4.1 feet per second. The division of flow will occur at station 511+20. When the same discharge occurs at higher elevations, the division of flow will occur about midway between the proposed bridge openings.

"6. The distribution of a discharge equal to that of the 1943 flood (850,000 cfs at 412.9 feet) in the approach section and through the proposed bridge openings is shown in figure 5. The main-channel opening will discharge 778,000 cfs with a mean velocity of 9.2 feet per second, and the relief opening will discharge 72,000 cfs with a mean velocity of 5.9 feet per second. The flow will divide near the relief opening at about station 504+00.

"7. The maximum elevation of the water surface upstream from the proposed constriction for the 50-year flood and the 1943 flood will be about 409.2 and 417.4 feet, respectively.

FLOODFLOW CHARACTERISTICS OF LITTLE CREEK AT STATE HIGHWAY 286, NEAR CONWAY, ARKANSAS, U.S. Geological Survey open-file report, May 1972, by J. L. Patterson and J. N. Sullavan.

The 50-year flood of Little Creek at State Highway 286 near Conway is 3,000 cubic feet per second. If the roadway height was raised four feet near the bridge over Little Creek, 1.5 feet of backwater on the upstream side of the bridge could be expected from a 50-year flood. If the roadway was not raised, backwater would be insignificant and 1,900 cubic feet per second would pass through the bridge and 1,100 cubic feet per second would flow over the bridge and roadway.

FLOODFLOW CHARACTERISTICS OF CADDO RIVER AT U.S. HIGHWAY 67 AND INTERSTATE HIGHWAY 30 AT CADDO VALLEY, ARKANSAS, U.S. Geological Survey open-file report, 1965, by L. D. Hauth and R. C. Christensen.

The 50-year flood for the Caddo River at U.S. Highway 67 crossing is 73,000 cubic feet per second.

Maximum floods on record at the gaging station on the Caddo River near Arkadelphia, Ark. occurred in 1927 (elevation, 207.4 feet) and on March 30, 1945, (elevation, 206.1 feet), with discharges unknown.

WATER-SUPPLY CHARACTERISTICS OF SELECTED ARKANSAS STREAMS, Arkansas Geological Commission Water Resources Circular No. 9, 1965, by M. S. Hines.

Water-supply characteristics of streams are determined by their low-flow frequency and flow duration. In Arkansas, the frequency of low flows and the duration of daily flows have been determined from records at 65 gaging stations and 97 partial-record sites. The analyses show that tributary streams in the northeastern part of the Coastal Plain, in the Springfield-Salem Plateau, in the Novaculite Uplift, and in the Athens-Piedmont Plateau have dependable water supplies, and that streams in the central and southern part of the Coastal Plain, the Boston Mountains, in the Arkansas Valley, and in the Fourche Mountains do not have dependable supplies. However, larger streams, such as the White, Black, Saline, and Ouachita Rivers, have dependable water supplies along their courses in Arkansas.

LOW-FLOW CHARACTERISTICS OF STREAMS IN THE MISSISSIPPI EMBAYMENT IN NORTHERN ARKANSAS AND IN MISSOURI, U.S. Geological Survey Professional Paper 448-F, 1966, by P. R. Speer, M. S. Hines, M. E. Janson, and others, *with a section on* Quality of the Water, by H. G. Jeffery.

"Limited low-flow data, in cubic feet per second per square mile, for 23 daily-record gaging stations and 37 partial-record stations are summarized for ready comparison. The summary gives the minimum average 7-day and 30-day discharges that may be expected to recur at 2- and 10-year intervals and the flow at the 90- and 95-percent duration points. More detailed data on the magnitude and frequency of low flows and flow duration, in cubic feet per second, are given for the 23 daily-record gaging stations.

"The 7-day low flows at the 2-year recurrence interval expressed on a per-square-mile basis, are used to demonstrate areal variations of low flow in this area. These indices range from 0 to 0.49 cubic foot per second per square mile.

"Drafts that may be made from specified amounts of storage with a chance of deficiency once in 10 and 20 years on a long-term average are related to the median annual 7-day low flow to permit preliminary estimates to be made of the storage required to supplement natural low flows.

"Chemical analyses of surface-water samples collected at 12 sites during low-flow periods show the dissolved solids to range from 90 to 333 ppm (parts per million); the hardness to range from 57 to 275 ppm; and the iron content to range from 0.00 to 0.08 ppm. The surface waters in the study area generally are suitable for some uses with little or no treatment, but for municipal and industrial supplies, the waters would require softening, coagulation, filtration, and pH adjustment for corrosion control."

LOW-FLOW CHARACTERISTICS OF STREAMS IN THE MISSISSIPPI EMBAYMENT IN SOUTHERN ARKANSAS, NORTHERN LOUISIANA, AND NORTHEASTERN TEXAS, U.S. Geological Survey Professional Paper 448-G, 1966, by P. R. Speer, M. S. Hines, A. J. Calandro, and others, *with a section on* Quality of the Water by H. G. Jeffery.

The 7-day low flows at the 2-year recurrence interval, expressed on a per-square-mile basis in this report are used to demonstrate area variations of low flow in the study area. These low-flow indices range from 0 to 0.20 cfs per square mile.

Streams in the Paleozoic rocks that are incised to sufficient depth to intercept the ground water have high low-flow indices. As these streams enter the embayment, they cross outcrops of Cretaceous, Tertiary, and Quaternary deposits. In this belt just inside the boundary of the embayment, many of the streams experience decreases in low-flow yield. The low-flow indices for streams that derive their base flow from the Quaternary deposits are generally low, but the deposits are an important contributor to the base flow of streams because of exposure over a large area.

Low-flow data for 50 daily-record gaging stations and 106 partial-record gaging stations are summarized in the report. The summary gives the minimum average 7- and 30-day discharges that may be expected to recur at 2- and 10-year intervals and gives the flow at the 90- and 95-percent duration points.

Chemical analyses of surface water from 36 sites during low-flow periods show that dissolved solids range from 12 to 12,900 ppm, hardness ranges from 6 to 1,010 ppm, and the iron content ranges from 0.00 to 1.2 ppm. The surface water in the area generally is suitable for nearly all purposes without extensive treatment.

STORAGE REQUIREMENTS FOR ARKANSAS STREAMS, U.S. Geological Survey Water-Supply Paper 1859-G, 1968, by J. L. Patterson.

"The supply of good-quality surface water in Arkansas is abundant. Owing to seasonal and annual variability of streamflow, however, storage must be provided to insure dependable year-round supplies in most of the State. Storage requirements for draft rates that are as much as 60 percent of the mean annual flow at 49 continuous-record gaging stations can be obtained from tabular data in this report. Through regional analyses of streamflow data, the State was divided into three regions. Draft-storage diagrams for each region provide a means of estimating storage requirements for sites on streams where data are scant, provided the drainage area, the mean annual flow, and the low-flow index are known." (See Water Resources Circular No. 10, same title, following.)

STORAGE REQUIREMENTS FOR ARKANSAS, Arkansas Geological Commission Water Resources Circular No. 10, 1967, by J. L. Patterson.

There is an abundant supply of good-quality surface water in Arkansas. However, due to seasonal and annual variability of streamflow, storage must be provided to insure dependable year-round supplies. In most of the State, storage requirements for draft rates up to 60 percent of the mean annual flow at 49 continuous-record gaging stations can be obtained from tabular data in this report.

Through regional analyses of streamflow data, the State has been divided into three regions. Draft-storage diagrams developed for each region provide a means of estimating storage requirements for sites on streams where data are limited, provided the drainage area, the mean annual flow, and the low-flow index are determined. These data are tabulated for 53 gaging stations used in the analysis and for 132 partial-record sites where only base-flow measurements have been made. Mean annual flow can be determined for any stream whose drainage lies within the State by using the runoff map in this report. Low-flow indices can be estimated by correlating base flows determined from several discharge measurements with concurrent flows at nearby continuous record-gaging stations whose low-flow indices have been determined. (See Water-Supply Paper 1859-G, same title.)

THE ARKANSAS RIVER FLOOD OF JUNE 3-5, 1921, U.S. Geological Survey Bulletin 487, 1922, by Robert Follansbee and E. E. Jones.

WATER IN ARKANSAS, A REPORT ON THE SURFACE WATER RESOURCES IN ARKANSAS, Prepared at the direction of the General Assembly of Arkansas by the Arkansas Water Study Commission, November 1956.

Act 250 of the 1955 General Assembly provided for the appointment of a commission to conduct a study of the proper use and management of surface-water resources of the State and to report its findings and recommendations to the next session of the General Assembly. The Commission was composed of 11 men, 2 appointed by the President of the Senate, 2 by the Speaker of the House, and 7 by the Governor. This report contains the results of the Commission's findings.

A county inventory was made to determine water problems and although, as stated, the list is not complete, it does indicate trends and areas where the most water problems occur. More than 25 different types of water problems were reported and these were categorized into a table by county under four major headings--diffused surface water, streams and lakes, ground water, and miscellaneous. More than three-fourths of the problems listed related to surface water and generally to excessive amounts. Well interference was by far the principal ground-water problem listed.

The report presents a general picture of the State's water resources as background information and the Commission concluded that Arkansas' existing (1956) water laws are not adequate to meet the problems and needs. The Commission also concluded that because surface and ground water are intimately related that legislation in regard to one will affect the other. Eleven recommendations are made at the end of the report principally directed toward establishing a beneficial utilization, management, and conservation State water policy.

PROFILES OF RIVERS IN THE UNITED STATES, U.S. Geological Survey Water-Supply Paper 44, 1901, by Henry Gannett.

The profiles of rivers given in this report show the distance between points, the height at each point, and the fall per mile between points on the rivers considered. Rivers covered in the report that pertain to Arkansas are the Mississippi, Red, Ouachita, Arkansas, White, and St. Francis Rivers. Each river is covered by a brief description of its headwaters, source of profile information, and general information on length and drainage area. As an example of the coverage to be expected, the Ouachita River is shown to be 545 miles long, is 1,750 feet above sea level at the head, is 60 feet above sea level at the mouth, and has a range of fall per mile of from 0.1 foot to 68.2 feet.

ANNUAL RUNOFF IN THE COTERMINOUS UNITED STATES, U.S. Geological Survey Hydrologic Investigations Atlas HA-212, 1966, by M. W. Busby.

Three maps of the United States are used to display average annual runoff, distribution of runoff, and variation in annual runoff. The runoff in Arkansas is shown to range from 15 to 25 inches and is highest in the Ouachita and Ozark Mountains. The average annual runoff for the entire State is listed at 17.7 inches. Variation in runoff has been categorized as low, medium, and high, and Arkansas falls in the medium category.

QUANTITATIVE ANALYSIS OF STREAM FLOW RATE EXTREMES, University of Arkansas, Water Resources Research Center Publication, Number 1, 1967, by H. M. Jeffus.

"Several statistical distributions have been examined for possible application to stream discharge data in Arkansas. The statistical distribution most applicable to stream discharge data in Arkansas is the Pearson type III skew frequency distribution. The log normal distribution fits the lower discharge rates, but cannot be used where zero discharge is likely to occur.

"The mean daily discharge rate is approximately one cubic foot per second per square mile. The minimum discharge rates are independent of the size of the drainage area. There is no correlation between coefficient of variation and area for minimum daily discharge.

"No correlation exists between skewness and area.

"Examples of the application of the parameters of the Pearson type III distribution to pollution control, flood forecasting and water supply are set forth.

STREAM FLOW QUANTITY AND QUALITY CORRELATIONS AND STATISTICAL ANALYSES, University of Arkansas, Engineering Experiment Station, June 1963, by J. D. Ward.

This report provides a means whereby large and often unwieldy collections of streamflow and stream water-quality data can be greatly condensed and yet be meaningful and useful.

In Arkansas, the average annual stream temperature is about 63.5°F with fluctuations of about 17.9°F on either side of this value. Stream-water quality in Arkansas improves with stream increases in discharge as far as dissolved constituents are concerned. Specific conductance tends to vary only a small amount with change in stream discharge but increases as the total dissolved-solids concentration increases. A lake or reservoir apparently causes a slight increase in total dissolved-solids concentration of the water. It seems that in most streams, a reasonably good idea of the water quality can be determined from specific conductance alone. In some streams, the actual stream discharge may also be determined from the specific conductance. The chemical characteristics of a lake or reservoir will depend not only on the depth from which the water is obtained but also on the time of year. A longer term stream record is more desirable than a short one. However, a short record can reasonably well reflect the properties of the stream.

Although about 382,000 recorded items of data have been reduced to about 3,000 calculated items of data, the actual information about a given stream has been greatly increased. Illustrative examples of how the condensation was accomplished are given in the first section of the report. Sections II through V list the data for the stream stations investigated. Section VI discusses immediate results of the investigation. A bibliography; appendix I, a glossary of symbols and terms; and appendix II, temperature equations; and appendix III, regression and correlation programs, conclude the report.

CYPRESS BAYOU, GRAND PRAIRIE REGION, ARKANSAS--AN EXAMPLE OF STREAM ALIENATION, U.S. Geological Survey Professional Paper 600-B, 1968, by M. S. Bedinger.

This report appears in Professional Paper 600-B (p. B148-B-150) along with several others that describe results and findings of current (1968) Geological Survey studies. The abstract of the paper on stream alienation, repeated here, fully highlights the paper.

"Stream drainage in the Grand Prairie region of Arkansas is predominantly toward the southeast, following the regional topographic slope. However, Cypress Bayou flows northward in the White River basin from a point near the Arkansas River, even though the valley of the bayou is open at its south end. The drainage divide between the Cypress Bayou basin and the Arkansas River basin is the summit of the natural levee of the Arkansas River. It is reasoned that the ancestral Cypress Bayou flowed southward into the Arkansas River, but that alluviation by the river blocked the mouth of the bayou, reversed the slope of the valley of the bayou, and forced the bayou to seek an outlet to the north over a low divide and into the White River basin. Thus, the mode of the drainage-pattern change was the antithesis of stream piracy or capture and is herein referred to as stream alienation."

Following is a list of flood-prone area maps available from the Arkansas Geological Commission or the U.S. Geological Survey in Little Rock, Ark. Each of these topographic maps shows areas subject to flooding by a flood that has a 1 in 100 chance on the average of occurring in any year. The number beside each map name indicates the map size in latitude and longitude. The 7.5-minute maps cover from 49 to 70 square miles, are 22 by 27 inches, and are at a scale of 1:24,000, which means that 1 inch represents 2,000 feet. The 15-minute maps cover from 197 to 282 square miles, are 29½ by 32½ inches, and are at a scale of 1:62,500, which means that 1 inch represents nearly 1 mile.

Alexander 7.5'
Alicia 15'
Alma 7.5'
Amagon 7.5'
Arkadelphia 7.5'
Ashdown East 7.5'
Ashdown West 7.5'
Atkins 7.5'
Augusta 15'
Auvergne 7.5'
Barling 7.5'
Batesville 7.5'
Beebe 7.5
Benton 7.5'
Bentonville North 7.5'
Bentonville South 7.5'
Big Flat 7.5'
Blytheville 15'
Booneville 15'
Boxley 7.5'
Bryant 7.5'
Buckner 7.5'
Buffalo City 7.5'
Cades 7.5'
Caddo Valley 7.5'
Carthage 7.5'
Calico Rock 7.5'
Camden 7.5'
Cecil 7.5'
Clarendon 15'
Clarksville 7.5'
Coal Hill 7.5'
Conway 7.5'
Cornerstone 7.5'
Corning 7.5'
Cotton Plant 7.5'
Cozahome 7.5'
Deckerville 15'
Dee 15'
Delaware 7.5'
DeQueen 7.5'
Des Arc East 7.5'
DeValls Bluff 7.5'
Edmondson 15'
El Dorado 15'
Fayetteville 7.5'
Felsenthal 15'
Fletcher Lake 7.5'
Fordyce 7.5'
Foreman 7.5'
Forrest City 7.5'
Fort Smith 7.5'
Fouke NE 7.5'
Fouke SE 7.5'
Fourche 7.5'
Fulton 7.5'
Gainesville 15'
Gleason 7.5'
Glenwood 15'
Gregory 7.5'
Gregory SW 7.5'
Grubbs 7.5'
Harrison 7.5'
Hartford 7.5'
Hartman 7.5'
Hasty 7.5'
Haynes 7.5'
Homan 7.5'
Hope 7.5'
Horseshoe Lake 15'
Houston 7.5'
Hunter 15'
Huntington 7.5'
Jacksonport 7.5'
Jacksonville 7.5'
Jasper 7.5'
Judsonia 7.5'
Kensett 7.5'
Kingsland 7.5'
Latour 15'
Lavaca 7.5'
Leslie 7.5'
Lewisville 7.5'
Lonoke 15'
Madison 7.5'
Magnolia 7.5'
Malvern 15'
Mandeville 7.5'
Marianna 15'
Marked Tree 15'
Marmaduke 15'
Marshall 7.5'
Maumee 7.5'
Mayflower 7.5'
McAlmont 7.5'
McGehee 15'
McRae 7.5'
Mammoth Spring 7.5'
Manila 15'
Mena 7.5'
Monticello North 7.5'
Monticello South 7.5'
Morrilton East 7.5'
Morrilton West 7.5'
Moscow 7.5'
Mountainburg 7.5'
Mount Ida 15'
Mount Judea 15'
Mulberry 7.5'
Murray 7.5'
Nashville 7.5'
Newark 7.5'
New Blaine 7.5'
Newport 7.5'
North Little Rock 7.5'
Osceola 15'
Ozark 7.5'
Paris 7.5'
Park Place 15'
Pastoria 15'
Piggott 15'
Pine Bluff NW 7.5'
Pocahontas 7.5'
Ponca 7.5'
Portland 7.5'
Potter 7.5'

Prague 7.5'
Prairie Grove 7.5'
Prescott East 7.5'
Prescott West 7.5'
Princedale 15'
Reydell 7.5'
Rob Roy 7.5'
Russellville East 7.5'
Russellville West 7.5'
Salem 15'
Sheridan 7.5'
Smackover 7.5'
Snowball 15'
Sonora 7.5'
South Fort Smith 7.5'
Springdale 7.5'
Spring Lake 7.5'
Stuttgart North 7.5'
Stuttgart South 7.5'
Taylor 7.5'
Tilton 15'
Tuckerman 7.5'
Van Buren 7.5'
Waldo 7.5'
Waldron 15'
Walnut Ridge 15'
Western Grove 7.5'
West Memphis 7.5'
Wheeler 7.5'
Wilmont 7.5'
Wynne 15'
Yellville 7.5'

"Flood Plain Information" reports contain technical information on past and potential floods along the various streams that appear in the titles of the reports. Most of the reports include information on settlement along the streams, flood records, flood stages and discharges, flooded areas, flood descriptions, future floods and their frequency, and flood hazards. Also generally included are maps showing the areas innundated by various floods. An example of some of the detailed material that appears in flood-plain information reports follows:

FLOOD PLAIN INFORMATION, PART 1, BAYOU BARTHOLOMEW AND TRIB UTARIES CITY OF PINE BLUFF, ARKANSAS, Department of the Army, Vicksburg District, Corps of Engineers, November 1973.

The maximum flood of record on Bayou Bartholomew occurred in May 1958. It had an estimated average frequency of occurrence of about 1 in 50 years. Rainfall over the upper basin averaged 20 inches for the period April 25, 1958, through May 20, 1958, with 5 inches of rainfall recorded at Pine Bluff during a 15-hour period on May 1, 1958

In Pine Bluff, some of the most severe flooding has been a result of summer thunderstorms, with the storms of July 1951 and August 1970 being the most memorable. Details of areas that would be innundated by flooding in the Pine Bluff area are shown in a series of maps.

FLOOD PLAIN INFORMATION, OUACHITA RIVER, CAMDEN, ARKANSAS, Prepared for the City of Camden by U.S. Army Engineer District, Vicksburg, Corps of Engineers, September 1968.

"The City of Camden, Ark., is situated on the west bank of the Ouachita River in Ouachita County. The community, with a population approaching 17,000, is on Navigation Pool No. 8, which is the upper end of the Ouachita River Navigation Project.* * *"

"Some lands along the river at Camden and vicinity are suitable for industrial facilities. Some of the areas subject to infrequent flooding may be developed economically by adapting the land and/or the facilities to take into account the flood damage potential.* * *"

"This report covers the Ouachita River between mile 340.9 and mile 358.7 above the mouth of the Black River. The Ouachita River joins the Black River at mile 56.6* * *"

"The greatest flood known to have occurred on the Ouachita River at Camden during the past 86 years or more occurred in May 1882. This flood reached a stage of 46.0 feet at determined from a high-water mark.* * *"

The following is a list of other "Flood Plain Information" reports that may be examined at offices of The U.S. Corps of Engineers.

FLOOD PLAIN INFORMATION, BLACK RIVER, CORNING LAKE, AND CYPRESS CREEK, CORNING, ARKANSAS, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, December 1973.

FLOOD PLAIN INFORMATION, EIGHT MILE CREEK, VICINITY OF PARAGOULD, ARKANSAS, Corps of Engineers, U.S. Army, Memphis, Tennessee, District, August 1971.

FLOOD PLAIN INFORMATION, BLACK RIVER, TOWN AND MANSKER CREEKS, POCAHONTAS, ARKANSAS, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, February 1968.

FLOOD PLAIN INFORMATION, CROOKED CREEK AND TRIBUTARIES, HARRISON, ARKANSAS, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, February 1970.

FLOOD PLAIN INFORMATION, LITTLE LA GRUE BAYOU, HOLT QUERTERMOUS AND PRICE BRANCHES, DEWITT, ARKANSAS, Corps of Engineers, U.S. Army, Memphis, Tennessee, District, June 1969.

FLOOD PLAIN INFORMATION, BIG CREEK, LOST CREEK, CHRISTIAN CREEK, AND WHITEMAN'S CREEK, JONESBORO, ARKANSAS, Corps of Engineers, U.S. Army, Memphis, Tennessee, District, March 1971.

FLOOD PLAIN INFORMATION, OUACHITA RIVER, CAMDEN, ARKANSAS, U.S. Army Engineer District, Corps of Engineers, Vicksburg, September 1968.

FLOOD PLAIN INFORMATION, ARKANSAS RIVER, NORTH LITTLE ROCK, ARKANSAS, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, June 1968.

FLOOD PLAIN INFORMATION, ARKANSAS RIVER AND TRIBUTARIES, RUSSELLVILLE, DARDANELLE, ARKANSAS, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, February 1969.

FLOOD PLAIN INFORMATION, WHITE RIVER, POLK BAYOU, AND MILLERS CREEK, BATESVILLE, ARKANSAS, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, November 1969.

FLOOD PLAIN INFORMATION, ARKANSAS RIVER AND TRIBUTARIES, PULASKI COUNTY, ARKANSAS, PART II, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, December 1972.

FLOOD PLAIN INFORMATION, FOURCHE CREEK AND TRIBUTARIES, LITTLE ROCK, ARKANSAS, PART I, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, June 1969.

FLOOD PLAIN INFORMATION, ARKANSAS RIVER AND TRIBUTARIES, LITTLE ROCK, ARKANSAS, PART II, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, August 1971.

FLOOD PLAIN INFORMATION, ARKANSAS RIVER AND TRIBUTARIES, LITTLE ROCK, ARKANSAS, PART III, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, June 1973.

FLOOD PLAIN INFORMATION, MULBERRY AND LITTLE MULBERRY CREEKS, MULBERRY, ARKANSAS, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, March 1972.

FLOOD PLAIN INFORMATION, ARKANSAS RIVER AND TRIBUTARIES, FORT SMITH, ARKANSAS, PART I, Corps of Engineers U.S. Army, Little Rock, Arkansas, District, November 1970.

FLOOD PLAIN INFORMATION, ARKANSAS RIVER AND TRIBUTARIES, FORT SMITH, ARKANSAS, PART II, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, July 1972.

FLOOD PLAIN INFORMATION, WEST FORK WHITE RIVER, TOWN, MUD, SCULL, AND CLEAR CREEKS, FAYETTEVILLE, ARKANSAS, Corps of Engineers, U.S. Army, Little Rock, Arkansas, District, March 1971.

FLOOD PLAIN INFORMATION, MILL CREEK, FORT SMITH, ARKANSAS, Corps of Engineers, U.S. Army, Tulsa, Oklahoma, District, March 1968.

FLOOD PLAIN INFORMATION, SALINE RIVER AND TRIBUTARIES, BENTON, ARKANSAS, U.S. Army Engineer District, Vicksburg, Corps of Engineers, October 1971.

FLOOD PLAIN INFORMATION, OUACHITA RIVER, ARKADELPHIA, ARKANSAS, U.S. Army Engineer District, Vicksburg, Corps of Engineers, February 1969.

FLOOD PLAIN INFORMATION, DAYS CREEK AND TRIBUTARIES, TEXARKANA, ARKANSAS-TEXAS, Corps of Engineers, U.S. Army, New Orleans, Louisiana, District, August 1970.

FLOOD INFORMATION FOR FLOOD-PLAIN PLANNING, U.S. Geological Survey Circular 539, 1967, by C. D. Bue.

"Floods are natural and normal phenomena. They are catastrophic simply because man occupies the flood plain, the high-water channel of a river. Man occupies flood plains because it is convenient and profitable to do so, but he must purchase his occupancy at a price--either sustain flood damage or provide flood-control facilities. Although large sums of money have been, and are being, spent for flood control, flood damage continues to mount. However, neither complete flood control nor abandonment of the flood plain is practicable. Flood plains are a valuable resource and will continue to be occupied, but the nature and degree of occupancy should be compatible with the risk involved and with the degree of protection that is practicable to provide. It is primarily to meet the needs for defining the risk that the flood inundation maps of the U.S. Geological Survey are prepared."

Group 2F--Ground water

A PRIMER ON GROUND WATER, U.S. Geological Survey.

For primary bibliographic entry see 2A.

ANALOG SIMULATION OF WATER-LEVEL DECLINES IN THE SPARTA SAND, MISSISSIPPI EMBAYMENT.

For primary bibliographic entry see 4B.

WATER QUALITY STUDY, OZARK WELL FIELD, ARKANSAS RIVER BASIN, ARKANSAS.

For primary bibliographic entry see 5A.

CITY OF OZARK--EFFECTS OF RESERVOIR ON WATER SUPPLY WELLS.

For primary bibliographic entry see 5A.

THE ROLE OF GROUND WATER IN THE NATIONAL WATER SITUATION, WITH STATE SUMMARIES BASED ON REPORTS BY DISTRICT OFFICES OF THE GROUND WATER BRANCH.

For primary bibliographic entry see 6B.

THE WATER SITUATION IN THE UNITED STATES WITH SPECIAL REFERENCE TO GROUND WATER.

For primary bibliographic entry see 6B.

SUMMARY OF THE WATER SUPPLY OF THE OZARK REGION IN NORTHERN ARKANSAS.

For primary bibliographic entry see 6B.

EMERGENCY GROUND-WATER SUPPLIES NEAR PINE BLUFF, ARKANSAS.

For primary bibliographic entry see 6B.

REGIONAL TRENDS IN WATER-WELL DRILLING IN THE UNITED STATES.

For primary bibliographic entry see 6B.

SHORTCUTS AND SPECIAL PROBLEMS IN AQUIFER TESTS.

For primary bibliographic entry see 7B.

ELECTRIC ANALOG OF THREE DIMENSIONAL FLOW TO WELLS AND ITS APPLICATION TO UNCONFINED AQUIFERS.

For primary bibliographic entry see 7B.

CONSTANT-HEAD PUMPING TEST OF A MULTIAQUIFER WELL TO DETERMINE CHARACTERISTICS OF INDIVIDUAL AQUIFERS.

For primary bibliographic entry see 7B.

METHODS FOR DETERMINING PERMEABILITY OF WATER-BEARING MATERIALS WITH SPECIAL REFERENCE TO DISCHARGING-WELL METHODS, *with a section on* DIRECT LABORATORY METHODS AND BIBLIOGRAPHY ON PERMEABILITY AND LAMINAR FLOW.

For primary bibliographic entry see 7B.

CORRECTIONS NECESSARY IN ACCURATE DETERMINATIONS OF FLOW FROM VERTICAL WELL CASINGS.

For primary bibliographic entry see 7B.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1935.

For primary bibliographic entry see 7C.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1936.

For primary bibliographic entry see 7C.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1937.

For primary bibliographic entry see 7C.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1938.

For primary bibliographic entry see 7C.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1939.

For primary bibliographic entry see 7C.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1940, PART 4. SOUTH-CENTRAL STATES.

For primary bibliographic entry see 7C.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1941, PART 4. SOUTH-CENTRAL STATES.

For primary bibliographic entry see 7C.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1942, PART 4. SOUTH-CENTRAL STATES.

For primary bibliographic entry see 7C.

DEPTH-TO-WATER MEASUREMENTS IN WELLS IN THE ALLUVIUM OF THE ARKANSAS RIVER VALLEY BETWEEN LITTLE ROCK, ARKANSAS, AND THE MISSISSIPPI RIVER.

For primary bibliographic entry see 7C.

CHANGES IN GROUND-WATER LEVELS IN DEPOSITS OF QUATERNARY AGE IN NORTHEASTERN ARKANSAS.

For primary bibliographic entry see 7C.

CHANGES IN WATER LEVELS IN DEPOSITS OF QUATERNARY AGE IN EASTERN ARKANSAS FROM 1938 TO 1953.

For primary bibliographic entry see 7C.

GROUND-WATER LEVELS IN OBSERVATION WELLS IN ARKANSAS, SPRING 1973.

For primary bibliographic entry see 7C.

GROUND-WATER LEVELS IN DEPOSITS OF QUATERNARY AND TERTIARY AGE, SPRING 1965.

For primary bibliographic entry see 7C.

DECLINE OF WATER LEVELS IN THE PINE BLUFF AREA.

For primary bibliographic entry see 7C.

ESTIMATED DEPTH TO WATER IN STATES WEST OF THE MISSISSIPPI RIVER.

For primary bibliographic entry see 7C.

WATER LEVELS IN RICE IRRIGATION WELLS IN THE GRAND PRAIRIE REGION.

For primary bibliographic entry see 7C.

GROUND-WATER TREND STILL DOWN IN 1963.

For primary bibliographic entry see 7C.

GROUND-WATER LEVELS IN WELLS IN THE GRAND PRAIRIE AND EASTERN ARKANSAS.

For primary bibliographic entry see 7C.

GROUND-WATER TEMPERATURES IN THE COASTAL PLAIN OF ARKANSAS.

For primary bibliographic entry see 7C.

CHEMICAL ANALYSES OF THE WATER FROM SELECTED WELLS IN THE ARKANSAS RIVER VALLEY FROM THE MOUTH TO FORT SMITH, ARKANSAS.

For primary bibliographic entry see 7C.

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF ARKANSAS FOR 1891, THE MINERAL WATERS OF ARKANSAS.

For primary bibliographic entry see 7C.

ARKANSAS WESTERN GAS COMPANY, ANNUAL REPORT, 1968.

For primary bibliographic entry see 10.

WATER-BEARING FORMATIONS IN THE COASTAL PLAIN OF ARKANSAS, Thirtieth Annual Arkansas Water and Sewage Conference Proceedings, March 1961, p. 57-66, by R. L. Hosman.

"The Cretaceous system contains no major aquifers, although it does include several water-bearing formations. The first Cretaceous sea advanced approximately as far north as the location of Murfreesboro, and the deposits laid down at that time were not nearly so extensive as those that were to follow. The beds of Early Cretaceous age crop out in southwestern Arkansas and dip rapidly in the subsurface toward the southeast. The three Lower Cretaceous aquifers, the Pike gravel, the Ultima Thuld Gravel Member of the Holly Creek Formation, and the Paluxy Sand contain fresh water only in and very near the areas where they are exposed at the land surface. Downdip in the subsurface, the water becomes too highly mineralized or salty for most uses. Whereas these beds cannot be considered major aquifers with respect to the entire Coastal Plain, they are nonetheless very important, because they contain the only fresh ground water available in the area. At one time, wells tapping these aquifers flowed. However, large withdrawals caused by some wells being pumped and others being permitted to flow continuously have lowered artesian pressures so that most wells no longer flow.* * *"

"Whereas the Early Cretaceous sea extended only as far north as Murfreesboro, the Late Cretaceous sea invaded the continent as far north as the southern tip of Illinois, and the deposits laid down in it are consequently much more widespread than those of Early Cretaceous age. The Upper Cretaceous deposits crop out in southwestern Arkansas and in a small area northwest of Newport, but in the remainder of the Coastal Plain part of the state they are covered by younger sediments of Tertiary and Quaternary age. Dipping to the southeast away from the area of outcrop, the Upper Cretaceous beds attain a total thickness in excess of 2,000 feet, and, in eastern Arkansas near the Mississippi River, the top of the beds is more than 3,000 feet below the land surface. Two Upper Cretaceous formations contain fresh water. Three others contain mineralized water even in the area of outcrop; however, in spite of the poorer quality of this water, it is used in areas where no other supply is available.* * *"

"The Nacatoch sand is the largest water-bearing formation in the Upper Cretaceous series and contains fresh water in its area of outcrop and for varying distances downdip. Northern Miller, southern Clark, and northeastern Nevada counties, where the Nacatoch contains salt water close to the surface near the outcrop area, are exceptions. It may be that sea water, entrapped in the formation at the time of deposition, has never been completely flushed out. In northeastern Arkansas, the Nacatoch sand contains potable water as far south as Jonesboro where it is more than 1,000 feet below the land surface. However, most wells in Arkansas tapping the Nacatoch are in the southwestern part of the state.* * *"

"The Arkadelphia marl is the uppermost unit of Late Cretaceous age. It consists of marl and limestone and is generally less than 200 feet thick. It is not an aquifer.

"Sediments of the Tertiary system extend over most of the Coastal Plain, generally east of U.S. Highway 67, and have an aggregate thickness of more than 3,000 feet in southeastern Arkansas. Tertiary beds crop out over about 25 percent of the Coastal Plain, mostly in the southern half, and are covered elsewhere by Quaternary alluvium. Several major aquifers of the Tertiary system are composed of extensive beds of massive sand and form a "water bank" representing an enormous reserve of ground water. In ascending order, the Tertiary deposits are divided into four groups, the Midway, Wilcox, Claiborne, and Jackson. Two of these groups, the Wilcox and Claiborne, contain major aquifers.* * *"

"Quaternary deposits form the surface over about two-thirds of the Coastal Plain of Arkansas and are the youngest materials present. Generally, they overlie deposits of Tertiary age, but in part of southwestern Arkansas they lie upon Cretaceous rocks. Quaternary sediments are composed chiefly of terrace and flood-plain deposits; although they vary greatly in thickness, they generally range from 100 to 200 feet thick. The materials are commonly coarse sand and gravel at the base, grading upward to fine sand and silt to clay and loam in the uppermost part. The beds of sand and gravel of the Quaternary system are the most important source of ground water for irrigation in the state, in that approximately three-fourths of the ground water pumped in the state comes from these materials.* * *"

"In summary, it is evident that the Coastal Plain of Arkansas is extremely rich in ground-water resources. Environmental conditions in the geologic past resulted in the deposition of porous materials that today are the water-bearing formations that play a large part in supporting the agricultural and industrial economy of the state. These water-bearing formations range from a few hundred to over 20,000 square miles in extent.* * *"

HYDROLOGIC SIGNIFICANCE OF THE LITHOFACIES OF THE SPARTA SAND IN ARKANSAS, LOUISIANA, MISSISSIPPI, AND TEXAS, U.S. Geological Survey Professional Paper 569-A, 1968, by J. N. Payne.

This study of the Sparta Sand is the initial phase in the geohydrologic investigation of the Claiborne Group.

The thicker sections of the Sparta Sand lie along the axes of the Mississippi embayment and Desha basin. The area of maximum thickness, 1,100 to 1,200 feet, is in Claiborne and Warren Counties, Miss., and Madison Parish, La.

A sand-percentage map indicates that the Sparta Sand was deposited as a delta-fluvial plain complex in Arkansas, Louisiana, and Mississippi and probably resulted from an ancestral Mississippi River system. In the channel areas, the maximum thickness of the sand units may be as much as 350 feet; in the interchannel areas the maximum thickness is generally less than 50 feet.

The Sparta Sand is recharged by infiltration of water from precipitation on the outcrop, by leakage from other aquifers, and by seepage from streams.

The areas of higher transmissibility in the Sparta Sand have the lowest concentration of dissolved solids. Thus differences in water quality can be attributed to differences in rate of ground-water movement.

THE CARRIZO SAND, A POTENTIAL AQUIFER IN SOUTH-CENTRAL ARKANSAS, U.S. Geological Survey Professional Paper 501-D, p. D158-D160, 1964, by R. L. Hosman.

"Electric-log interpretations made as part of a water-resources study of the Mississippi embayment indicate that the Carrizo Sand of Eocene age is a potential aquifer in an area of about 5,000 square miles in south-central Arkansas. The dissolved-solids content of water from a recently drilled 2,050-foot test hole was less than 1,000 parts per million, confirming these interpretations."

CRETACEOUS AQUIFERS IN THE MISSISSIPPI EMBAYMENT, U.S. Geological Survey Professional Paper 448-C, 1965, by E. H. Boswell, G. K. Moore, L. M. MacCary, and others, *with discussions of* Quality of the Water, by H. G. Jeffery.

"The aquifers of Cretaceous age supply water in an area of about 30,000 square miles and are potential sources of supply in an additional 15,000 square miles where many of the units contain water having less than 1,000 parts per million dissolved solids.* * *"

"Generally the aquifers are not intensively developed; the total withdrawal and flow from them is about 90 million gallons per day. In many places only the shallowest aquifer is used, although one or more deeper aquifers are present.

"The aquifers are recharged primarily by precipitation on the outcrop. Because the aquifers are saturated, most of the streams crossing the Cretaceous outcrop area receive water from the aquifers during periods of no precipitation; therefore, most of the streams are perennial. This condition will continue until large ground-water withdrawals in areas close to the outcrop of the aquifers cause the hydraulic gradient to steepen sufficiently to make additional water move downdip rather than discharge into streams.* * *"

"The temperature of the water from the Cretaceous aquifers ranges from about 60° to 95°F. Water from most of the aquifers is of good chemical quality; it is a calcium of sodium bicarbonate type, the calcium bicarbonate type being predominant in the outcrop area and at shallow depths. Iron is the most troublesome chemical constituent; the higher iron concentrations occur in the outcrop areas and at shallow depths. As the water moves downdip, it changes to a sodium bicarbonate type, and the iron content decreases.* * *"

"Most of the general water-level declines in the Cretaceous aquifers are the result of unrestricted flow from wells and of municipal and industrial withdrawals and are not indicative of overdevelopment of the aquifers. As additional supplies are developed, the water levels will continue to decline, and many of the wells which now flow will then have to be pumped."

QUATERNARY AQUIFERS IN THE MISSISSIPPI EMBAYMENT, U.S. Geological Survey Professional Paper 448-E, 1968, by E. H. Boswell, E. M. Cushing, and R. L. Hosman, *with a discussion of* Quality of the Water, by H. G. Jeffery.

"Alluvial deposits of Quaternary age form ground-water reservoirs in an area of about 45,000 square miles in the Mississippi embayment. The Mississippi River valley alluvial aquifer is one of the most prolific sources of ground water in the embayment. Also hydrologically important is the Red River Valley alluvial aquifer in Arkansas, Louisiana, and Texas. Ground water is also available from alluvial deposits along other tributary streams.

"The alluvial aquifers are desirable sources of water for irrigation and industry. They are used for public supplies only where an ample supply of water of better quality is not available from deeper aquifers.

"Water from the alluvial aquifers is generally a hard to very hard calcium bicarbonate or calcium magnesium bicarbonate type containing excessive iron. Water temperature ranges from 59°F in the northern part of the embayment to 68°F in the southern part but is nearly constant at any locality.

"Most industrial and irrigation wells are less than 150 feet deep. Wells yielding 500 gallons per minute or more are common over more than 90 percent of the Mississippi River alluvial plain, and yields of more than 5,000 gallons per minute have been reported. Water levels are generally less than 20 feet below the land surface.

"The amount of water stored in the Quaternary deposits is slightly more than 120 trillion gallons. Withdrawals in 1965 averaged about 1,430 million gallons per day, or 1,600,000 acre-feet. About 85 percent of this amount was seasonal pumpage for irrigation. Water-level declines of 20-30 feet are usual in areas of large withdrawal; however, water levels in many areas generally recover to near normal each year.

"The principal source of recharge is precipitation. Some recharge occurs locally along streams during high stages, but generally ground water is discharged to the streams."

TERTIARY AQUIFERS IN THE MISSISSIPPI EMBAYMENT, U.S. Geological Survey Professional Paper 448-D, 1968, by R. L. Hosman, A. T. Long, T. W. Lambert, and others, *with discussions of* Quality of the Water, by H. G. Jeffery.

"The aquifers of Tertiary age contain water having less than 1,000 parts per million dissolved solids in an area of about 75,000 square miles and are used as sources of water supply in almost all this area. The total withdrawal from Tertiary aquifers is about 500 million gallons per day. In much of the area, two or more Tertiary aquifers are available for development, although generally only the shallowest aquifer is used. Most of the Tertiary aquifers are areally extensive, and some contain fresh water at depths in excess of 2,000 feet.

"The aquifers are recharged by precipitation on the outcrop and by downward percolation of water from overlying alluvium where the outcrops are covered by Quaternary deposits.

"Although analysis of test data shows that the hydraulic characteristics of the Tertiary aquifers differ from aquifer to aquifer and vary within any given aquifer, the permeabilities of the lower Wilcox aquifer are generally more consistent and higher than for other Tertiary aquifers. However, a hydrologic unit of the Claiborne Group, the Memphis aquifer--Sparta Sand, is the most productive.

"The temperature of the water from the Tertiary aquifers ranges from about 62°F to 97°F. All the Tertiary aquifers contain water of good quality, but the quality generally deteriorates with depth as mineralization increases. Excessive mineralization occurs at depths of a few hundred feet to more than 3,000 feet. Generally, water in the Tertiary aquifers at shallow depths or where recharge occurs from overlying Quaternary alluvium is a calcium bicarbonate type with varying amounts of magnesium and iron; downdip, the water changes to a sodium bicarbonate-sodium chloride type with varying amounts of magnesium and sulfate. Iron is the most troublesome chemical constituent; the content generally decreases with depth. Locally, saline water occurs in aquifers that are shallower than other aquifers containing fresh water. The Sparta Sand contains mineralized water at shallow depths in an area both updip and downdip from fresh water.* * *"

GEOHYDROLOGY OF THE COASTAL PLAIN AQUIFERS OF ARKANSAS. U.S. Geological Survey Hydrologic Investigations Atlas HA-309, 1969, by R. L. Hosman.

The Coastal Plain of Arkansas is underlain by vast artesian aquifer systems and most of the surface is blanketed by alluvial sands and gravels which contain water. These aquifers are diagrammatically represented in a series of five three-dimensional blocks that cover the Coastal Plain. The aquifers are shown in color, water uses from the aquifers are tabulated by county, and chemical-quality diagrams provide a generalized picture of the water quality. Two smaller scale maps of Arkansas are used to show the surface geology and altitude of the base of fresh water in the Coastal Plain.

According to a summary, Quaternary aquifers are the most widely used for irrigation and rural domestic and stock supplies. Well yields range from a few gallons per minute to about 6,000 gpm; most yields range from 500 to 2,000 gpm. The Cockfield Formation is used mostly for rural domestic and stock supplies and well yields generally are less than 400 gpm. The Sparta Sand is the most widely used Tertiary aquifer; industries and municipalities make the heaviest demand on the Sparta. Well yields may be low where the sands are thin, irregular, and lenticular but may be as much as 3,000 gpm where the sands are extensive and thick. The Cane River Formation is not utilized extensively;

most of the water is withdrawn from low-yielding wells for rural domestic and stock use. The Carrizo Sand is a practically unused aquifer. Owing to sparse development, little is known about yields from the Carrizo, but because of its thickness in east-central Arkansas large well yields may be obtainable. The Memphis aquifer is comprised of sandy facies of the Carrizo Sand, Cane River Formation, and Sparta Sand and represents a tremendous reserve because few wells in Arkansas tap these sands. Known yields range from 100 to 1,000 gpm but larger yields are possible. A persistent sandy zone as much as 300 feet thick in the Wilcox Group in northeastern Arkansas is known as the lower Wilcox aquifer. Withdrawal from this aquifer is relatively small; well yields range from 100 to 2,000 gpm. Three aquifers are recognized in Cretaceous deposits. These are the Nacatoch Sand, Tokio Formation, and Trinity Group. The Nacatoch is the highest yielding aquifer of the three, with yields as much as 300 gpm.

A table shows that transmissibilities of the various aquifers in the Coastal Plain in Arkansas range from 1,300 to 300,000 gpd per foot and that specific capacities range from 2 to 70 gpm per foot of drawdown.

MAP SHOWING ALTITUDE OF THE BASE OF FRESH WATER IN COASTAL PLAIN AQUIFERS OF THE MISSISSIPPI EMBAYMENT, U.S. Geological Survey Hydrologic Investigations Atlas HA-221, 1966, by E. M. Cushing.

"In determining the ground-water resources of a region one of the questions to be answered is: "How deep is the base of the fresh water." The contour map shows the altitude of the base of fresh water in units of Cretaceous age and younger in the Mississippi embayment.* * *"

"Fresh water for this study is water containing less than 1,000 ppm (parts per million) of dissolved solids. The base of fresh water and the geologic unit containing the deepest fresh water were determined from electric logs of oil- and gas-test wells.* * *"

"In the southwestern part of Dallas County, Ark., parts of Ouachita County, Ark., and in the south-central part of Lafayette County, Ark., the base of the fresh water is in sand beds of the Cane River Formation. In these areas the base of fresh water is shown on the map as being in the overlying Sparta Sand because the areas are too small to be of regional importance.

"In southern Arkansas, northwestern Louisiana, and northeastern Texas, other small areas exist where the base of fresh water is at a lower altitude than that shown on the map. Generally, the base of fresh water in these areas is in the lenticular sands of small areal extent; some of these areas may be associated with geologic structures.

"If this map were to be used as a guide to determine the depth and the geologic unit that could be utilized for the disposal of highly mineralized water, the following facts should be considered: (1) the base of fresh water is not necessarily the top of the saline or highly mineralized water; (2) water containing more than 1,000 ppm is presently being used in some parts of the region and additional quantities may be utilized in these areas or other areas in the near future; and (3) local small areas in which the base of fresh water is at a lower altitude are not shown. Although these areas are not regionally important, they are locally important in the development of ground-water supplies.* * *"

WATER WELL SURVEY, EL DORADO REFINERY, Monsanto Company, El Dorado Refinery, El Dorado, Arkansas, December 30, 1966, by J. K. Rudder and B. J. Turbeville.

The average water consumption rate (1966) is 2,038 gpm or 2.93 mgd pumped from six wells. Individual well yields range from 775 gpm to 885 gpm. Depths to water under static conditions range from 374 feet to 424 feet below the motor bases. Drawdowns range from 25 feet to 44 feet. Well depths range from 511 feet to 551 feet. From 1948 to 1966, water levels declined about 100 feet.

MAPPING TRANSMISSIBILITY OF ALLUVIUM IN THE LOWER ARKANSAS RIVER VALLEY, ARKANSAS, U.S. Geological Survey Professional Paper 475-C, 1963, by M. S. Bedinger and L. F. Emmett.

"Areal differences in transmissibility were mapped by using information from aquifer tests, specific-capacity tests, and lithologic logs. Aquifer-test results served as a basis for estimating transmissibility from specific capacity, and laboratory determinations of the relation of permeability to grain size were used in estimating transmissibility from lithologic logs."

Values of transmissibility ranged from less than 100,000 gpd per foot to more than 300,000 gpd per foot in the Arkansas River valley from Little Rock to the mouth of the Arkansas River.

HYDROLOGIC SIGNIFICANCE OF LITHOFACIES OF THE CANE RIVER FORMATION OR EQUIVALENTS OF ARKANSAS, LOUISIANA, MISSISSIPPI, AND TEXAS, U.S. Geological Survey Professional Paper 569-C, 1972, by J. N. Payne.

"The regional dip of the Cane River or equivalents is into the Mississippi embayment and Desha basin or into the gulf coast geosyncline.

"The thickness of the Cane River Formation ranges from 70 feet in LaSalle Parish, La., to 750 feet in the Desha basin of Arkansas. Several major structural features were active during Cane River time; they cause local variations in thickness.

"The Cane River Formation represents the most extensive marine invasion of Claiborne time; consequently over most of the area it is composed of shale. Sand-percentage maps and maximum sand-unit thickness maps indicate that the formation contains an appreciable amount of sand that was laid down as channel sands or as bar and beach deposits along the margins of the embayment.

"The relation of permeability and transmissivity to sand-thickness is believed to be similar to the relation found in the Sparta and Cockfield Formations. The coefficient of permeability probably increases with increase in sand thickness."

THE THERMAL SPRINGS OF HOT SPRINGS NATIONAL PARK, ARKANSAS--FACTORS AFFECTING THEIR ENVIRONMENT AND MANAGEMENT, U.S. Geological Survey open-file report, 1970, by M. S. Bedinger, R. T. Sniegocki, and J. L. Poole.

The hot springs of Hot Springs National Park, Ark., issue from an artesian ground-water system. The water is of meteoric origin. The recharge area is the outcrop of the Bigfork Chert in the breached anticline between West Mountain and Sugarloaf Mountain and their northeasterly extensions. A minor part of recharge is to the Arkansas Novaculite within Hot Springs National Park.

The radioactivity and the dissolved-mineral and radon content of the hot water are similar to those of the cold water in springs and wells in the area. Dissolved gases in the water reflect the former atmospheric and soil-air environments of the water.

The high temperature of the water is due to deep circulation of the water and contact with rocks heated by an igneous mass. Although the time of travel of a particular particle of water may be quite long, the time response of the artesian flow system to changes in recharge will be much less.

Flow of the hot springs has not been accurately determined on a periodic basis. With the flow data on hand, it appears there has been no significant decrease in flow.

The effect of urbanization and land use on the hot springs flow cannot be assessed until the spring flow has been measured for a sufficient period of time and the hydrology in the recharge area is more completely known. Urbanization and land use probably have moderately increased peak flows in Hot Springs Creek. As urbanization intensifies, the flood hazard on Central Avenue in Hot Springs will increase.

THE WATERS OF HOT SPRINGS NATIONAL PARK, ARKANSAS--THEIR ORIGIN, NATURE, AND MANAGEMENT, U.S. Geological Survey open-file report, 1974, by M. S. Bedinger, F. J. Pearson, Jr., J. E. Reed, R. T. Sniegocki, and C. G. Stone.

The 47 hot springs of Hot Springs National Park, Ark., issue from the plunging crestline of a large overturned anticline, along the southern margin of the Ouachita anticlinorium in the Zigzag Mountains. The springs emerge from the Hot Springs Sandstone near the anticlinal axis, between the traces of two thrust faults that are parallel to the axis of the anticline.

The combined flow of the hot springs ranges from 750,000 to 950,000 gallons per day. The flow is highest in the winter and spring and is lowest in the summer and fall. The temperature of the combined hot springs water is about 62° Celsius (144° F). The radioactivity and chemical concentration of the hot springs are similar to that of cold-water springs and wells in the area. The dissolved-solids concentrations of the waters in the area generally range from 175 to 200 milligrams per liter. Percent analysis (1973) showed the radium concentration to be 2.1 picocuries per liter.

The tritium and ^{14}C analyses of the water indicate that the water is a mixture of a very small amount of water less than 20 years old and a preponderance of water about 4,000 years old.

The geochemical data, flow measurements, and geologic structures of the region support the concept that virtually all the hot-springs water is local, meteoric water. Recharge to the hot-springs artesian-flow system is by infiltration of rainfall in the outcrop areas of the Bigfork Chert and the Arkansas Novaculite. The water moves slowly to depth where it is heated by contact rocks of high temperature. Highly permeable zones, related to jointing or faulting, collect the heated water in the aquifer and provide avenues for the water to travel rapidly to the surface.

THE HOT SPRINGS OF ARKANSAS, 57th Congress, First Session, Senate Document 282, 1902, by J. K. Haywood and W. H. Weed.

Senate Document 282 contains two reports. The first by J. K. Haywood is titled "Report of an Analysis of the Waters of the Hot Springs on the Hot Springs Reservation, Hot Springs, Garland County, Ark., with an Account of the Methods of Analysis Employed and the Medicinal Value of Various Substances Usually Found in Mineral Water." The second report by Walter Harvey Weed is titled "Geological Sketch of Hot Springs, Arkansas."

Temperature data are available for 46 springs, most having been measured twice; once in 1900 and approximately a year later in 1901. The minimum temperature measured was 46.4°F for Liver Spring (cold spring) and the maximum was 147°F for

Big Iron Spring (hot spring). As much as 7.2°F variation was noted in the Ed Hardin Spring between December 21, 1900, and January 8, 1901. Many springs were the same temperature at the time of the temperature measurement.

Flow measurements also are tabulated in Haywood's report for 46 springs. The total flow of all springs is given as 826,308 gpd with the minimum for any one spring being 511 gpd (Kidney Spring) and the maximum 201,600 gpd (Big Iron Spring).

Chemical analyses are listed for each of the 46 springs. The total mineral matter present is very nearly the same in all springs. Calcium (Ca), silica (SiO_2), and bicarbonate (HCO_3) are the predominant constituents in the water.

Weed's report covers the geologic aspects in the vicinity of the hot springs and describes the rocks and their structure. According to Weed, the spring water is of meteoric origin and is heated by a still-heated body of igneous rocks at depth below the surface. Weed further postulates that the springs are losing their heat so slowly the loss is almost inappreciable.

NOTES ON CERTAIN HOT SPRINGS OF THE SOUTHERN UNITED STATES, U.S. Geological Survey Water-Supply Paper 145, 1905, by W. H. Weed.

Weed's paper covers the distribution of hot springs and their geologic relationships in the Southern United States. Some attention is given the Warm Springs of Georgia but most of the paper is devoted to the hot springs in Arkansas. Weed provides an excellent description of the geological and structural features associated with the hot springs as well as chemical analyses of the tufa deposits and the hot springs water. Other items considered are life of the hot springs, the flow of the springs, the sources of water, and the heat source. According to Weed, the heat is provided by a large body of still-heated igneous rocks underlying central Arkansas and water of meteoric origin, moving as that in ordinary springs, is heated as it passes near the hot rocks.

THE HOT-WATER SUPPLY OF THE HOT SPRINGS, ARKANSAS, Journal of Geology, Volume 30, 1922, by Kirk Bryan.

Bryan (p. 425-449) presents data collected during examination to see if the water supply can be increased. He also suggests that part of the water may be juvenile. Four other springs with temperatures of 74° F to 97° F are listed for Arkansas.

DESCRIPTION OF THE HOT SPRINGS QUADRANGLE, ARKANSAS, U.S. Geological Survey Atlas 215, 1923, by A. H. Purdue and H. D. Miser.

According to these authors, water collects in an anticlinal valley northeast of the orifices of the hot springs, penetrates down into a syncline, and emerges, owing to difference in altitude, in the plunging anticline of Hot Springs Mountain. The heat source is underlying masses of hot rocks.

THE COLLECTING AREA OF THE WATERS OF THE HOT SPRINGS, HOT SPRINGS, ARKANSAS, Journal of Geology, Volume 18, 1910, by A. H. Purdue.

This report (p. 278-285) concludes that the collecting area is in a valley north of the hot springs orifices; the water penetrates down into a syncline and rises in the Hot Springs anticline; the location of the springs is due to the southwest plunge of the anticlinal axis. The report also suggests that the heat may be due in part to hot rock of numerous dikes.

This report also was published in the Indiana Academy of Science Proceedings, 1909, p. 269-275.

THE HOT SPRINGS OF ARKANSAS, Journal of Geology, Volume 32, Number 6, 1924, by Kirk Bryan.

According to Bryan (p. 449-459) the hot water rises through fractured sandstone at the nose of a plunging anticline. There are three principal hypotheses of origin. The one having most advocates is that the water is entirely meteoric, enters a porous bed in an anticline, passes under a syncline, and emerges in the next anticline because of hydrostatic pressure. Another theory states that the water is derived from a cooling and crystallizing igneous mass directly under the springs. This theory is given little likelihood of being feasible. The third theory states that fault fissures extend deep into the interior of the earth from which juvenile water rises and, mixed with meteoric water, come to the surface. This theory rests only on general argument.

CHEMICAL ANALYSES OF SPRING WATERS IN THE HOT SPRINGS NATIONAL PARK, ARKANSAS, AREA, U.S. Geological Survey open-file report, March 1953, by G. A. Billingsley and J. H. Hubble.

This report contains the results of analyses of samples of water from 26 hot and cold springs in the Hot Springs National Park, Ark., and of two warm-water wells outside the Park. The two warm wells are located at Hope and Prescott, Ark.

The total mineral content of the 12 hot springs sampled ranged from 179 to 202 ppm and the temperature of the water ranged from 127° F to 146° F. The hot springs flow calcium bicarbonate-type waters, which are moderately hard with appreciable quantities of silica. Except for temperature, four of the cold springs were quite similar to the hot springs, with a total dissolved-solids concentration ranging from 149 to 222 ppm. Five of the cold springs contained acid waters with pH values ranging from 3.62 to 5.0 and contained less than 50 ppm total dissolved solids.

The Prescott well, 1,070 feet deep, yielded water containing a total mineral content of 1,200 ppm. The Hope well, 1,500 feet deep, yielded water containing 1,150 ppm total dissolved solids.

ON THE RADIOACTIVE PROPERTIES OF THE WATERS OF THE SPRINGS ON THE HOT SPRINGS RESERVATION, HOT SPRINGS, ARKANSAS, American Journal of Science, 4th Series, Volume 20, 1905, by B. B. Boltwood.

Results of the examination made in 1904 on samples from 44 springs are given on pages 128-132. This information also is published in the annual report of the Secretary of the Interior for 1904.

RADIOACTIVITY OF THERMAL WATERS AND ITS RELATIONSHIP TO THE GEOLOGY AND GEOCHEMISTRY OF URANIUM, University of Arkansas, Institute of Science and Technology, March 1953, by R. H. Ardnt and P. E. Damon.

"The major research effort has centered around investigations at Hot Springs National Park and Potash Sulphur Springs, Ark.

"The chemical composition and radioactivity of the spring waters of Hot Springs National Park and vicinity have been studied and an attempt is being made to correlate this information with geologic field studies and laboratory studies. Geologic field studies have disclosed that the hot spring waters rise in fractured rock lying between two heretofore-unrecognized fault zones. Detailed geologic mapping at Potash Sulphur Springs and chemical analysis of samples have shown that the Wilson property is not of commercial value as a uranium prospect, but it remains a good prospect for the production of niobium and vanadium. This area has been used as an outdoor laboratory for the investigation of the migration of radioactive elements in natural waters.

"A uranium-prospecting method is being developed which utilizes the migration of radioactive isotopes in natural waters as well as improved methods for the investigation of areal radioactivity. It is hoped that these techniques, combined with such conventional geophysical techniques as magnetic surveys, will lead to the discovery of subsurface uranium deposits.

"New instrumental and analytical methods for the determination of the activity and composition of samples of solids and of water have been developed."

RADIOACTIVITY OF THE SPRING WATERS OF HOT SPRINGS NATIONAL PARK AND VICINITY IN ARKANSAS, University of Arkansas, Institute of Science and Technology, March 1953, by R. K. Kuroda, P. E. Damon, and H. I. Hyde.

"The hot waters are extremely variable in radon content (0.1 to 30 millimicrocuries per liter) presumably because each spring has its own radium-bearing tufa source of radon. The average radon content is about 0.8 millimicrocuries per liter.

"The cold waters are also extremely variable (0.1 to 7.3 millimicrocuries per liter) and average about the same as the hot springs.* * *"

RADIOACTIVITY OF RIVERS AND LAKES IN PARTS OF GARLAND AND HOT SPRING COUNTIES, ARKANSAS, Economic Geology, Volume 48, Number 7, November 1953, by R. H. Arndt and P. K. Kuroda.

"A wide range of radon content in surface waters was noted incidental to studies of radon on spring and well waters of Hot Springs and Potash Sulphur Springs, Garland County, Arkansas. Subsequently a reconnaissance survey of radioactivity of nearby streams and lakes showed the radon contents of streams range from 0.0084 to 1.07 millimicrocuries per liter of water, and those of lakes range from less than 0.001 to 0.123 millimicrocuries. Streams flowing over Ordovician black shales contained an average of 0.275 millimicrocurie radon per liter of water. Those flowing over black Stanley shale of Mississippian age contained an average of 0.046 millimicrocurie radon per liter of water.

"The radon content in Potash Sulphur Creek where it flows over the uranium bearing rocks of the Potash Sulphur Springs syenite complex ranged from 0.09 to 3.16 millimicrocuries per liter of water. Ground water in a drill hole in uranium-bearing rock contained an average of 58.75 millimicrocuries per liter of water. Waters from small springs were shown to lose as much as 41.3 percent of total radon content in the first 4 feet of surface flow below the point of emergence. The methods of radon determination in the field are believed applicable to prospecting for low-grade uraniferous deposits especially in black shale areas, in areas of heavy overburden, and in areas of saturation by ground water where ordinary detection devices may be somewhat limited."

THE EQUILIBRIUM BETWEEN RADON AND ITS DECAY PRODUCTS IN THE WATERS OF HOT SPRINGS NATIONAL PARK, HOT SPRINGS, ARKANSAS, University of Arkansas, Institute of Science and Technology, March 1953, by P. K. Kuroda.

"The equilibrium between radon and its decay products in the waters of Hot Springs National Park, Arkansas, and in the waters of Wilson Mineral Springs, Arkansas, was investigated and the depths of the underground radon sources were estimated. At Hot Springs National Park, radioactive tufas were considered to be the radon source, and values obtained--expressed in terms of time (τ minutes)--varied from 41 to 84. At Wilson Mineral Springs, in which the uranium deposits were considered to be the radon source, values of approximately 20 minutes were obtained for the springs which flow freshly from the orifices."

THERMAL SPRINGS IN THE UNITED STATES, U.S. Geological Survey Water-Supply Paper 679-B, 1937, by N. D. Stearns, H. T. Stearns, and G. A. Waring.

This is the first general compilation and discussion of the thermal springs in the United States that includes geologic relations of the springs. Earlier generalized compilations were done by G. K. Gilbert in 1875 and A. C. Peale in 1833. A large amount of literature can be found on individual thermal springs and this literature is covered in an annotated bibliography beginning on page 98 of Water-Supply Paper 679-B. Eight reports dealing with Arkansas' hot springs are annotated on pages 98 and 99. The hot springs in Arkansas are noted to be the only thermal springs in the Interior Highlands, a region covering southern Missouri, northwestern Arkansas and eastern Oklahoma. Theories on the origin of the water and heat as advanced by Purdue and Bryan are summarized.

THERMAL SPRINGS OF THE UNITED STATES AND OTHER COUNTRIES OF THE WORLD, A SUMMARY, U.S. Geological Survey Professional Paper 492, 1965, by G. A. Waring, revised by R. R. Blankenship and Ray Bentall

Information on the location of hot springs, the temperature of the water, the rate of flow, the chemical character of the water ar evolved gases, and the uses made of the water are given in the firs part of the report. The second part of the report consists of a list of references on thermal springs.

Thermal springs at Hot Springs, Ark., are described on page 10 of the report as issuing from Mississippian sandstone on a plunging anticline. Eighteen references for thermal springs in Arkansas are listed on page 259.

LARGE SPRINGS IN THE UNITED STATES, U.S. Geological Survey Water-Supply Paper 557, 1927, by O. E. Meinzer.

Mammoth Spring, the only spring listed in the report for Arkansas, is in Fulton County, Arkansas, near the line between secs. 5 and 8, T. 21N., R. 5W.

"It issues as a subterranean stream near the base of a high bluff of cherty limestone. The course of the subterrnaean river that feeds the springs is thought to be marked 8 miles northwest, by a sink hole three-fourths of a mile long known as the 'Grand Gulf.' The spring pool is 64 feet deep at its mouth, and the water apparantly issues from a large cavern and from other large crevices in the limestone. The water is described as having a bluish tinge but as being odorless and tasteless and having a temperature of 58° or 59° F in summer. The water is hard having about 158 ppm of limestone and 139 parts of magnesia.

"The discharge was estimated by Purdue at about 150,000 gpm or about 335 cfs, but in 1904 it was, according to Fuller, as low as 150 cfs. On December 13, 1922, the discharge was 258 cfs, according to a measurement by F. H. Davis, of the United States engineer office at Memphis, Tenn.* * *"

NOTES ON CERTAIN LARGE SPRINGS OF THE OZARK REGION, MISSOURI AND ARKANSAS, U.S. Geological Survey Water-Supply Paper 145, 1905, by M. L. Fuller.

Fuller's paper provides a brief description of only one spring in Arkansas--Mammoth Spring. He describes the water as having a bluish tinge, 58° or 59°F, and a flow reported as much as 350 cubic feet per second but was only 150 cubic feet per second in 1904.

RECENTLY DISCOVERED HOT SPRINGS IN ARKANSAS, Journal of Geology, Volume 19, 1911, by A. H. Purdue.

CHEMICAL CHARACTER OF THE HOT SPRINGS OF ARKANSAS AND VIRGINIA, Industrial and Engineering Chemistry, Volume 22, Number 6, Easton, Pennsylvania, 1930, by M. D. Foster.

GEOLOGY AND YOU, Arkansas Gazette, June 18, 1960, through March 31, 1963.

A series of articles, prepared by the U.S. Geological Survey in cooperation with the Arkansas Geological and Conservation Commission, were published in various issues of the Arkansas Gazette from June 1960 through March 1963. The articles, although scientifically factual, are popularized for the lay reader. The dates of publication, authors, and titles of the articles are:

June 18, 1960	"Geology Series to be Published"
June 19, 1960	Geology and You - "Geological Series Will Detail Science of Earth," by R. W. Ryling
June 26, 1960	Geology and You - "Geological Explanation of Pinnacle Mountain," by D. R. Albin.
July 3, 1960	Geology and You - "The Fall Line Divides State Into Equal Parts," by R. O. Plebuch.
July 10, 1960	Geology and You - "Electric Log Important to Geologist," by R. L. Hosman.
July 24, 1960	Geology and You - "Barometric Effect on Water Levels," by J. W. Stephens.
Dec. 25, 1960	Geology and You - "Cooperative Study Shows Fluctuation of Ground Water," by G. A. Bearden, Jr.

Jan 1, 1961	Geology and You - "A Report on Bauxite in Arkansas," by L. F. Emmett.
Jan. 8, 1961	"The Embayment--Our Town Could Have Been a Seaport--At Least It Once Had Its Own Ocean," by by R. L. Hosman.
Jan. 22, 1961	Geology and You - "River Levels Affect Water Wells," by Joe Edds.
June 18, 1961	"Arkansas Caves--They're a Source of Major Interest to Scientist and Spelunkers Alike," by M. S. Bedinger.
August 10, 1961	Ground Water - "The Earth is a Reservoir and an Endless Cycle Keeps it Supplied," by D. R. Albin.
Dec. 19, 1961	"Our High Ouachitas Were Once Part of a Prehistoric Inland Sea Bottom," by R. M. Cordova.
March 31, 1963	"Arkansas Wells Show Path of Nuclear Pressure Wave," by J. R. May.

CORRELATION OF THE CARRIZO SAND IN ARKANSAS AND ADJACENT STATES, Geological Society of America Bulletin, volume 73, p. 389-394, March 1962, by R. L. Hosman.

"The Carrizo Sand (Eocene), the basal unit of the Claiborne Group, can be recognized in the subsurface throughout much of southeastern Arkansas and is correlated with the Carrizo Sand of Louisiana and the Meridian Sand Member of the Tallahatta Formation of Mississippi. The term Carizzo Sand is appropriate for use in Arkansas, as the stratigraphic terminology most workers apply to the Claiborne Group in Arkansas conforms with the terminology of Louisiana. A surface exposure of the Carrizo Sand in Arkansas is lithologically identical with described exposures of the Carrizo in northwestern Louisiana."

GEOLOGY OF THE DeQUEEN AND CADDO GAP QUADRANGLES OF ARKANSAS, U.S. Geological Survey Bulletin 808, 1929, by H. D. Miser and A. H. Purdue.

The water resources of the DeQueen-Caddo Gap quadrangles are covered in pages 182-189 of Bulletin 808. According to the report, all the rock formations, including even the shales, contain water which issues as springs or may be reached by wells.

The best aquifers are listed as being the Crystal Mountain Sandstone, Bigfork Chert, Arkansas Novaculite, Trinity Formation and the Woodbine Formation. Of these, the Bigfork Chert is the best aquifer because of its uniformly shattered condition, its considerable thickness, and large area of outcrop.

Hot springs are noted at four localities in the Caddo Gap quadrangle. One of these is in the gap through Caddo Mountain known as Caddo Gap; another is reported to be 2 miles southwest of the gap; the third is at the east end of Redland Mountain, 11 miles west of Greenwood; and the fourth is on Little Missouri River, 6½ miles southeast of Bigfork post office. The Caddo Gap springs were noted to have a temperature of about 95°F.

Two maps of the southern parts of the two quadrangles show by means of contours the maximum depth to which wells should be drilled to obtain water from the Trinity, Woodbine, and Tokio Formations. Areas where flowing wells can be expected also are delineated.

An excellent description of the geology of the area includes stratigraphy, structure, and geologic history. The most unique aspect covered in the section on economic geology is the description of diamonds, their history and occurrence, and production and character.

The report is designed to provide detailed geologic coverage of the quadrangles and in so doing provides an excellent description of those geologic aspects, such as rock nature and structure, that greatly control the occurrence, nature, and behavior of the water resources in the area.

GEOLOGICAL INVESTIGATION OF THE ALLUVIAL VALLEY OF THE LOWER MISSISSIPPI RIVER, War Department, Corps of Engineers, U.S. Army, December 1944, by H. N. Fisk.

This comprehensive detailed report describes the nature and origin of the alluvial valley of the lower Mississippi River, including the sequence of events in valley evolution establishing the river in its present course. The nature and distribution of the alluvium established from approximately 16,000 borings are shown in detail in cross sections. Major topics in the report cover the entrenched valley system, recent alluvium, the alluvial plain, recent geological history, the Mississippi River, and in an appendix, the geological setting of the Mississippi Alluvial Valley.

GENERAL PHYSICAL FEATURES OF ARKANSAS, Arkansas Geological Survey, 1927, by G. C. Branner.

Twenty-eight topographic quadrangles were available for the State of Arkansas in 1927. Also listed are 15 geologic maps for various parts of the State. Soil survey bulletins were available for 20 different areas. According to a Department of the Interior estimate, Arkansas streams could be used to generate 125,000 horsepower for 90 percent of the time. A map shows the locations of 10 stream-gaging stations that were in operation at the time. Stream-gaging data and period of record are tabulated for 21 locations, 11 of which are in Missouri.

THE GEOLOGY OF WASHINGTON COUNTY, Arkansas Geological Survey Annual Report for 1888, Volume 4, 1891, by F. W. Simonds.

Although this report is principally about the topography and geology of Washington County, pages 16 through 24 cover what is called the hydrography north and south of the Boston Mountains. In addition, a list of the plants of Arkansas by J. C. Branner and F. V. Coville is given at the end of the report.

Drainage characteristics of the White and Illinois Rivers, Lee Creek, and Frog Bayou are covered in detail. Several springs were examined, the largest known as Johnson's spring or the Big Spring.

On August 2, 1888, the measured flow of Johnson's Spring was 2,345,967 gallons in 24 hours. Most of the largest springs issue from the Boone chert. In some localities such as in the western part of Fayetteville, Ark., it is difficult to obtain good wells. An unusual well on the summit of Kissler Mountain penetrates 4 feet of gritty sandstone and 13 feet of shale. According to the report, the top of the mountain is less than a quarter of a mile across and the strata are practically horizontal, yet the supply of water is unfailing.

UPPER CRETACEOUS FORMATIONS OF SOUTHWESTERN ARKANSAS, Arkansas Geological Survey Bulletin 1, 1929, by C. H. Dane.

This report provides detailed information concerning the characteristics, sequence, and surface distribution of the various formations found in Clark, Pike, Nevada, Hempstead, Howard, Miller, Little River, and Sevier Counties. This information is useful for an understanding of the ground-water potential in the area. On page 178 of the report, under economic geology, a brief description of ground water indicates that the Nacatoch Sand and the Tokio Formation are the best aquifers.

ST. PETER AND OLDER ORDOVICIAN SANDSTONES OF NORTHERN ARKANSAS, Arkansas Geological Survey Bulletin 4, 1930, by A. W. Giles.

Perhaps the information in this report that is most directly pertinent to water resources are the sections on lithologic features of the rocks. The subjects covered in these sections are: Interbedded and interstitial materials, mechanical analyses, grain shape, porosity, and chemical composition. The St. Peter Sandstone is listed as having an average porosity (percent of voids) of 42.44 percent and the Calico Rock Sandstone, 43.94 percent.

GEOLOGY OF THE ARKANSAS PALEOZOIC AREA, Arkansas Geological Survey Bulletin 3, 1930, by Carey Croneis.

This detailed geologic study of the Paleozoic area of Arkansas provides an excellent base for developing an understanding of the water resources of the northwestern half of the State. The information is useful in understanding streamflow characteristics and the occurrence of ground water. The sections on oil and gas possibilities and rock porosity, along with stratigraphic and structural relations, are particularly significant.

SUBSURFACE GEOLOGY OF PRE-EVERTON ROCKS IN NORTHERN ARKANSAS, Arkansas Geological and Conservation Commission Information Circular 21, 1960, by W. M. Caplan.

"The pre-Everton Ordovician rocks are more prospective for fresh water than for petroleum in the report area. The water is introduced through outcrops in southern Missouri. Roubidoux and Gunter beds are the most prospective of these sediments for fresh water. Where water is present regionally downdip in the pre-Everton section evidence suggests it will be brackish or saline rather than fresh. Cambrian potentialities for petroleum or fresh water are virtually unexplored."

GENERAL GEOLOGY OF THE MISSISSIPPI EMBAYMENT, U.S. Geological Survey Professional Paper 448-B, 1964, by E. M. Cushing, E. H. Boswell, and R. L. Hosman.

"The Mississippi embayment comprises about 100,000 square miles in the Gulf Coastal Plain. It is a wedge-shaped region extending from its apex in southern Illinois southward to about the 32d parallel and includes parts of Alabama, Arkansas, Illinois, Kentucky, Louisiana, Mississippi, Missouri, Tennessee, and Texas.

"Most of the major geologic units include water-bearing strata that form vast aquifers, many of which cross State boundaries and are of regional importance. The deep-lying Jurassic rocks are not known to contain potable water, but the Cretaceous, Tertiary, and Quaternary deposits include numerous aquifers, most of which contain fresh water at shallow to moderate depths.

"Geologically, the Mississippi embayment is a syncline which plunges to the south and whose axis generally parallels the Mississippi River. The syncline is filled with sedimentary rocks ranging in age from Jurassic to Quaternary and reaching a maximum thickness of about 18,000 feet in the southern part of the region. The lithology and continuity of the geologic units are variable because of modifying structural features and because of the differing depositional environments during the geologic evolution of the region. On the basis of interpretations of electric logs and some driller's logs, contour maps were prepared showing configuration of the top of the Paleozoic rocks, the top of the Cretaceous System, the base of the sandy zone above the Porters Creek Clay, the base of the Cane River Formation or its equivalents, and the top of the Sparta Sand. A fence diagram and four sections show the stratigraphic relation of the major geologic units, and for areas near the outcrops of these units the sections are more detailed.

"Important structural features in the embayment are the Sabine and Monroe uplifts, the Jackson dome, the East Texas and Desha basins, and the Arkansas and Pickens-Gilbertown fault zones. These structures, all of post-Palezoic age, were formed, in part, contemporaneously with the sedimentation of the embayment and have had considerable influence on the depositional environment of the region."

DESCRIPTION OF THE TAHLEQUAH QUADRANGLE, OKLAHOMA-ARKANSAS, U.S. Geological Survey Geologic Atlas Folio 122, 1905, by J. A. Taff.

This report describes the physiographic relations of the Ozark region in the Arkansas Valley, the topography and stratigraphic and structural geology of the Tahlequah quadrangle, and, under "Economic Geology" gives a brief account of the springs and underground waters.

OUTLINES OF ARKANSAS' MINERAL RESOURCES, Arkansas Geological Survey, 1927, by G. C. Branner.

Although this report principally covers metallic and nonmetallic minerals and fuels, the mineral waters of Arkansas are treated in detail on pages 161 through 169.

Mammoth Spring is listed as having an estimated discharge of 900 cfs (about 405,000 gpm). Sixteen firms marketing mineral waters in Arkansas from 1889 through 1922 sold a total of 20,491,029 gallons at a total value of $2,166,285. The partial list of Arkansas springs (53 listed) shows that most of the springs are located in the Interior Highlands of Arkansas and generally are associated with rocks of Paleozoic age. However, Lithia Spring, in Hempstead County, apparently issues from rocks of Cretaceous age. Water-power potential in Arkansas is estimated to be 125,000 horsepower, available 90 percent of the time. Four hydroelectric plants in operation (1927) are on Illinois Bayou near Russellville, Ark., two on Mammoth Spring, and one on the Ouachita River (Remmel Dam) near Hot Springs, Ark. Ten stream-gaging stations are shown to be in operation, seven on the White River and tributaries and three on the Ouachita River and tributaries.

MINERAL RESOURCES OF BENTON, CARROLL, MADISON, AND WASHINGTON COUNTIES, Arkansas Geological Survey, County Mineral Report 2, 1940, Reissued 1968, Compiled under the direction of G. C. Branner.

Although the report is largely devoted to metallic mineral resources and nonmetallic minerals, such as clay and quartz, the description and sequence of geologic formations given are very useful in gaining an understanding of the water resources of the area. On pages 52-56 of the report, a table lists most of the larger springs in the area and gives the approximate flow and owner. The range in flow of the 230 springs listed is from 1,000 to 10,080,000 gallons per day.

WHITE RIVER GRAVEL STUDY, duplicated report, 1972, by L. E. Mack.

In the millions of years it has taken nature to carve out of solid rock what is now known as the White River valley, only a remnant of this erosional process remains in the form of gravel and other sediments in the White River bottoms. No appreciable sediment passes through Bull Shoals Dam. Replenishment of sands and gravel to the White River does occur from periodic flooding of its tributaries, principally Crooked Creek and the Buffalo River. Most of the gravel that is found in the White River at the present time is from the collapse and spreading out of sand and gravel from the banks of low terraces along the White River.

The report recommends that no gravel be removed from the bed or banks of the White River between Bull Shoals Dam and the confluence of Crooked Creek with the White River. Also the report recommends that the low terraces be included as a part of the bed and banks of the White River through legal processes, whereas high terraces be left in private ownership.

GROUND WATER IN THE UNITED STATES, A SUMMARY OF GROUND-WATER CONDITIONS AND RESOURCES, UTILIZATION OF WATER FROM WELLS AND SPRINGS, METHODS OF SCIENTIFIC INVESTIGATION AND LITERATURE RELATING TO THE SUBJECT, U.S. Geological Survey Water-Supply Paper 836-D, 1939, by O. E. Meinzer.

THE OCCURRENCE OF GROUND WATER IN THE UNITED STATES, WITH A DISCUSSION OF PRINCIPLES, U.S. Geological Survey Water-Supply Paper 489, 1923, by O. E. Meinzer.

GROUND WATER IN THE UNITED STATES, A SUMMARY, U.S. Geological Survey Water-Supply Paper 836-D, 1948, by O. E. Meinzer.

GROUND-WATER HYDRAULICS, U.S. Geological Survey Professional Paper 708, 1972, by S. W. Lohman.

Group 2G--Water in soils

ARKANSAS RIVER MULTIPLE-PURPOSE PROJECT, SURVEY OF AGRICULTURAL ASPECTS, PHASE I, U.S. Department of Agriculture in Cooperation with U.S. Corps of Engineers, November 1960.

The Corps of Engineers navigation project on the Arkansas River will be beneficial to agriculture along the river in some respects and detrimental in others.

Beneficial effects are: (1) there will be less encroachment on agricultural land by the river after channel stabilization; (2) crop yields under certain circumstances could be improved by a more stable ground-water level caused by a minimum pool; (3) the availability of irrigation water could be increased; (4) there will be an increase in available water from a raised ground-water table for some locations.

Detrimental effects are: (1) increased river stage will cause a surface-drainage problem at certain points; (2) there will be higher river stages at certain points; (3) sediment deposits may cause plugs for inflowing streams; (4) channel deterioration may result where tributary streams enter the river; (5) the salt content of the soil may increase in areas of project-induced high ground-water levels; (6) the life expectancy of surface ditch systems may be reduced: (7) a raised ground-water level will reduce water-holding capacity of the soil, cause crop yields to be adversely affected, cause early intrusion of salt water into wells, and will increase pumping costs to offset increase in seepage to the drainage system; (8) a lower ground-water level may cause crop yields to be adversely affected, may cause a decrease in the amount of water available for irrigation, and may increase the erosion hazard from overbank drainage discharges.

The report recommends that the agricultural survey be continued because water-surface profiles and ground-water maps were not available at the time of this survey.

SOIL ASSOCIATION MAP, STATE OF ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, April 1959.

This map on a scale of about five-eighth inch per mile (1 to 1,000,000) shows, by color patterns, 47 different soil types in Arkansas. On the back of the map a description of each soil type is given that includes information about the nature of the slope on which the soils lie, soil color and texture, the crops that are grown on the soil, and the types of vegetation commonly found on a given soil type.

THE SOILS OF ARKANSAS, University of Arkansas, Agricultural Experiment Station, Bulletin 187, June 1923, by Martin Nelson, W. H. Sachs, and R. H. Austin.

This report consists of a classification of Arkansas soils with a detailed description of 74 soil types. Included with each description is an analysis of the soil and acidity and the nitrogen and phosphorous content. Nitrogen and phosphorus are reported in pounds per 2,000,000 pounds of soil and may be expressed as pounds per acre. Nineteen soil-type areas are noted. These are based on the kinds of rocks from which the soils are derived and the physiographic-topographic features associated with soils. A map of the State shows the location and extent of each of these 19 soil-type areas.

Drainage, climate, and vegetation, all intimately related to water resources as well as soil types, are discussed in a general fashion. The report indicates that most of the soils of Arkansas are of residual origin, that is, formed from the breakdown of the rocks upon which the soil is found. Hence, a knowledge of the nature of the original rocks is important to soils mapping.

SOIL SURVEY OF ARKANSAS COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, September 1972, by G. R. Maxwell, D. G. Binkley, and D. G. West.

SOIL SURVEY OF ASHLEY COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1914, by E. S. Vanatta, B. D. Gilbert, E. B. Watson, and A. H. Meyer.

SOIL SURVEY, BRADLEY COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, April 1961, by F. C. Larance.

SOIL SURVEY, CHICOT COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, March 1967, by Hardy Cloutier and C. J. Finger.

SOIL SURVEY, CLEVELAND COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, June 1968, by F. C. Larance, J. E. Jay, W. R. Elder, J. L. Daniels, and G. E. Barnum.

SOIL SURVEY OF COLUMBIA COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1916, by Clarence Lounsbury and E. B. Deeter.

SOIL SURVEY OF CONWAY COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1908, by J. L. Burgess and C. W. Ely.

SOIL SURVEY OF CRAIGHEAD COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1917, by E. B. Deeter and Vincent Davis.

SOIL SURVEY, CROSS COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, August 1968, by J. L. Gray and V. R. Catlett.

SOIL SURVEY OF DESHA COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, March 1972, by H. V. Gill, F. C. Larance, Hardy Cloutier, and H. W. Long.

SOIL SURVEY OF DREW COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1919, by B. W. Tillman, F. A. Hayes, and F. Z. Hutton.

SOIL SURVEY OF FAULKNER COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1919, by E. B. Deeter and H. I. Cohn.

SOIL SURVEY OF THE FAYETTEVILLE AREA, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1907, by H. J. Wilder and C. F. Shaw.

SOIL SURVEY, GREENE COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, December 1969, by N. W. Robertson.

SOIL SURVEY OF HEMPSTEAD COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1917, by A. E. Taylor and W. B. Cobb.

SOIL SURVEY OF HOWARD COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1919, by M. W. Beck, M. Y. Longacre, F. A. Hayes, and W. T. Carter, Jr.

SOIL SURVEY OF JEFFERSON COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1916, by B. W. Tillman, R. R. Burn, W. B. Cobb, Clarency Lounsbury, and G. G. Strickland.

SOIL SURVEY OF LONOKE COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1925, by E. W. Knobel, Clarence Lounsbury, L. V. Davis, E. D. Fowler, and A. W. Goke.

SOIL SURVEY OF MILLER COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1904, by J. O. Martin and E. P. Carr.

SOIL SURVEY OF MISSISSIPPI COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1916, by E. C. Hall, T. M. Bushnell, L. V. Davis, W. T. Carter, Jr., and A. L. Patrick.

SOIL SURVEY OF MISSISSIPPI COUNTY, ARKANSAS, U.S.Department of Agriculture, Soil Conservation Service, June 1971, by D. V. Ferguson and J. L. Gray.

SOIL SURVEY, OUACHITA COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, May 1973, by V. C. Catlett.

SOIL SURVEY OF PERRY COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1923, by E. B. Deeter, T. M. Bushnell, and L. A. Wolfanger.

SOIL SURVEY OF POPE COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1915, by Clarence Lounsbury and E. B. Deeter.

SOIL SURVEY OF PRAIRIE COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1906, by W. T. Carter, Jr., F. N. Meeker, H. C. Smith, and E. L. Worthen.

SOIL SURVEY OF PULASKI COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1926, by E. B. Deeter, A. H. Meyer, and T. H. Benton.

SOIL SURVEY, ST. FRANCIS COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, November 1966, by J. L. Gray and V. R. Catlett.

SOIL SURVEY OF THE STUTTGART AREA, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1902, by J. E. Lapham.

SOIL SURVEY, WASHINGTON COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, March 1969, by M. D. Harper, W. W. Phillips, and G. J. Haley.

SOIL SURVEY, WOODRUFF COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, August 1968, by G. R. Maxwell, J. V. Clark, G. R. Dahlke, and J. E. Hoelscher.

SOIL SURVEY OF YELL COUNTY, ARKANSAS, U.S. Department of Agriculture, Bureau of Soils, 1917, by E. B. Deeter and Clarence Lounsbury.

Group 2H--Lakes

ENVIRONMENTAL CHANGES PRODUCED BY COLD-WATER OUTLETS FROM THREE ARKANSAS RESERVOIRS.

For primary bibliographic entry see 6G.

DARDANELLE RESERVOIR ILLINOIS BAYOU EMBAYMENT BACKGROUND SURVEY, PROGRESS REPORT No. 9

For primary bibliographic entry see 6G.

DARDANELLE RESERVOIR ILLINOIS BAYOU EMBAYMENT BACKGROUND SURVEY, PROGRESS REPORT No. 12.

For primary bibliographic entry see 6G.

PRELIMINARY REPORT ON THE HYDROLOGY OF HORSESHOE LAKE, ARKANSAS, U.S. Geological Survey administrative report, August 1970, by A. G. Lamonds.

This report summarizes the results of the first year of study of the factors that affect the stage of Horseshoe Lake. Pumpage (1970) from the lake is small and changes in lake level are a result of natural factors such as variations in precipitation, evaporation, and underground seepage into or out of the lake.

The lake stage normally ranges from 190 to 193 feet mean sea level but in dry years may be as low as 186 feet mean sea level. The frequency in which unusually low lake levels occur has increased in the last 15 or 20 years. This is due to the fact that the lake receives less floodwater from Fish Bayou because of drainage improvements made on the St. Francis River and an increase in net seepage from the lake as a result of lower average annual stage of the Mississippi River.

Alternative sources of water for supplementing the inflow to the lake are pumpage from the Mississippi River or from nearby wells.

HYDROLOGY OF HORSESHOE LAKE, ARKANSAS, U.S. Geological Survey open-file report, 1971, by A. G. Lamonds.

"During the summer and fall, seepage and evaporation losses from Horseshoe Lake, an oxbow or an "old river" lake adjacent to the Mississippi River, exceed inflow to the lake, and seasonal declines of 2.5-3.0 feet in the lake level are common. In exceptionally dry years, the minimum lake level has been as much as 4 feet below the normal seasonal low. These low levels severely affect the recreational uses of the lake.

"Seepage and evaporation rates at Horseshoe Lake were determined from hydrologic and meterologic data. Analysis of these data indicates that the direction of seepage is out of the lake except for a period of about 2 months in the spring, when the stage of the Mississippi River is high.

"The lake can be maintained at a constant level by supplementing the inflow to the lake with surface or ground water. Contributions to the lake from local drainage can be increased, but this water contains undesirable amounts of pesticides, herbicides, and plant nutrients, and the flow is insufficient to eliminate seasonal declines in the lake level. Water from the Mississippi River can be used to maintain a given lake level, but the bacteriological quality of water from the river makes this an undesirable source of supplemental water. Water from the Quaternary alluvium contains troublesome amounts of iron, but it probably is free of pesticides, herbicides, and coliform bacteria which are commonly found in surface water.

"An electric-analog model was used to determine the rate at which inflow to the lake must be supplemented to maintain various lake levels. During this investigation, the lake could have been maintained very near the normal spring level by supplementing the inflow at a maximum rate of 10,600 gallons per minute. The analog model was also used to determine the effects of pumping wells on seepage. With the exception of wells near the southeast end of the lake, wells located within one-half mile of the lake would obtain more than 50 percent of their yield from the lake after pumping for 90 days."

LAKES OF ARKANSAS, Arkansas Soil and Water Conservation Commission, 1968.

Listed in this report are all lakes in Arkansas of 5 acres, or more, surface area. Lake locations are shown by township, range, and section and are tabulated by county. A total of 2,318 lakes in 71 of the 75 counties are shown. The grand total of lake surface area in Arkansas is 506,468 acres.

In the tables the owner of the lake, the use, and the lake capacity are given.

THERMAL SURVEY OF DARDANELLE RESERVOIR, U.S. Geological Survey open-file report, 1970, by J. N. Sullavan.

Depth of water and vertical water-temperature profiles were obtained at 11 or more points in each of 3 cross sections at 4 points in Dardanelle Reservoir during July, August, and September 1967. Air temperature, reservoir stage and flow, and the water-temperature data are listed in six tables. The maximum difference between surface and bottom temperature was about 8°F and in some locations the surface and bottom temperatures were the same. The maximum depth observed was 51.5 feet.

DARDANELLE RESERVOIR, Arkansas Polytechnic College, Russelville, Arkansas, prepared by the Faculty Advisory Committee for Leisure Science.

The report contains information on the history, geology, archeology, paleontology, fish, wildlife, plantlife, and recreation resources of the Lake Dardanelle area. The reservoir contains a conservation pool of 34,300 surface acres with a shoreline of 315 miles. Water-based recreation activities are a focal point of interest. Twenty public-use areas and the locations and facilities available at each are listed. An appendix contains drawings and a key for identification of trees and plants in the area.

RESERVOIRS FOR IRRIGATION IN THE GRAND PRAIRIE AREA, AN ECONOMIC APPRAISAL, University of Arkansas, Agricultural Experiment Station Bulletin 606, December 1958, by Arthur Gerlow and Troy Mullins.

The rapid decline in the supply of ground water in the Grand Prairie area has stimulated interest in reservoirs as a means of utilizing surface water for rice irrigation. Most of the reservoirs are less than 40 acres, are located on cropland, and are complete enclosures rather than impoundments with only one or two sides leveed. The cost of fill work for complete enclosures averaged $106 per acre enclosed.

Another major cost item is the pumping plant for moving water into or out of the reservoir. Smaller units used for discharging water cost about $1,900 each; larger units used for filling the reservoir cost about $3,600. The estimated average investment for land, levee construction, and pumping plants for 20-, 40-, 80-, and 160-acre completely enclosed reservoirs was $7,403, $12,074, $20,711, and $38,249, respectively.

The completely enclosed reservoirs in the survey were used to irrigate an average of 1.7 acres of rice per surface acre within the reservoirs. At this level of efficiency, it is estimated that the costs per acre of rice irrigated would range from $19.24 for a 20-acre reservoir to $12.47 for a 160-acre reservoir.

Data were compiled on cost of irrigating from wells and compared with the cost summaries for reservoirs. For 32 wells powered with electricity, the costs per acre of rice irrigated average $14.42. Only the 80- and 160-acre reservoirs could be used to irrigate at a lower cost per acre than by use of wells.

DISTRIBUTION OF TRACE ELEMENTS IN IMPOUNDMENTS, Arkansas Water Resources Research Center Publication Number 6, 1970, by J. F. Nix.

"Results indicate that the chemical regime of the impoundments which were studied was greatly influenced by the cool water releases from an upstream impoundment. A cold reservoir furnished dissolved oxygen to the lower portion of the impoundments and prevented the accumulation of large quantities of iron and manganese. More typical hypolimnic conditions were observed in the side pockets of the reservoir.

"Data suggest that outside of hypolimnic zones in the reservoir, soluble iron is present in very small quantities, usually less than ten parts per billion."

LIMNOLOGICAL STUDIES IN ARKANSAS, 1, PHYSICO-CHEMICAL AND NET PLANKTON STUDIES OF LAKE FORT SMITH IN ITS FOURTH YEAR OF IMPOUNDMENT, Proceedings, Arkansas Academy of Science, volume 5, 1952, by C. E. Hoffman and David Causey.

LIMNOLOGICAL STUDIES IN ARKANSAS, 2, THE EFFECT OF INTENSE RAINFALL ON THE ABUNDANCE AND VERTICAL DISTRIBUTION OF PLANKTON IN LAKE FORT SMITH, ARKANSAS, Proceedings, Arkansas Academy of Science, Volume 5, 1952, by C. E. Hoffman.

SOUTH CENTRAL RESERVOIR INVESTIGATIONS, 1965 ANNUAL REPORT, Fayetteville, Arkansas, 1965, by T. O. Duncan, J. W. Mullan, W. R. Heard, and Alfred Houser.

NATIONAL RESERVOIR RESEARCH PROGRAM, 1965 ANNUAL REPORT, Fayetteville, Arkansas, 1965, by R. M. Jenkins.

Group 2I--Water and plants

THERMOPHILIC BLUE-GREEN ALGAE IN HOT SPRINGS NATIONAL PARK, MASTERS THESIS, East Texas State University, 1970, by J. C. Tankersley III.

The purpose of the study was to survey the two open (display) springs; to confirm the presence of *Phormidium treleasei* Gomont; to examine the springs for other algae present; and to benefit the public and science by correcting some of the outdated and erroneous information currently being disseminated about the hot springs.

After data were collected of the physical and chemical limits of the springs, samples, as well as 35-mm color slides of materials collected at specific stations, were sent to three well-known authorities in this field. After receiving their opinions, it was determined that *Phormidium treleasei* were not present in the material examined. A listing of each algae (or any other plant or animal found) identified, its location, and the temperature range of its environment was compiled. The results were compared with an earlier survey. A total of 13 species of blue-green algae were identified, the majority of which were living. The rest were identified from either preserved material or photographs.

Although the presence of *Phormidium treleasei* Gomont was not established, the study brought to light new records of blue-green algae species for Hot Springs, Arkansas: *Anabaena variabilis*, *Anacystis thermalis*, *cylinderosperum* sp., *Mastigocladus laminosus* f. anaboenoid, *Nostoc* sp., *Plectonema notatum*, *Phormidium purpurascens*, *Phormidium ramonsum*, *Phormidium tenue*, *Plectonema gracillimum*, *Plectonema nostocorum*, *Porphyrosiphon notarisii*, and *Schizothrix calcicola*. Other types of organisms which have not been reported previously are: Flexibacteria, *Nitzschia* sp., Protozoan cyst, and *Ulothrix* sp.

FOREST SPECIES AS INDICATORS OF FLOODING IN THE LOWER WHITE RIVER VALLEY, ARKANSAS, U.S. Geological Survey Professional Paper 750-C, p. C248-C253, 1971, by M. S. Bedinger.

"The dominant environmental factor of forest habitats within the lower valley of the White River, Ark., is flooding. The flood plain consists of a series of terraces. Distribution of forest species on the terrace levels is related to flooding. The relationship is sufficiently distinct to permit determination of flood characteristics at a given site by evaluation of forest-species composition. The vegetation of the lower White River valley can be divided into four groups. Each group occurs on sites having distinctly different flooding characteristics On sites flooded 29-40 percent of the time, the dominant species are water hickory and overcup oak. On sites flooded 10-21 percent of the time, a more varied flora exists--including nuttall oak, willow oak, sweetgum, southern hackberry, and American elm. The third group of sites is subject to flooding at intervals of from 2 to 8 years. This group is marked by presence of southern red oak, shagbark oak, and black gum. The presence of blackjack oak marks the fourth group (not flooded in historic times)."

THE DESTRUCTION OF OUR MOST VALUABLE WILDLIFE HABITAT, Arkansas Planning Commission, October 1969, by T. H. Holder.

DISAPPEARING WETLANDS IN EASTERN ARKANSAS, Arkansas Planning Commission, 1970, by T. H. Holder.

"The study has revealed that the destruction of wetlands and woodlands in the Delta Region of Arkansas has reached almost catastrophic proportions. Approximately 150,000 acres of Delta timberlands have been cleared during each of the last 10 years. This rate of clearing cannot be maintained for many more years because considerably less than 2 million acres of woodlands remain in the entire 10-million acre Delta Region in eastern Arkansas. The annual rate is expected to decline but it appears that ultimately, unless some definite and aggressive action is taken to the contrary, practically every privately owned wooded area in eastern Arkansas will be cleared."

Recommendations in the report include:

1. Institute a direct action program to preserve wetlands and associated woodlands [details for nine direct-action programs are given];

2. Encourage the preservation of Delta wetlands and associated woodlands by providing economic incentives to landowners [three methods are outlined]; and

3. Discourage the destruction of Delta wetlands and woodlands through establishing a policy to suppress bringing additional agricultural land into production until there is a national need for more agricultural land, review all Federal construction projects, expand zoning regulations to include protection of woodlands, and enact State legislation for stream preservation.

LET'S DO SOMETHING GOOD FOR THE ENVIRONMENT DOWN ON THE CACHE RIVER DITCH, Arkansas Department of Pollution Control and Ecology, 1973, by T. H. Holder.

Spoil banks along the Cache River are comprised of very fertile soil that left to their own fate will soon be covered with cottonwood and willow. These trees have very low value for most varieties of wildlife. Pecan, oak, hickory, mulberry, wild cherry, and many other varieties are famous as food for wildlife and will grow well on the spoil banks.

Several groups, such as the Green Thumb workers, Boy Scouts, and governmental agencies, are working to plant seeds and seedlings of a large variety of trees and shrubs that are more beneficial to wildlife. One of the main problems is a shortage of suitable high-quality stock to plant. Suitable material can be delivered to the Arkansas Deaf School in Little Rock where it will be picked up and planted on the spoil banks along the Cache River.

ARKANSAS FORESTS, U.S. Department of Agriculture, Forest Service, 1960, by H. E. Sternitzke.

The report provides information on the kind, amount, and condition of forest resources as of 1960, the industries they support, and the possibilities for improving wood production. Comparison with the inventory that was completed in 1951 shows the forests are greater in area by 7 percent, or about 1.4 million acres. This survey shows that 62 percent of Arkansas' total land area is in forests. Softwood growing stock (mostly pine) has increased nearly a third, and softwood sawtimber has gained 44 percent. However, these gains are mostly in the northwestern half of the State and 26 percent in the Coastal Plain of Arkansas between 1935 and 1960.

PLANTS AS INDICATORS OF GROUND WATER, U.S. Geological Survey Water-Supply Paper 577, 1927, by O. E. Meinzer.

IRON CONTENT OF SELECTED WATER AND LAND PLANTS, U.S. Geological Survey Water-Supply Paper 1459-G, 1960, by E. T. Oborn.

DENDROCHRONOLOGY IN PINES OF ARKANSAS, Ecology, Volume 23, Number 3, July 1942, by Edmund Schulman.

Group 2J--Erosion and sedimentation

FLUVIAL SEDIMENT IN SIXMILE CREEK SUBWATERSHED SIX NEAR CHISMVILLE, ARKANSAS, U.S. Geological Survey open-file report, 1971, by H. R. Fancher, Jr.

"From 1957 to 1970, 4,288 tons of suspended sediment was discharged from subwatershed six reservoir. During this time the average annual runoff was about 13.2 inches.

"Particle-size analyses indicated that most of the sand carried into the reservoir was retained. The highest measured inflow-sediment concentration was 10,300 milligrams per litre. The highest measured outflow-sediment concentration was 761 milligrams per litre, and the highest daily sediment discharge was 49 tons.

"The trap efficiency of reservoir six was about 95 percent for the 14-year period of the study."

A RECONNAISSANCE INVESTIGATION OF SEDIMENTATION IN LAKE WINONA, SALINE COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, June 1950, by V. H. Jones and J. A. Ogle.

A RECONNAISSANCE INVESTIGATION OF SEDIMENTATION IN LAKE HAMILTON, HOT SPRINGS, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, June 1950, by J. A. Ogle.

ADVANCE REPORT ON THE SEDIMENTATION SURVEY OF LAKE BENNETT, CONWAY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, October 1936, by L. M. Glymph, Jr., and V. H. Jones.

ADVANCE REPORT ON THE SEDIMENTATION SURVEY OF LAKE BOONEVILLE, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, November 22-December 4, 1935, by L. M. Glymph, Jr., and V. H. Jones.

Group 2K--Chemical processes

A PRIMER ON WATER QUALITY.

For primary bibliographic entry see 2A.

Field 3--WATER SUPPLY AUGMENTATION AND CONSERVATION

Group 3A--Saline water conversion

MAP SHOWING ALTITUDE OF THE BASE OF FRESH WATER IN COASTAL PLAIN AQUIFERS OF THE MISSISSIPPI EMBAYMENT.

For primary bibliographic entry see 2F.

Group 3B--Water yield improvement

No entries.

Group 3C--Use of water of impaired quality

No entries.

Group 3D--Conservation in domestic and municipal use

No entries.

Group 3E--Conservation in industry

No entries.

Group 3F--Conservation in agriculture

RESERVOIRS FOR IRRIGATION IN THE GRAND PRAIRIE AREA, AN ECONOMIC APPRAISAL.

For primary bibliographic entry see 2H.

SURVEY OF AGRICULTURAL ASPECTS, ARKANSAS RIVER MULTIPLE-PURPOSE PROJECT, PHASE I, U.S. Department of Agriculture, November 1960.

EFFECTS OF THE ARKANSAS RIVER MULTIPLE-PURPOSE PROJECT ON AGRICULTURAL PRODUCTION, VOLUME I, MAIN REPORT, U.S. Department of Agriculture, Soil Conservation Service, June 1970.

CATFISH FEEDING AND GROWTH, U.S. Department of the Interior, Fish and Wildlife Service, Bureau of Sports Fisheries and Wildlife, Fish Farming Experiment Station, Stuttgart, Arkansas.

CONSTRUCTION COSTS, OPERATIONAL EXPENSES AND METHODS EMPLOYED IN FISH FARMING (as above).

RESERVOIRS FOR FISH-RICE FARMING, U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Fish Farming Experiment Station, Stuttgart, Arkansas, FWS Circular 125.

IRRIGATION FOR ARKANSAS, University of Arkansas, Agricultural Extension Service, College of Agriculture and Home Economics Leaflet No. 211, June 1954.

ARKANSAS CONSERVATION NEEDS INVENTORY, U.S. Department of Agriculture, Soil Conservation Service, Arkansas Soil and Water Conservation Commission, June 1969.

Field 4--WATER QUANTITY MANAGEMENT AND CONTROL

Group 4A--Control of water on the surface

CONSERVATION OF WATER AND RELATED LAND RESOURCES, BUFFALO RIVER BASIN, ARKANSAS, INTERIM REPORT.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, CANAL 18 WATERSHED, DESHA AND DREW COUNTIES, ARKANSAS.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, LEE-PHILLIPS WATERSHED, LEE AND PHILLIPS COUNTIES, ARKANSAS.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, WELLS BAYOU WATERSHED, DESHA COUNTY, ARKANSAS.

For primary bibliogrpahic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, REDFORK WATERSHED, DESHA COUNTY, ARKANSAS.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, ARK-LA WATERSHED, CHICOT COUNTY, ARKANSAS, AND EAST CARROLL PARISH, LOUISIANA.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, CROOKED LAKE BAYOU WATERSHED, MISSISSIPPI COUNTY, ARKANSAS.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, MUD CREEK WATERSHED, INDEPENDENCE COUNTY, ARKANSAS.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, CROOKED BAYOU WATERSHED, CHICOT COUNTY, ARKANSAS.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, FLESCHMAN'S BAYOU WATERSHED, ASHLEY AND CHICOT COUNTIES, ARKANSAS.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, CANEY BAYOU WATERSHED, CHICOT COUNTY, ARKANSAS.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, WHITE RIVER BACKWATER WATERSHED, PHILLIPS, DESHA, AND MONROE COUNTIES, ARKANSAS.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, HANEY CREEK WATERSHED, LITTLE RIVER COUNTY, ARKANSAS.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, GARRET BRIDGE WATERSHED, LINCOLN COUNTY, ARKANSAS.

For primary bibliographic entry see 6B.

WORK PLAN FOR WATERSHED PROTECTION AND FLOOD PREVENTION, WESTFORK POINT REMOVE CREEK WATERSHED, CONWAY, POPE, AND VAN BUREN COUNTIES, ARKANSAS.

For primary bibliographic entry see 6B.

Group 4B--Ground water management

MEMORANDUM IN REGARD TO POSSIBLE CONSERVATION OF GROUND-WATER SUPPLIES IN GRAND PRAIRIE REGION, ARKANSAS, BY MEANS OF RECHARGE WELLS, AND BY RESERVOIRS FOR IMPOUNDING SURFACE WATER, 1931, by D. G. Thompson.

Artificial recharge is a method that might be used in the Grand Prairie region to counteract the effect of past over-draft of the ground-water supply. The method has been practiced in California with very effective results. In California, recharge has been brought about by water spreading across large expanses of sand or gravel. This method is not applicable in the Grand Prairie because the water-bearing beds are overlain by a considerable thickness of clay through which little water percolates. Consequently, effective artificial recharge in the Prairie would have to be accomplished through wells.

No data are available that might indicate whether recharge through a well in the Grand Prairie region would be feasible, the cost of using a recharge well, or the problems to be solved in using one. A significant problem to be considered is that recharge water at times would carry more or less finely divided sediment that might clog the recharge well and render it useless. Thompson believes that recharge by means of wells in the Prairie is possible but whether it can be done at a cost low enough to make it economically practical has to be determined.

Substitution of surface water for ground water to irrigate rice offers a second method of conserving the ground-water supply in the Grand Prairie region. Diversion of water from the White River near DeValls Bluff, Ark., has been given considerable thought as a source of surface water for rice irrigation. Also Bayou Meto, Bayou Lagrue, and smaller streams in the area have been considered. However, the flow in these streams is very low at times and it doubtless would be necessary to have standby wells to provide water in a dry season.

A plan that warrants further consideration is to provide storage by building levees around timbered areas or "islands" that lie a very few feet below the level of the Prairie. In order to not interfere with the natural drainage it might be necessary to pump water over the levees into the reservoir, but the cost of doing so would be very little as compared to the cost of lifting the water 75 to 100 feet or more from wells as at present. Items to be considered in this kind of development of surface water are the cost of the land, the cost of levees, the cost of pumping to collect water and distribute it, and the balance between evaporation and transportation.

STUDIES OF ARTIFICIAL RECHARGE IN THE GRAND PRAIRIE REGION, ARKANSAS; ENVIRONMENT AND HISTORY, U.S. Geological Survey Water-Supply Paper 1615-A, 1963, by Kyle Engler, F. H. Bayley 3d, and R. T. Sniegocki.

"The Grand Prairie region of Arkansas is unique in many respects. It is peculiarly adapted to rice cultivation because of an abundant supply of irrigation water, an extensive 'clay cap' that holds the water without excessive loss by downward percolation, and relatively level land which permits the construction of well-spaced levees.

"The cultivation of rice began in the Prairie in 1904. The annual withdrawal of large quantities of water from deposits of Quaternary age to irrigate rice since that time has resulted in a gradual decline of water levels, until the Prairie is now considered a water-problem area.

"In 1951 the U.S. Congress authorized the U.S. Army Corps of Engineers to undertake studies of artificial ground-water recharge in the Grand Prairie region. In 1953 the U.S. Geological Survey began a research study in the Grand Prairie to investigate the fundamental principles of artificial recharge to an aquifer. These two factors, coupled with the interest in the University of Arkansas in artificial recharge, marked the beginning of the project. To avoid duplication of effort, the three agencies pooled resources and cooperated excellently in the exchange of information throughout the course of the study.

"The purpose and scope of study differ slightly for each agency. Generally, however, the objective is to determine the feasibility of relieving ground-water shortages by injecting surface water through wells."

HYDROGEOLOGY OF A PART OF THE GRAND PRAIRIE REGION, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1615-B, 1964, by R. T. Sniegocki.

"The first phase of the study of artificial recharge through wells in the Grand Prairie consisted of the collection and interpretation of detailed geologic and hydrologic information in the vicinity of the proposed recharge-test site. This report is the result of that hydrogeologic investigation.

"Test drilling and construction of observation wells were extensive within a 24-square mile area around the recharge-test site. Geologic sections and isopach maps of various hydrogeologic units show that the deposits of Quaternary age are continuous over a large area. These deposits consist of two major zones--namely, a basal zone of sand and gravel blanketed by an upper zone of very dense, relatively impervious silt and clay. It has not been possible to distinguish with any certainty the Recent from the Pleistocene parts of the Quaternary deposits. Particle-size analyses of samples of the aquifer sand collected near the recharge well show that the material had an effective size of 0.06 to 0.25 mm and a uniformity coefficient of 5.8 to 1.4.

"Aquifer coefficients were determined by means of conventional pumping-test methods and by evaluation of drill cuttings from test holes. The coefficient of storage of the aquifer where it is unconfined was determined to be approximately 0.30. Application of this coefficient to the volume of unwatered sand in the Grand Prairie region indicates the removal of at least 2 million acre-feet of water from storage since 1906 as a result of rice irrigation. This large volume of unwatered sand provides potential storage space for an equivalent quantity of water.

"Chemical analyses of samples of ground water collected from the aquifer show that waters in the project area are of the calcium bicarbonate type. There is some variation in the concentration of dissolved solids and of the individual constituents, but the quality of the ground water is relatively uniform during a pumping season and in different wells within the area.* * *"

EQUIPMENT AND CONTROLS USED IN STUDIES OF ARTIFICIAL RECHARGE IN THE GRAND PRAIRIE REGION, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1615-C, 1963, by R. T. Sniegocki, F. H. Bayley 3d, and Kyle Engler.

"Studies of artificial recharge have been underway in the Grand Prairie region since 1953. The studies have required the use of many different kinds of equipment and control procedures.

"Recharge-well specifications were not available; therefore, well design was considered to be an integral part of this investigation. Certain generalities regarding well construction may be stated, but this study does not conclusively establish a design for recharge wells.

"Much of the equipment and control used have been adapted to field conditions from standard methods. The practicality of recharge operations, with special regard for simplicity and cost, has been considered as much as possible in the field layout.

"Essentially, the equipment and procedures used were satisfactory for conducting an experimental recharge operation. Some difficulty was experienced when attempting to repeat test conditions or maintain constant testing conditions for a prolonged period of time."

PRINCIPLES OF SIPHONS WITH RESPECT TO THE ARTIFICIAL-RECHARGE STUDIES IN THE GRAND PRAIRIE REGION, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1615-D, 1963, by R. T. Sniegocki and J. E. Reed.

"In artificial-recharge experiments in the Grand Prairie region, siphoning has caused both favorable and adverse effects. This report discusses these effects and methods of utilizing or minimizing them. For any recharge rate, negative pressure exists in the injection line when water is siphoned into the recharge well. The length of the injection line in which the vapor-pressure limit prevails is principally controlled by the depth to water in the recharge well. Filtering through a closed system into the recharge well allows the negative head to increase normal filter-head loss and destroys filter effectiveness. A valve at the discharge end of the injection line provides a means of eliminating negative pressure in the line."

GEOCHEMICAL ASPECTS OF ARTIFICIAL RECHARGE IN THE GRAND PRAIRIE REGION, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1615-E, 1963, by R. T. Sniegocki

"Chemical changes in the injected water and native ground water during artificial recharge through a well have an important bearing on the success or failure of recharge-well operation. Water stability and changes in chemical quality of the water that may be caused by changed environment should be examined critically when contemplating recharge. In this study the principal chemical changes observed that may cause clogging of the recharge well and aquifer were a change in calcium carbonate saturation of the injected and native water, whereby the calcium carbonate precipitated; precipitation of iron when reducing and oxidizing waters are mixed; ion exchange and clay dispersion; and changes in water stability caused by water treatment.

"The native ground water at the test site was stable with respect to its environment. However, the injected water tended to pick up carbon dioxide as it moved through the aquifer. Native ground water would readjust to the changed environment upon reentry into the zone of carbon dioxide depletion causing deposition of calcium carbonate.

"The Eh-pH relationship of the native ground water and recharge water could cause iron to be precipitated as ferric hydroxide at the interface of the ground water and injected water in the aquifer. Incomplete removal of the injected water would tend to cause an accumulation of precipitated iron in the aquifer, eventually plugging a large volume of material.

"The native ground water averaged about 25 percent sodium and in the injection supply averaged about 45 percent. Surface water injected into the aquifer would displace the native ground water and increase the abundance of monovalent cations surrounding aquifer materials, thus creating favorable conditions for ion exchange. However, most of the aquifer materials are chemically inert, and clay dispersal caused by ion exchange probably was not a serious clogging factor.

"The chemical treatment of surface water by coagulation with alum and chlorination with chlorine gas caused most of the changes in chemical quality. Although the treated water may have been stable with respect to its aluminum content in the settling canal, mixing with the native ground water in the aquifer could alter the pH and alkalinity of the two solutions. This would cause postinjection flocculation of residual aluminum and subsequent clogging of the aquifer. Heavy chlorination of the injected water also may cause clogging owing to precipitation of iron and other metals. Dissolved iron and organic matter are easily oxidized by chlorine. Iron precipitated in this manner would tend to lower aquifer permeability, and oxidation of organic matter would release gases, leading to air entrainment.

"Well redevelopment is an important phase in water injection and may provide the means for economical and practical operation of a recharge well."

PROBLEMS IN ARTIFICIAL RECHARGE THROUGH WELLS IN THE GRAND PRAIRIE REGION, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1615-F, 1963, by R. T. Sniegocki.

"Most of the problems of recharge through wells involve clogging of the well and aquifer. In this study, the principal causes of clogging were air entrainment, suspended particles in the recharge water, and micro-organisms. Other problems in operating a recharge well included the effects of injecting water with a high viscosity and the interpretation of water-level changes in the aquifer during recharge tests. The results of this investigation indicate that wells should be recharged with treated water. Water-treatment cost and contemplated use of the reclaimed water are the principal factors involved in determining the economic feasibility of artificial recharge."

TESTING PROCEDURES AND RESULTS OF STUDIES OF ARTIFICIAL RECHARGE IN THE GRAND PRAIRIE REGION, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1615-G, 1965, by R. T. Sniegocki, F. H. Bayley 3d, Kyle Engler, and J. W. Stephens.

"Two differently constructed wells were used to make 23 recharge tests, all but one using surface water treated in various ways. The degree of water treatment used in early tests was reduced in some of the later tests. Slightly more than 23 million gallons of water was recharged during the series. A summary of the procedures and pertinent data for each test are given in this report.

"A prerequisite to successful recharge through a well at the test site was the availability of a supply of water having very low turbidity and few micro-organisms. An analysis of the cost of recharge through wells, based on the results of this study, showed that water which had been recharged and recovered for use would cost more than $30 per acre-foot. The major item contributing to the total recharge cost was the treatment of an injection supply to obtain water having low turbidity and few micro-organisms.

"A coarse-grained media filter might be used to reduce water-treatment costs of some waters. However, the results of filtration tests at the recharge site were unsatisfactory, apparently because of unknown filtration characteristics of the injected supply."

LABORATORY STUDY OF AQUIFER PROPERTIES AND WELL DESIGN FOR AN ARTIFICIAL-RECHARGE SITE, U.S. Geological Survey Water-Supply Paper 1615-H, 1966, by A. I. Johnson, R. P. Moston, and S. F. Versaw.

"The first phase of study of artificial recharge through wells in the Grand Prairie region of Arkansas was the collection of detailed geologic and hydrologic data from the proposed test site. Hydrologic and physical properties of the aquifer were determined from analysis of samples taken at the recharge well and from nearby test holes. The samples were analyzed in the Hydrologic Laboratory of the U.S. Geological Survey.

"Using laboratory-analysis data, quantitative aquifer characteristics were estimated--a coefficient of transmissibility of 60,000 gallons per day per foot and a specific yield, or coefficient of storage, of about 0.34. Laboratory data also were used to predict a specific capacity of 30 gallons per minute per foot of drawdown for the proposed recharge well.

"The aquifer is fairly uniform in particle-size distribution; gravel content is highest in the basal Quaternary sediments deeper than 115 feet, where the median diameter is about 0.5 mm and the uniformity coefficient between 1 and 2. The upper Quaternary sands are less uniform; they consist mostly of very fine particles having a median diameter near 0.1 mm and a uniformity coefficient averaging about 16.

"Particle-size analyses were used to develop filter-pack (gravel-pack) and well-screen designs for recharge well 2. An artificially placed filter pack was recommended for the aquifer below 115 feet in depth. A 1.6 mm (0.064 in., or No. 60) slot was recommended for the well screen, combined with a filter pack made up of material having a median diameter of about 2 mm.

"Construction of recharge well 2 did not conform to design specifications. The filter pack had a median particle diameter of about 0.7 mm, or approximately one-third the size originally recommended, and the screen had only a 0.016-inch slot. A decrease in permeability was observed during the test of recharge well 2, and laboratory experiments confirmed the belief that this reduction was due to the design of the filter pack and the manner of its placement. The experiments indicated that compaction of the filter pack caused by surging action from well development and from pumping and injection tests, could cause a permeability reduction of approximately 25 percent."

GROUND WATER-SURFACE WATER INTEGRATION STUDY IN THE GRAND PRAIRIE OF ARKANSAS, Arkansas Water Resources Research Center, Publication Number 11, December 1972, by C. L. Griffis.

"A mathematical model of the Quaternary Aquifer of the Grand Prairie, Arkansas, was developed and used to evaluate a variety of methods of artificially recharging this aquifer. In addition, the model was used to evaluate the impact of various levels of water management and the probable movement of artificially recharged water in the aquifer.

"Improved water management and the use of recharge wells were the two alternatives that showed the most promise as potential solutions. The rate of movement of recharged water was determined by the model to be 300 ft/year under a gradient of 16 ft/mile."

DRAINAGE OF WET LANDS IN ARKANSAS BY WELLS, U.S. Geological Survey Water-Supply Paper 160, 1906, by A. F. Crider.

Crider points to the successful use of drainage wells in France, Georgia, and Michigan and indicates that perhaps the method would be useful in Arkansas in the Coastal Plain where drainage would be desirable. Methods, costs per acre, and value of drainage are discussed.

Crider states that in southeastern Missouri land worth $3 an acre sold for $50 to $100 an acre after drainage was achieved through the use of canals.

ARKANSAS' COURSE IN WATER MANAGEMENT, The Arkansas Economist, Volume 1, Number 3, University of Arkansas, College of Business Administration, Spring 1959, by Abel Wolman.

This article is adapted from an address delivered to the Arkansas Water Conference study group, February 12, 1959, Hotel Marion, Little Rock.

Wolman points out that Arkansas is rich if not profligate in its potential water resources and is ripe for water management. He compliments the State on moving slowly in developing water laws and although present laws (1959) have no teeth in them, Wolman considers this a sound modest approach.

Strong advice is given concerning realities of life--that the State of Arkansas is going to move in the water-resources field before all the knowledge is at hand. However, although it is important that the State move toward action, it is equally important that water-resources knowledge be accumulated while in motion. For the State of Arkansas, the principle to gradualism should prevail.

The middle road is the best, the one between the opportunist and the perfectionist. The opportunist wants to do something yesterday that he does not quite well understand and the perfectionist does not want to do anything until many years hence because he does not understand.

Wolman recommends a three-party program for action: private development wherever possible, public development where necessary, but only where necessary by the State, and lastly, Federal development only where necessary by the Federal Government.

GROUND WATER IN PERSPECTIVE, American Water Resources Association, Water Resources Bulletin, Volume 9, number 1, February 1973, by R. L. Nace.

"Owing to their enormous capacity, ground-water reservoirs are at least equal in importance to the ground water itself. As regulators of water movement in the hydrological cycle, these reservoirs surpass all lakes combined, natural and manmade. While many aquifers are not well understood, data on many others are adequate for long-range broadscale planning. An example is the basalt aquifer of the Snake River Plain in Idaho. However, the area has managerial problems which concern the time, the place and the feasibility of manipulations of water. All continents of the world contain great aquifers. For every huge aquifer, however, hundreds of smaller ones occur, and even these contain astonishing amounts of water. Aquifers in the Ohio River Basin of the United States are good examples. Management of total water resources is a difficult problem at many places. But many problems could be met and many water shortages alleviated or eliminated by use of aquifers, not merely as sources of water, but as reservoirs for management of water."

ANALOG SIMULATION OF WATER-LEVEL DECLINES IN THE SPARTA SAND, MISSISSIPPI EMBAYMENT, U.S. Geological Survey Hydrologic Investigations Atlas HA-434, 1972, by J. E. Reed.

An analog model of the Sparta Sand was used to predict and evaluate the regional effect of increasing future water withdrawals from the Sparta. The locations and rates of pumping of present (1970) and proposed new withdrawals were projected to the year 1990. The 1965 withdrawal rate was about 350 mgd; the 1990 withdrawal rate was estimated to be 630 mgd. The model response to projected pumping is shown by means of contour lines on a map of the Mississippi embayment.

The principal areas of withdrawals of water from the Sparta Sand in Arkansas are near Magnolia, El Dorado, Pine Bluff, and West Memphis. For the period 1886-1965, water levels in the Sparta had declined about 220 feet near Magnolia, 300 feet near El Dorado, 200 feet near Pine Bluff, and 100 feet near West Memphis. For the period 1886-1990, water level declines at these same locations were shown by the model to be 450 feet near Magnolia, 450 feet near El Dorado, 350 feet near Pine Bluff, and 120 feet near West Memphis. Declines of this magnitude will place the water level below the top of the aquifer in places and will greatly decrease well yields as the transmissivity is reduced.

PROGRESS REPORT ON STUDIES OF ARTIFICIAL RECHARGE IN THE GRAND PRAIRIE REGION, ARKANSAS, U.S. Geological Survey open-file report, 1954, by R. T. Sniegocki.

ARTIFICIAL-RECHARGE EXPERIMENTS IN THE GRAND PRAIRIE REGION OF ARKANSAS, Water for Texas Conference Proceedings, 3d Annual, 1957, by R. T. Sniegocki.

ARTIFICIAL-RECHARGE EXPERIMENTS IN THE GRAND PRAIRIE REGION OF ARKANSAS, Southwest Water Works Journal, Volume 39, Number 9, December 1957, by R. T. Sniegocki and J. W. Geurin.

PROGRESS REPORT ON STUDIES OF ARTIFICIAL RECHARGE IN THE GRAND PRAIRIE REGION, ARKANSAS, 1956, U.S. Geological Survey open-file report, 1957, by R. T. Sniegocki.

PLUGGING BY AIR ENTRAINMENT IN ARTIFICIAL-RECHARGE TESTS, Water Well Journal, Volume 13, Number 6, 1959, by R. T. Sniegocki.

GROUND-WATER RECHARGE, University of Arkansas, Arkansas Farm Research, Volume 4, Number 3, Fall 1955, by Kyle Engler.

GROUND-WATER RECHARGE BY MEANS OF A VERTICAL WELL, University of Arkansas, Rice Journal, Volume 60, Number 7, Annual Issue 1957, by Kyle Engler.

WATER VISCOSITY AND ITS EFFECTS ON ARTIFICIAL RECHARGE, American Water Works Association Journal, Volume 52, Number 12, 1960, by R. T. Sniegocki

REPORT OF WATER INJECTION, Arkansas Oil and Gas Commission, 1960.

Group 4C--Effects of water on man's non-water activities

No entries.

Group 4D--Watershed protection

For primary bibliographic entries see 6B.

Field 5--WATER QUALITY MANAGEMENT AND PROTECTION

Group 5A--Identification of pollutants

CHEMICAL CHARACTER OF THE HOT SPRINGS OF ARKANSAS AND VIRGINIA.

For primary bibliographic entry see 2F.

COLD WATER FOR INDUSTRY.

For primary bibliographic entry see 6D.

STUDY AND INTERPRETATION OF THE CHEMICAL CHARACTERISTICS OF NATURAL WATER.

For primary bibliographic entry see 7B.

CALCIUM CARBONATE SATURATION IN GROUND WATER, FROM ROUTINE ANALYSES.

For primary bibliographic entry see 7B.

CALCULATION AND USE OF ION ACTIVITY.

For primary bibliographic entry see 7B.

FIELD MEASUREMENT OF ALKALINITY AND pH.

For primary bibliographic entry see 7B.

NOTES ON PRACTICAL WATER ANALYSIS.

For primary bibliographic entry see 7B.

STABILITY FIELD DIAGRAMS AS AIDS IN IRON CHEMISTRY STUDIES.

For primary bibliographic entry see 7B.

CHEMICAL EQUILIBRIUM DIAGRAMS FOR GROUND-WATER SYSTEMS.

For primary bibliographic entry see 7B.

ARKANSAS MUNICIPAL WATER SUPPLIES CHEMICAL DATA.

For primary bibliographic entry see 7C.

FLUORIDE CONTENT OF GROUND WATER IN THE COTERMINOUS UNITED STATES.

For primary bibliographic entry see 7C.

SUMMARY REPORT, SOURCES OF POLLUTION IN GRAND (NEOSHO) RIVER BASIN, PART II, Arkansas Water Pollution Control Commission, May 1961.

"The major streams in the Illinois River drainage area contain water of good natural quality throughout their lengths in Arkansas. Deterioration of water quality due to organic waste effluents is evident only in limited reaches of minor tributaries. Treated sewage from the cities of Prairie Grove and Springdale was found to be causing undesirable conditions in the receiving streams immediately below the sewage outfalls. Additional treatment in the form of final sedimentation is recommended for the Prairie Grove sewage treatment plant. The quality of effluent from the existing Springdale sewage treatment plant can be improved only through closer operational control and regulation of industrial waste discharges to the municipal sewer system. A total of eight industries were found to be discharging all or part of their water wastes to municipal sewers, causing problems in the operation and maintenance of sewage treatment facilities. Five industries were found to be discharging wastes without serious damage to receiving streams, but also without a Commission permit."

REPORT ON WATER POLLUTION, GRAND (NEOSHO) DRAINAGE BASIN, U.S. Public Health Service, January 1953.

"Water resources represent a major economic asset of the basin and are used principally for public and industrial water supplies, power generation, livestock watering, irrigation, recreation, and fish and wildlife propagation. Surface runoff is high and satisfactory water yields can be obtained for many purposes with little storage. Most ground water comes from poor aquifers of variable depth producing water of variable quality and unreliable yields.* * *"

"Pollution of surface waters is not considered extensive within the basin. Wastes from municipal sources and from numerous small industries present pollution problems which are generally confined to local areas. Refineries, paper plants, oil fields, lead and zinc mines, ore concentrating mills, coal mines, and a large chemical plant are major industries capable of causing serious damage to water quality but there are, at present, no known serious problems originating from these sources.* * *"

"Pollution abatement needs for sources of industrial wastes include 34 new treatment plants, seven enlargements or additions to existing plants, two replacements of existing plants, and needs for 18 industries are undetermined. Six industries have adequate waste treatment facilities.* * *"

The report also covers physical features of the basin, water use, and State agencies responsible for exercising control over pollution.

SUMMARY REPORT ON SMACKOVER CREEK DRAINAGE BASIN, Arkansas Water Pollution Control Commission, 1958, by G. T. Kellogg, April 22, 1958.

"The Smackover Creek drainage basin, with the exception of the Camp Creek tributary, is so grossly polluted as to render not only Smackover itself unusable as process or drinking water but the entire Ouachita River below the mouth of Smackover also unusable. Drinking water and most industrial process waters must be below 250 ppm chloride concentration. Smackover, at its mouth averaged 17,686 ppm during the course of the survey. This concentration represented 49 percent of the total volume of chlorides discharged daily in the drainage basin from oil production (102,200,000 pounds or 51,100 tons of salt daily). With the exception of the domestic waste treatment plant at Monsanto Chemical Plant, all domestic and industrial wastes were inadequately treated, creating localized gross pollution in every instance of discharge. Although not mentioned in the body of the report, careless oil producing and refining operations have frequently resulted in oil slicks which covered the entire surface of the Ouachita for miles below Smackover Creek, being observed by Commission survey personnel.

"The Ouachita River (mile 297) below the mouth of Smackover Creek during the 1957 river survey averaged 363 ppm of chloride at 0.2 foot depth and 413 ppm at 0.8 foot depth. Upstream at mile 315 the chlorides averaged 8.9 and 6.9 ppm respectively.

"During the 1956 river survey, chloride concentrations as high as 3,800 ppm were measured on the river bottom when only 98 ppm occurred at the surface (mile 303). Concentrations of 1,300 ppm were measured throughout the river at a flow of 3,900 cfs (mile 296). Apparently brine stratification occurs below river flows of 1,000 cfs."

SUMMARY REPORT, SOURCES OF POLLUTION IN LOWER RED RIVER BASIN, PART I, Arkansas Water Pollution Control Commission, April 1959.

"Salt water from oil fields is causing gross localized pollution in several small tributary streams in the Lower Red River Drainage Basin. Several very small streams are rendered completely useless by this brine drainage with chloride contents at these stations ranging from 10,000 ppm to 32,000 ppm and one larger stream with a flow of 11.5 cfs has a chloride content of 642 ppm.* * *"

SUMMARY REPORT, SOURCES OF POLLUTION IN UPPER RED RIVER BASIN AND LOWER RED RIVER BASIN, PART II, Arkansas Water Pollution Control Commission, April 1960.

"Pollution of streams in the Red River Basin is in most cases strictly localized, consisting of fecal contamination below sewage outfalls, salt water damage from oil fields, and chemical pollution from industrial establishments.* * *"

"The water quality of Red River is inferior throughout its length in Arkansas but is slightly improved by good quality water from its principal Arkansas tributaries, the Cossatot, Little, Saline, and Sulphur Rivers."

WATER POLLUTION CONTROL SURVEY OF DARDANELLE RESERVOIR, Arkansas Pollution Control Commission, 1969.

"The overall water quality of the reservoir was good with the exception of the upper end where Ozark discharged partially treated sewage into the river just above the dam. The effects of this discharge were noted approximately 20 miles downstream. The water quality in the streams of the area was good except for Sixmile Creek which received the effluent from the Paris sewage treatment plant and Whig Creek which received the effluent from the Russellville sewage treatment plant and Standard Rendering.

"The special bacteriological survey on the Illinois Bayou indicated no sources of fecal contamination except at point #58 on Prairie Creek. This high count was attributed to urban run-off from the city of Russellville. Other high counts of a non-fecal nature were attributed to agricultural run-off.* * *"

The report includes sections on municipal wastes for each city along the reservoir; industrial wastes, industry by industry, and results of the bacteriological and biological survey.

REPORT ON WATER POLLUTION, WHITE RIVER BASIN, 1952, U.S. Public Health Service, 1952.

"The surface waters of the White River Basin are abundant in quantity and generally of good quality. Underground water resources are generally limited and are of variable mineral quality throughout the basin.* * *"

"Pollution of surface waters throughout the basin is not extensive. Wastes discharged from municipalities and numerous small industries produce pollution conditions which in most cases do not seriously affect downstream uses.* * *"

"Existing water pollution control legislation in Arkansas is regarded as adequate for administration of a comprehensive pollution abatement program in the basin. Insufficient funds, however, have seriously hampered the program activities of the State Water Pollution Control Commission.* * *"

The report includes sections on a physical description of the basin, uses of water, damages from pollution, benefits from pollution abatement, pollution measures in effect and pollution measures required.

REPORT ON WATER POLLUTION, OUACHITA RIVER BASIN, Arkansas Water Pollution Control Commission, 1952.

"Pollution from municipal sources is generally regarded as a local problem except where it complements serious industrial waste pollution. Wastes from oil fields in the west-central portion of the basin, and from pulp and paper mills located along the middle reach of the Ouachita contribute significantly to the degradation of the receiving streams. Pollution from natural sources, principally silt, is a minor problem in the basin.* * *"

"Natural pollution in the area is not extensive. Damages have occurred due to the formation of sulfuric acid from pyrites around Magnet Cove and Malvern, Arkansas, and from lignites in certain other areas.* * *"

The report includes sections on the physical nature of the area, water use, damages from pollution, pollution measures in effect, and pollution abatement measures needed.

SUMMARY REPORT, SOURCES OF POLLUTION IN GRAND (NEOSHO) RIVER BASIN, PART I, Arkansas Water Pollution Control Commission, May 1960.

"Pollution of streams in the Grand (Neosho) River is confined to smaller tributaries without significant damage to any of the major streams, and is due to discharge of raw or poorly treated sewage and organic industrial waste. Three municipal sewage treatment plants were found to be in need of additional or expanded facilities--Bentonville, Decatur, and Siloam Springs. New or expanded facilities are presently scheduled for Bentonville and Decatur. Although the Siloam Springs plant operates at near maximum efficiency, the condition of the receiving stream dictates some additional treatment. Chlorination of the final effluent is recommended. The Gentry sewage-treatment plant is heavily loaded by wastes from seasonal canning operations, and additional treatment in the form of final sedimentation is desirable.

"Industries in the basin, vegetable canneries, milk and cheese processors, and poultry processors, all discharge their wastes to municipal sewer systems and contribute substantially to the problems of maintenance and operation of sewage treatment facilities. More stringent regulations are recommended concerning industrial discharge to municipal sewers.

"The major streams--Flint Creek, Spavinaw Creek and Little Sugar Creek--are of good quality throughout their lengths in Arkansas."

REPORT ON WATER POLLUTION, ARKANSAS RIVER BASIN, VAN BUREN TO MOUTH, Arkansas Water Pollution Control Commission, October 1953.

"Chemical pollution is the most important single factor restricting productive use of the river water. Most pollution of this type is derived from upstream sources and interstate agreements regarding pollution control will be necessary to maximum development of the Arkansas River within the basin.

"Municipal sewage pollution in the basin is extremely heavy. Approximately 215,800 persons in the basin are connected to community sewers.* * *"

Only about 8.6 percent of the estimated municipal sewage loading is removed by existing waste treatment works. Large additional organic waste loadings are contributed by canneries and other food processing plants.* * *"

The report includes sections on a description of the basin, economic development, uses of water resources, pollution and damages from pollution, benefits from pollution abatement, and prevention measures required.

REPORT ON WATER POLLUTION, ARKANSAS RIVER BASIN, TULSA, OKLAHOMA, TO VAN BUREN, ARKANSAS, Arkansas Water Pollution Control Commission, October 1953.

"The Arkansas River is the largest basin water resource and the most readily and economically accessible source of water supply to the greatest number of potential users. However, the river has been damaged to such an extent by pollution that productive use of the river water is negligible, both in and downstream from the basin. The degree of pollution is such that large volumes of water of excellent quality discharged into the river from major tributaries do not serve to restore the Arkansas River to appreciable productive use.

"Chemical pollution is the most important factor restricting productive use of river water as well as the most serious pollution control problem because of the technical and economic problems involved in abatement measures. Sources of pollution include natural salt deposits and saline springs upstream from the basin and oil field brines from productive areas both in and upstream from the basin.* * *"

The report includes sections on the physical description of the area, uses of water, damages from pollution, benefits from pollution abatement, pollution prevention measures in effect and pollution measures required.

SUMMARY REPORT, WATER POLLUTION CONTROL SURVEY OF THE UPPER OUACHITA RIVER BASIN, PART I, Mena to Malvern, Arkansas, Water Pollution Control Commission, September 1963.

"The principal water pollution problems existing on the Upper Ouachita River and its tributaries stem from three major causes which are among the most difficult in the field to correct. They are (1) acid mine drainage, (2) fecal contamination of recreational lakes from widespread homes and resorts, and (3) infiltration of storm or ground water into sewer systems of municipalities, rendering an otherwise satisfactory treatment facility practically useless.* * *"

During the field survey made from June to October of 1962, and during the summer of 1963, all cities, industries, business operations such as motels, and scattered homes located on impoundments were investigated as potential sources of pollution in an area of 1,680 square miles. Data collected during the survey are included in the report.

WATER QUALITY STUDY, OZARK WELL FIELD, ARKANSAS RIVER BASIN, ARKANSAS, Federal Water Pollution Control Administration, Dallas, Texas, May 1967.

"The ground water reservoir that supplies the city of Ozark's well field is now recharged primarily by infiltration of precipitation, and partially by seepage of river water induced by drawdown of the ground water piezometric surface by pumping. The U.S. Geological Survey found that during 1965, about 52 percent of the water pumped was induced from the river.

"Since a large portion of the water pumped from city wells is river water that has been induced into the ground water reservoir, the quality changes in Ozark's municipal water supply are directly related to the sequence of quality changes in the river water.

"In the Arkansas River at Ozark, high mineral concentrations occur during low flow periods and low concentrations occur during high flow periods. Prior to completion of reservoirs included in the Arkansas River Multiple-Purpose Plan, extreme variations in flow resulted in wide fluctuations in mineral quality.

"The Arkansas River Multiple-Purpose Plan, after completion, will improve the mineral quality of Arkansas River water at Ozark. This improvement is attributable to the averaging of mineral concentrations through upstream flow regulation.

"The U.S. Geological Survey has projected that, under post-construction conditions with the estimated 1970 pumping rate, an average of 93 percent of the water pumped by city wells will be induced from the river. It has been estimated that pumpage from the Ozark well field will increase from 121.3 million gallons in 1965 to 146 million gallons in 1970.

"Under 1970 pumping conditions, chloride and total dissolved solids concentration in Ozark's municipal water supply will often exceed desirable (250 milligrams per liter (mg/l) chloride, and 500 mg/l total dissolved solids) maximum limits either with or without completion of the Arkansas River Multiple-Purpose Plan. However, a better quality water will be provided after the plan is completed since maximum mineral concentration levels will be reduced and fluctuations in mineral concentrations will be stabilized making changes in the taste of the water less noticeable.

Changes in the quality of water pumped from Ozark's well field aquifer that may be attributed to the Arkansas Multiple-Purpose Plan will not preclude further use of the aquifer for municipal water supply purposes."

CITY OF OZARK--EFFECTS OF RESERVOIR ON WATER SUPPLY WELLS, U.S. Army Engineer District, Little Rock Corps of Engineers, Ozark Lock and Dam, Supplement Number 4 to Design Memorandum Number 4, September 1967.

"The supplement presents the results of detailed studies by the Federal Water Pollution Control Administration and the U.S. Geological Survey regarding the effects of the Arkansas River Multiple-Purpose Plan on the water wells which supply the city of Ozark. Reports of these agencies are included as Appendixes I and II. The studies were based on a projected pumpage of 146 million gallons of water in 1970 when Ozark Reservoir is scheduled to be in operation. The studies indicated that the mineral quality of the Arkansas River water at Ozark will be improved through flow regulation of reservoirs in the Arkansas River Multiple-Purpose Plan; and the percent of water induced into the well field will be increased by the Ozark Reservoir. It was concluded that chloride and total dissolved solids in the municipal supply will often exceed desirable maximum limits either with or without the Arkansas River Multiple-Purpose Plan. However, a better quality water will be available after the plan is completed since maximum mineral concentration levels will be reduced and fluctuations in mineral concentrations will be stabilized making changes in the taste of the water less noticeable. The changes in the water quality will not preclude further use of the aquifer for municipal water supply purposes."

STREAM COMPOSITION OF THE COTERMINOUS UNITED STATES, U.S. Geological Survey Hydrologic Investigations Atlas HA-61, 1962, by F. H. Rainwater.

This atlas is comprised of three maps of the coterminous United States which show separately the prevalent dissolved-solids concentrations, prevalent chemical type, and average sediment concentration of rivers.

According to plate 1, most of the streams in Arkansas contain 300 ppm or less dissolved solids. Exceptions are the Arkansas, Red, and lower Ouachita Rivers where dissolved solids may be as high as 1,100 ppm.

Plate 2 shows that water in nearly all streams in Arkansas is of the calcium magnesium carbonate bicarbonate type. The water in the Arkansas, Red, and lower Ouachita Rivers is of the sodium potassium sulfate chloride type.

Sediment concentrations in Arkansas rivers range from 200 to over 1,000 ppm, according to plate 3.

TEMPERATURE OF SURFACE WATERS IN THE COTERMINOUS UNITED STATES, U.S. Geological Survey Hydrologic Investigations Atlas HA-235, 1966, by J. F. Blakey.

Temperature is probably the most important but least discussed parameter in determining water quality. This atlas consists of three maps showing most probable temperatures of surface waters in the coterminous United States. Sheet 1 shows the most prevalent temperature of surface waters to be expected; sheet 2 shows the average number of days per year when surface-water temperatures are 80°F or greater; and sheet 3 shows the average number of days per year when temperatures are at or near freezing (32°F-34°F).

Sheet 1 shows that the median annual temperature of surface water in Arkansas for 1960-62 was 65°F to 69°F in the southern two-thirds of the State and 60°F to 64°F for the northern third. Sheet 2 shows that we can expect the surface water in the southern four-fifths of Arkansas to have a temperature of 80°F or more for an average of 51 to 100 days per year. In the northern part of the State, we can expect this condition for from 11 to 50 days. A small anomalous area on the White River reflects the cold water outlet from Bull Shoals Reservoir and here the map indicates the temperature of the water never exceeded 80°F (1960-62). Sheet 3 shows that surface water in the southern third of Arkansas has a temperature exceeding 34°F the year round. In the northern two-thirds of the State, surface water will be near freezing an average of 1 to 10 days per year.

RECONNAISSANCE OF SELECTED MINOR ELEMENTS IN SURFACE WATERS OF THE UNITED STATES, OCTOBER 1970, U.S. Geological Survey Circular 643, 1971, by W. H. Duram, J. D. Hem, and S. G. Heidel.

A nationwide reconnaissance of selected minor elements in water resources of the 50 States and Puerto Rico was made by the U.S. Geological Survey in cooperation with the U.S. Bureau of Sports Fisheries and Wildlife during the autumn of 1970. More than 720 samples were analyzed for arsenic, cadmium, chromium, cobalt, lead, mercury, and zinc.

Samples were collected at 13 locations in Arkansas. These were the White River near Goshen, Lake Fayetteville, North Sylamore Creek near Fifty-Six, Lake Fort Smith on Frog Bayou, Arkansas River at Lock and Dam 13 below Fort Smith, Lake Winona, Arkansas River below Lock and Dam 6 below Little Rock, Bayou Meto near Lonoke, Arkansas River near Lock and Dam 3 below Pine Bluff, Cossatot River near Vandervoort, Hot Springs Reservoir on Bull Bayou, Ouachita River near Malvern, and Hurricane Creek near Sheridan.

Samples from the White River, North Sylamore Creek, Arkansas River at Lock and Dam 13, and the Arkansas River near Lock and Dam 3 contained more than 50 micrograms per litre of arsenic--the maximum considered safe for drinking water. Samples from Lake Winona, Arkansas River at Lock and Dam 6, Hot Springs Reservoir, Ouachita River near Malvern, and Hurricane Creek near Sheridan contained more than 10 micrograms per litre of cadmium--the Public Health Service upper limit for drinking water.

Chromium, cobalt, lead, zinc, and mercury were well below upper limits in the samples collected.

PREIMPOUNDMENT WATER QUALITY SURVEY OF THE CADDO RIVER, ARKANSAS, Department of Chemistry, Ouachita Baptist University, Arkadelphia, Arkansas, October 1967, by J. F. Nix.

"The water quality of the Caddo River apparently is highly dependent on the river mile of the stream. It appears that many of the dissolved species present in the river are acquired in the upstream region and are diluted by low mineralized tributaries as the river flows toward the confluence with the Ouachita River.

"A comparison of the results of this study and data taken by the U.S. Geological Survey (1960) shows that the water quality of the Caddo River has remained essentially unaltered in the past eight years.

"The Caddo River and its tributaries seem to be essentially free of pollution. Gravel washing operations in the last three to four miles of the river constitute the only man-made operation that significantly alters the water quality of the stream. There are some indications that the water quality of the river around Glenwood and Amity, Arkansas, may be slightly altered by domestic waste but the effect is very small, if any, and certainly would not constitute pollution.

"The tributaries of the Caddo River that were studied are generally lower in dissolved species than the Caddo River. Although DeGray Creek enters the Caddo River downstream from the DeGray Dam and hence will have no effect on the reservoir, its lower quality water should be noted. It is doubtful that water from this stream could be used as a domestic water source.

"The diurnal study shows the Caddo River to be a dynamic system with fluctuations of many components occurring from some source other than photosynthesis and influx of runoff waters."

INTERIM REPORT ON WATER QUALITY INVESTIGATION, DEGRAY RESERVOIR, ARKANSAS, Arkansas Water Resources Research Center Publication Number 9, 1970, by J. F. Nix.

Impoundment of the Caddo River near Arkadelphia, Ark., began in August 1969. Although the reservoir had not reached normal pool elevation, thermal stratification accompanied by severe hypolimnic oxygen depletion has been observed. The dissolved-oxygen data show that an underflow occurs in the fall of the year and carries dissolved oxygen into the hypolimnic zone. The gradients of dissolved-oxygen concentration observed during the winter indicate that the reservoir does not undergo complete mixing.

A short summary of the results of trace elements and other water-quality parameters is also included.

HARDNESS OF GROUND WATERS IN ARKANSAS, U.S. Geological Survey open-file report, 1970, by William Buller.

"Hardness of water is of concern to the water user for both economic and esthetic reasons. Hard water consumes soap before a lather will form; it deposits soap curd on wash basins; and it forms scale in boilers, water heaters, and pipes.* * *" Hardness of water is caused mainly by the alkaline earth metals. In natural waters in Arkansas, calcium and magnesium are generally the only metals of the alkaline earth group present in quantities greater than trace amounts, so hardness discussed in this report may be considered as calcium and magnesium hardness.* * *"

"The U.S. Geological Survey classifies hardness of water as follows:"

Hardness in terms of equivalent amounts of calcium carbonate (mg/1)	Classification
0- 60	Soft
61-120	Moderately hard
121-180	Hard
More than 180	Very hard

The report contains five maps of Arkansas and by use of patterns shows what water hardness can be expected in the Interior Highlands, Cretaceous aquifers in southwest Arkansas, and Tertiary and Quaternary aquifers in the Coastal Plain. In general, Arkansas' ground waters are extremely variable in hardness depending upon the aquifer, well location, and well depth. The only aquifers consistently yielding soft water are those of Tertiary age in the southern half of the Coastal Plain.

PRELIMINARY RECONNAISSANCE, WATER QUALITY SURVEY OF THE BUFFALO NATIONAL RIVER, University of Arkansas, Water Resources Research Center, Publication Number 19, October 1973, by E. E. Dale, Jr., R. L. Meyer, J. F. Nix, D. G. Parker, Eugene Schmitz, and K. R. Steele.

Most of the report consists of a presentation of data collected by a series of investigations. These data include measurements of streamflow and measurements and analyses of river water samples for temperature, dissolved oxygen, pH, color, turbidity, nitrate, orthophosphate, hardness, chloride, fluoride conductivity, suspended solids, total solids, coliform organisms, biochemical oxygen demand, total organic carbon, sodium, potassium, calcium, magnesium, iron, manganese, cobalt, chromium, nickel, copper, zinc, and sulfate. Analyses of sediment samples collected from the Buffalo River include sodium, potassium, calcium, magnesium, iron, manganese, cobalt, chromium, nickel, copper, zinc, cadium, lead, and silver. Floating algae were sampled, identified, and arranged in taxonomic categories. Other information includes a description of bottom fauna, vegetation along the river, principal forest communities, and recommendations for future research work and a monitoring program.

CHARACTERIZATION OF SOILS AND WATER IN THE BEAVER RESERVOIR AREA: PRE-IMPOUNDMENT STUDIES OF CHEMICAL PROPERTIES, University of Arkansas, Agricultural Experiment Station Bulletin 702, October 1965, by M. E. Horn and D. E. Garner.

A basic premise of this study is that the chemical quality of water in a reservoir is greatly influenced by the general chemical properties of soils and rocks in the watershed and those inundated by waters of the reservoir.

The general chemical makeup of the White River changes significantly as it flows through contrasting geologic provinces. In its headwaters in the Boston Mountains, the White River flows through a region of sandstone and shale rocks and associated acid soils and its water is slightly acid to neutral, has low alkalinity and hardness, and contains small amounts of calcium and magnesium. Farther north the White River enters the Springfield Plateau, a region of soils derived from cherty limestone. Here the water becomes harder and more alkaline. A few miles upstream from the site of Beaver Dam, the White River enters an area consisting of dolomitic limestones where the water becomes still harder and more alkaline.

Dissolved oxygen at all sites commonly was in the range from 70 to 100 percent saturation; however, notable instances of supersaturation and of deficit occurred.

Striking increases in sodium, sulfate, phosphorus, and other components in the White River at Wyman, first observed in June 1963 sampling, indicated pollution from West Fork of the White River. This pollution, combined with the extremely low-water conditions, resulted in a severe fishkill during the fall of 1963 and in early 1964 in West Fork and in the Wyman area of the White River.

Data collected, sampling procedures, and other aspects of the study aimed at investigating the problem of dwindling game fish populations in manmade lakes, after about 10 years of impoundment, also are covered in the report.

VIRUS MOVEMENT IN GROUND WATER SYSTEMS, University of Arkansas, Water Resources Research Center Publication Number 4, 1969, by W. A. Drewry.

"Results of this study show that virus absorption by soils is greatly affected by the pH, ionic strength, and soil-water ratio of the soil-water system and various soil properties. Also, it is shown that one cannot predict the relative virus absorbing ability of a particular soil based on the various tests normally used to characterize the soil. It is shown that virus movement through a continuous stratum of common soil under gravity flow conditions and with intermittent dosing should present no health hazard if usual public health practices relating to locating water supply wells are followed. Test results also indicate no greater or lesser movement of virus through soils with a highly polluted water than with a non-polluted water."

SURVEY OF FERROUS-FERRIC CHEMICAL EQUILIBRIA AND REDOX POTENTIALS, U.S. Geological Survey Water-Supply Paper 1459-A, 1959, by J. D. Hem and W. H. Cropper.

COPRECIPITATION EFFECTS IN SOLUTIONS CONTAINING FERROUS, FERRIC, AND CUPRIC IONS, U.S. Geological Survey Water-Supply Paper 1459-E, 1960, by J. D. Hem and M. W. Skougstad.

RESTRAINTS ON DISSOLVED FERROUS IRON IMPOSED BY BICARBONAIE REDOX POTENTIAL, AND pH, U.S. Geological Survey Water-Supply Paper 1459-B, 1960, by J. D. Hem.

CHEMICAL EQUILIBRIA AND DATES OF MANGANESE OXIDATION, U.S. Geological Survey Water-Supply Paper 1667-A, 1963, by J. D. Hem.

MISSISSIPPI RIVER WATER QUALITY, Southwest Water Works Journal, Volume 42, Number 5, August 1960, p. 23-29, by R. C. Palonze.

Group 5B--Sources of pollution

VIRUS MOVEMENT IN GROUND-WATER SYSTEMS.

For primary bibliographic entry see 5A.

Group 5C--Effects of pollution

No entries.

Group 5D--Waste treatment processes

No entries.

Group 5E--Ultimate disposal of wastes

No entries.

Group 5F--Water treatment and quality alteration

WATER CONDITIONING, University of Arkansas, Agricultural Extension Service Circular 512, Revised October 1965, by J. L. Gattis.

Poor water quality costs a family money. Hardness in water requires extra soap. Hard water also has an abrasive effect which causes clothes to wear out sooner than they should. Scale which forms in water heaters requires extra fuel and the heater life is shortened. Water pipes become clogged more rapidly with scale. Acid water causes faster deterioration of plumbing and may cause the iron concentration in water to be high. Iron is objectionable because it imparts a bad taste and stains clothes and fixtures.

Each of the water-quality problems is not too difficult or costly to handle through treating procedures. The hardness in water is readily handled through use of a resinous ion exchange material in a water softener. The most satisfactory method for handling acid water is by feeding soda-ash solution into the water. Oxidation and filtration are used to remove iron from water. If the iron concentration is less than 3.0 ppm, a chemical in the polyphosphate family can be added to the water to prevent the iron from coming out of solution and staining clothes and fixtures.

Group 5G--Water quality control

TABLE ROCK LAKE, WHITE RIVER WATERSHED, MISSOURI AND ARKANSAS, TABLE ROCK AERATION TESTS, Little Rock District, Corps of Engineers, May 1972.

In the fall of 1970, water discharged during generation at the Table Rock power installation was observed to have dissolved oxygen concentrations of about 3 ppm. Natural reaeration in downstream Lake Taneycomo was insufficient to increase the dissolved oxygen to an acceptable level to maintain the Lake Taneycomo trout fishery. Critical dissolved-oxygen conditions could be expected to some degree from September through December each year.

Two methods of aeration were evaluated. The first method was direct point injections of compressed air into the turbine facilities of unit 4 in the Table Rock power installation. The second method was the use of a lake diffuser system in Table Rock Lake immediately upstream of the turbine penstocks.

The results of these tests indicate that downstream dissolved-oxygen concentrations can be increased by compressed air aeration with direct injection of lake diffusers although the diffusers are less effective than direct injection. Drain-line or draft-tube air injection is recommended as the primary means for increasing downstream dissolved-oxygen concentrations.

WATER-QUALITY MODELING FOR WASTE-LOAD ALLOCATION STUDIES IN ARKANSAS--STREAM DISSOLVED OXYGEN AND CONSERVATIVE MINERALS, U.S. Geological Survey open-file report, February 1974, by M. E. Jennings and C. T. Bryant.

"Waste-load allocation studies in Arkansas form a central part of the development and implementation of basin water-quality management plans required of the Arkansas Department of Pollution Control and Ecology by the Environmental Protection Agency (EPA). This report describes the methodology to be used in Arkansas waste-load allocation studies. Steady-state segmented dissolved-oxygen (DO) analysis of river-basin segments is the recommended basis for waste-load allocation studies. A dilution model, based on the mass-balance principle, is used for analyses of stream conservative mineral loads. Data collection and laboratory procedures to support such a modeling effort are discussed."

STREAM POLLUTION PREVENTION AND ABATEMENT PANEL, Southwest Water Works Journal, Volume 42, Number 5, August 1960, p. 14-21, with a section for Arkansas, by G. T. Kellogg.

Field 6--WATER RESOURCES PLANNING

Group 6A--Techniques of planning

No entries.

Group 6B--Evaluation process

WATER FACTS.

For primary bibliographic entry see 2A.

WATER-SUPPLY CHARACTERISTICS OF SELECTED ARKANSAS STREAMS.

For primary bibliographic entry see 2E.

LOW-FLOW CHARACTERISTICS OF STREAMS IN THE MISSISSIPPI EMBAYMENT IN SOUTHERN ARKANSAS, NORTHERN LOUISIANA, AND NORTHEASTERN TEXAS.

For primary bibliographic entry see 2E.

STORAGE REQUIREMENTS FOR ARKANSAS STREAMS.

For primary bibliographic entry see 2E.

WATER IN ARKANSAS, A REPORT ON THE SURFACE WATER RESOURCES IN ARKANSAS.

For primary bibliographic entry see 2E.

FLOOD INFORMATION FOR FLOOD-PLAIN PLANNING.

For primary bibliographic entry see 2E.

WATER WELL SURVEY, EL DORADO REFINERY.

For primary bibliographic entry see 2F.

THE THERMAL SPRINGS OF HOT SPRINGS NATIONAL PARK, ARKANSAS--FACTORS AFFECTING THEIR ENVIRONMENT AND MANAGEMENT.

For primary bibliographic entry see 2F.

THE WATERS OF HOT SPRINGS NATIONAL PARK, ARKANSAS--THEIR ORIGIN, NATURE, AND MANAGEMENT.

For primary bibliographic entry see 2F.

THE ROLE OF GROUND WATER IN THE NATIONAL WATER SITUATION, WITH STATE SUMMARIES BASED ON REPORTS BY DISTRICT OFFICES OF THE GROUND WATER BRANCH, U.S. Geological Survey Water-Supply Paper 1800, 1963, by C. L. McGuinness.

The following taken from Water-Supply Paper 1800 pertains to Arkansas:

"Large and well-sustained water supply and few serious water problems to date.* * *"

"Ground water available in at least small to moderate quantities-from a few gallons to a few hundred gallons per minute--throughout State. Larger supplies available locally in northwestern half, especially in northern tier of counties in Ozark Plateaus and in White, Arkansas, Ouachita, and Little River valleys. Ground-water supplies largest in Coastal Plain, especially in Mississippi Alluvial Plain in east.

"Withdrawal use of water, all fresh, in 1960 about 1.5 bgd, 51 mgd surface water and 48 mgd ground water for public supply; 18 and 33 mgd for rural supply; 313 and 147 mgd for industrial supply including 270 mgd surface water and 7 mgd ground water for public-utility fuel-electric power, and 150 and 770 mgd for irrigation, plus conveyance loss of 73 mgd. Hydropower use about 8.2 bgd.* * *"

"Substantial hydrologic information available and more being actively gathered to support rapid industrial and agricultural development."

THE WATER SITUATION IN THE UNITED STATES WITH SPECIAL REFERENCE TO GROUND WATER, U.S. Geological Survey Circular 114, June 1951, by C. L. McGuinness.

This report discusses the occurrence of ground water in nature and its relation to surface water and to the national water picture as a whole, and it lists numerous existing water problems and discusses their solutions.

In the summary of the current (1951) water situation by States, Arkansas is listed as having few water-supply problems. Water-resources data are scanty and information is needed on quantity and quality of water available from smaller streams and on extent and yield of ground-water reservoirs.

WATER FOR ARKANSAS, Arkansas Geological Commission, 1969, by R. T. Sniegocki and M. S. Bedinger.

This report attempts to present in layman's language an appraisal of Arkansas' water resources. The chapter "How Much is There " indicates that of the 120 billion gallons of water that fall on Arkansas each day on an average annual basis, only about 30 billion gallons per day is directly available for use. This is about 20 times more than present (1969) daily use in Arkansas. A "Water Resources Who's Who" at the end of the report provides a list of State and Federal organizations, gives their addresses, and describes their areas of responsibility and the work they do that influences the water future of Arkansas. The report, printed in full color, contains 11 figures covering water occurrence and its quality. In addition, liberal use is made of photographs and illustrations to describe the hydrologic cycle, physiographic provinces in Arkansas, runoff, water use, well records, and other water-related features.

SOURCES OF WATER FOR INDUSTRY WITH SPECIAL REFERENCE TO MUNICIPAL SUPPLIES, University of Arkansas, Industrial Research and Extension Center, Arkansas Industrial Development Commission, October 1963, by L. E. Mack.

"The heart of this publication is the tabulation of present municipal water supply capacities. The data are based on information supplied during August-October, 1962.* * *"

"The northwestern half of the state provides excellent topography for the capture of surface water. The southeastern half of the state provides aquifers for abundant ground water supplies.* * *"

SUMMARY OF THE WATER SUPPLY OF THE OZARK REGION IN NORTHERN ARKANSAS, U.S. Geological Survey Water-Supply Paper 110, 1905, by G. I. Adams.

This report contains a summary of the water supply of the Ozark region in northern Arkansas. The information is related principally to the geologic subdivisions of the Ozarks and springs associated with various rocks.

EMERGENCY GROUND-WATER SUPPLIES NEAR PINE BLUFF, ARKANSAS, Arkansas Geological and Conservation Commission Special Ground-Water Report Number 5, 1962, by J. W. Stephens.

This report contains information on emergency ground-water supplies available within a 15-mile radius of Pine Bluff, Ark. The information is intended to aid Civil Defense organizations, municipalities, industries, and individuals in preparing for and surviving a nuclear attack or natural disaster.

In the event of a nuclear attack, major electric-power supply facilities and transmission lines probably would be destroyed or disabled, and all surface-water supplies and exposed storage facilities would be contaminated. Therefore, the only source of potable water would be from wells having independent sources of power to operate the pumps.

Table 1 lists 68 wells in the area that have independent sources of power such as butane, diesel, tractor, gasoline, and natural gas. Although these pumps generally are exposed to the atmosphere and would receive some radioactive fallout, the water in the aquifer is protected by the soil above it. Several minutes of pumping would flush the pumps sufficiently to allow use of the water.

A map of Pine Bluff and vicinity shows the locations of the wells and the roads leading to them.

WATER-SUPPLY POSSIBILITIES AT ARKADELPHIA, CALION, CLARKSVILLE, FULTON, AND WATSON, Arkansas Geological Commission, 1965.

A water supply of 5 mgd was desired at Arkadelphia, Calion, Clarksville, Fulton, and Watson, Ark., and the water was to be of drinking quality with a chloride content of less than 100 ppm.

At Arkadelphia, 5 mgd could be obtained from the Ouachita River with no storage required. A system of 10 wells in the alluvium along the Ouachita River southeast of Arkadelphia might supply the required quantity and quality of water.

At Calion, Ark., a system of 5 to 10 wells in the Sparta Sand spaced at least 1,000 feet apart and screened at depths of about 600 feet should satisfy the water needs. However, there is a possibility of interference with pumping in the vicinity of El Dorado, Ark. The possibility of obtaining the desired quantity and quality of water from alluvium along the Ouachita River in the vicinity of Calion does not hold much promise based on present knowledge.

Spadra Creek at Clarksville presently (1965) supplies the city 0.5 mgd and could furnish 5 mgd if storage was increased. Dardanelle Reservoir, 2.5 miles south of Clarksville could supply the quantity needed but unless the water quality improves, it would not meet the quality requirement.

Millwood Reservoir, 12 miles west of Fulton, Ark., could supply 5 mgd for Fulton but the water quality may not be acceptable at all times. Wells in the alluvium a few miles south of Fulton could be used to supply the required quantity of water but at some locations the quality requirements would be difficult to meet. The Red River at Fulton could supply 5 mgd but extensive water treatment would be required.

Watson, Ark., could be supplied with 5 mgd of water from 5 to 10 wells drilled in the Sparta Sand about 800 feet deep with a spacing of about 1,000 feet.

Water from the alluvium and Arkansas River also would be present in sufficient quantity to meet the demand but water treatment would be required.

GROUND WATER IN THE LOWER ARKANSAS RIVER VALLEY, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1669-V, 1964, by M. S. Bedinger and H. G. Jeffery.

"The alluvium and terrace deposits of Quaternary age are the principal sources of ground water in the area. The predominant characteristic of the alluvium is the change from gravel or coarse sand at the base to fine-grained material at the top. The alluvium ranges in thickness from 76 feet at a well in Desha County to 195 feet at test hole in Lincoln County and averages about 100 feet. The terrace deposits in the southwest consist of coarse sand and gravel at the base and silt and clay at the surface; they range in thickness from about 60 feet in Pulaski County to about 100 feet in Lincoln County. The terrace deposits of the Grand Prairie region in Arkansas County consist of material grading variably from coarse sand or gravel at the base to relatively 'heavy' clay at the surface; these deposits range in thickness from 75 to 200 feet. Rainfall is the most important source of recharge in the valley. Recharge from rainfall in the Grand Prairie, however, is negligible because of a thick section of dense clay at the surface, and the main source of recharge is underflow from adjacent areas and influent seepage from the Arkansas and presumably the White River.* * *"
"Ground water from the alluvial aquifer is predominantly of the calcium magnesium bicarbonate type, and the dissolved solids content varies considerably. The water is classified good to excellent for irrigation. The iron content and the hardness of most supplies make the water undesirable for domestic use, and in a few areas, chloride concentration is high enough to cause an undesirable salty taste.* * *"

GEOLOGY AND GROUND-WATER RESOURCES OF BRADLEY, CALHOUN, AND OUACHITA COUNTIES, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1779-G, 1964, by D. R. Albin.

"The geologic units at the surface in the counties are of Eocene, Pleistocene, and Recent age. Water for domestic and small-farm use can be obtained in and at short distances downdip from the outcrop areas of each of the formations. However, only the Sparta Sand, the Cockfield Formation, the terrace deposits, and the alluvium are major fresh-water aquifers.

"Each of the aquifers is capable of yielding larger quantities of water than presently are being withdrawn from them. However, in a small area near Camden the total pumpage from the Sparta Sand is almost the maximum sustained yield.

"The ground water in Bradley, Calhoun, and Ouachita Counties primarily is of the sodium bicarbonate type. Water from the Sparta Sand and the Cockfield Formation is suitable for most municipal, industrial, agricultural, and domestic uses."

RECONNAISSANCE OF THE GROUND-WATER RESOURCES OF THE ARKANSAS VALLEY REGION, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1669-BB, 1963, by R. M. Cordova.

"Ground water occurs in two distinct environments in the Arkansas Valley region. One includes the alluvial deposits of Quaternary age of the Arkansas River and its tributaries; the other includes the consolidated rocks of Pennsylvanian to Ordovician age, which underlie the entire region. The present report is primarily concerned with the consolidated rocks and the alluvium of the tributary streams.

"The consolidated rocks are the principal source of ground water outside the alluvial area of the Arkansas River. Most wells probably will not yield more than 60 gpm, although 1 well yielded 100 gpm. Rural homes, poultry and livestock farms, small commercial establishments, and small municipalities generally pump water from wells 50 to 200 feet deep. The depth to an adequate water supply is controlled by the size, degree of interconnection, and number of water-bearing openings intercepted by the well and not by the rock unit. Depth of drilling is limited by the depth to salt water, which ranges from about 500 to 2,000 feet but in most places is about 1,000 feet. If a water supply must be obtained from the consolidated rocks, then a detailed geologic and ground-water study should be made. From the data obtained, depths and locations of wells can be chosen which will take advantage of the optimum conditions of occurrence and movement of ground water.

"Alluvial deposits of the tributary streams cannot be utilized as major sources of ground water because of their low permeability. Test drilling may prove valuable in locating high-permeability zones. In most of the region the available ground water satisfies rural-domestic needs, but larger supplies must be sought in the underlying consolidated rocks.

"Chemical analyses of well water in the consolidated rocks show that the sodium anion and the bicarbonate cation predominate in most of the rock units, that the dissolved-solids content generally is less than 500 ppm, that the iron content is less than 2.0 ppm, and that the hardness is less than 200 ppm. Water temperatures ranging from 61° to 63°F were recorded in most wells in the consolidated rocks having depths to water greater than 20 feet and in all wells that were pumped for long periods of time."

GROUND-WATER POTENTIAL OF THE ALLUVIUM OF THE ARKANSAS RIVER BETWEEN LITTLE ROCK AND FORT SMITH, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1669-L, 1963, by M. S. Bedinger, L. F. Emmett, and H. G. Jeffery.

"Alluvium along 200 miles of the Arkansas River from Fort Smith, Ark., on the western border of the State, to Little Rock in the approximate geographic center of the State, is potentially the most important aquifer in the Interior Highlands of Arkansas. The flood plain of the river generally is 1 to 3 miles wide, but in places its width is 5 miles. The flood plain is underlain by alluvial sand, gravel, silt, and clay which ranges in thickness from about 40 feet near Fort Smith to about 80 feet near Little Rock. Wells tapping the alluvium yield between 300 and 700 gpm (gallons per minute). Wells tapping the sandstone and shale of Mississippian and Pennsylvanian age, which border the alluvium, generally yield less than 50 gpm.

"Generally, ground water in the alluvium is under water-table conditions. Movement of ground water is from the valley wall to the river, and the river acts as a drain throughout most of the year.

"The alluvium is recharged primarily by infiltration of rainfall. On the average, the aquifer is recharged at the rate of 10 inches per year or approximately 130 mgd (million gallons per day). Pumpage from the alluvium is about 3.2 mgd. The amount of recharge to the aquifer can be increased many times over the natural recharge rate by constructing wells that will induce recharge from the river.

"The quality of water in the alluvium generally is suitable for domestic and irrigation purposes. The hardness and high content of iron and nitrate, however, makes the water undesirable for some industrial uses."

GROUND-WATER RESOURCES OF THE EL DORADO AREA, UNION COUNTY, ARKANSAS, University of Arkansas, Bureau of Research, Research Series No. 14, May 15, 1948, by R. C. Baker, F. A. Hewitt, and G. A. Billingsley.

This report covers an area of about 18 by 20 miles in Union County with El Dorado, Ark., being nearly in the center.

The principal purpose of this study was to determine whether the present (1948) pumpage from the sands of the Sparta Formation was exceeding the safe yield of that aquifer. The safe yield is defined in the report as the maximum amount of water that can be withdrawn perennially without depleting the supply or impairing its quality. According to the report, by 1952, at a pumping rate of about 12.5 mgd, the water level would decline to about 90 feet below sea level and this rate would not exceed the safe yield of the Sparta in the El Dorado area. However, a pumping rate of 15 mgd would exceed the safe yield. Apparently there was no evidence to indicate that the 1947 withdrawal rate of 10.6 mgd was causing any adverse effect on the water quality.

Several recommendations regarding the collection of hydrologic data in the El Dorado area are given at the end of the report.

The data would be useful in future evaluation of the ground water in the Sparta Sand.

UNDERGROUND WATERS OF EASTERN UNITED STATES, U.S. Geological Survey Water-Supply Paper 114, 1905, by M. L. Fuller.

This report contains a section on ground water in Louisiana and southern Arkansas, prepared by A. C. Veatch (p. 179-187) and a section on ground water in northern Arkansas (p. 188 through 197), prepared by A. H. Purdue. Veatch describes the geology and water horizons indicating that with the exception of the consolidated rocks in the southern half of Arkansas ground water availability is reasonably predictable.

Purdue divides the northern part of Arkansas into two natural divisions on the basis of their water supplies and calls them the Paleozoic and Tertiary Regions. (These are geologic age terms for rocks.) The Tertiary Region (northeast Arkansas) is reported to have abundant ground-water supplies, whereas the Boone Chert is listed as the principal water-bearing formation in northwestern Arkansas. An interesting statistic reported shows that in 1902 seven companies selling spring water reported sales amounting to 149,100 gallons with a value of $52,575.

RESUME OF THE GROUND-WATER RESOURCES OF BRADLEY, CALHOUN, AND OUACHITA COUNTIES, ARKANSAS, Arkansas Geological and Conservation Commission Water Resources Summary Number 1, 1962, by D. R. Albin.

This resume is a companion report to Water-Supply Paper 1779-G, "Geology and Ground-Water Resources of Bradley, Calhoun, and Ouachita Counties," but presents the ground-water information in a much simplified pictorial fasion. Maps of the Carrizo Sand, Sparta Sand, Cane River Formation, and Cockfield Formation show where wells can be drilled that should yield from 100 to 1,000 gpm. The quality of water that can be expected from these formations is given in a table showing the maximum, minimum, and most representative concentration of constituents that was noted from the various water samples analyzed.

GROUND WATER RESOURCES OF EASTERN ARKANSAS IN THE VICINITY OF U.S. HIGHWAY 70, U.S. Geological Survey Water-Supply Paper 1779-V, 1964, by H. N. Halberg and J. E. Reed.

"Throughout most of eastern Arkansas in the vicinity of U.S. Highway 70, the deposits of Quaternary age and of the Claiborne Group are major fresh-water aquifers. The "1,400-foot" sand of the Wilcox Group also will yield large quantities of fresh water to wells in eastern Cross, St. Francis, and Lee Counties. Wells tapping any of these deposits can be expected to yield between 300 and 2,000 gallons per minute. Less than 300 gallons per minute of fresh water may be obtained from the Claiborne and Wilcox Groups in Lonoke and Prairie Counties. Supplies sufficient for households and farms generally are available from the Atoka Formation in northwestern Lonoke County and from deposits of Pliocene age along Crowleys Ridge."

GROUND-WATER RESOURCES OF ASHLEY COUNTY, ARKANSAS, University of Arkansas, Institute of Science and Technology, Research Series No. 16, March 1949, by F. A. Hewitt, R. C. Baker, and G. A. Billingsley.

"Ashley County is favored by having a large amount of ground water of good quality. The water occurs in two principal geologic formations, the Cockfield Formation of Tertiary age and sands of Quaternary age. The Sparta Sand of the Tertiary system, found at depths ranging from 250 to 500 feet, is virtually unexplored with respect to its water-bearing properties; however, it is a potential source of water in a large part of the county. No samples of water from the Sparta were available for analysis. Water sands of the Cockfield Formation are a source of water of fairly good quality throughout the county. The aquifers of the Cockfield have been developed on a small scale and at the present time are supplying small amounts of water for industrial, public, and domestic uses. The Cockfield Formation is found at depths of 25 to 175 feet in Ashley County. The Quaternary deposits, which form the surface rock in most of Ashley County, are the most important source of ground water in the county at the present time. Approximately 20,000,000 gallons are pumped from them daily for use in industry, irrigation, and domestic and public consumption. Water in the Quaternary deposits generally is of good quality, although in the eastern part of the county it is quite hard and contains a considerable quantity of iron which makes it unsuitable for some industrial purposes without special treatment. The total average pumpage from the Tertiary and Quaternary beds in Ashley County has increased from less than 300,000 gallons per day in 1900 to about 21,000,000 gallons per day in 1947.

"Ashley County has large undeveloped ground-water reserves, particularly in the deposits of Quaternary age. However, it is not possible to evaluate the reserves at present, owing to the lack of information as to recharge and as to local variations in the permeability of the deposits."

GROUND WATER SUPPLIES FOR RICE IRRIGATION IN THE GRAND PRAIRIE REGION, ARKANSAS, Agricultural Experiment Station Bulletin 457, June 1945, by Kyle Engler, D. G. Thompson, and R. G. Kazmann.

"The data obtained in the present investigation led to the conclusion that the large quantities of ground water that have been used for irrigation in the Grand Prairie region have been in a large part replaced by percolation of water into the area, and that in the future extensive replenishment of the ground-water supply may be expected each year by natural processes. It has been shown, however, that the consumption of water from the Pleistocene beds, which is the principal source of supply, is greater than the quantity that is annually added to them. It has been estimated that the flow through the Pleistocene beds into the Grand Prairie region is in the magnitude of 135,000 acre-feet a year, which is sufficient for the irrigation of about 75,000 acres of rice. As the acreage irrigated with water pumped from the Pleistocene beds is in excess of this amount, it is imperative that consideration be given to methods for remedying the situation by increasing the water supply or reducing the acreage.

"Of the several possible remedial methods that have been suggested, three of them--the use of water from deep-lying Tertiary beds, the impounding of water in small reservoirs within the region, and the substitution of other crops for rice--may be practiced by the rice growers individually. More water could probably be obtained from the deep-lying Tertiary beds in the region.

"The diversion of water from the White or Arkansas Rivers would necessarily involve collective action by large groups of rice growers, and cooperative action would also be needed for artificial recharge. It is desirable that experimental recharge wells be drilled in the Grand Prairie region, and that thoroughly controlled tests be made to find the best methods of using the wells to replenish the ground-water supply to determine, as conclusively as possible, whether recharge is practicable."

THE GROUND-WATER RESOURCES OF COLUMBIA COUNTY, ARKANSAS, U.S. Geological Survey Circular 241, 1953, by D. B. Tait, R. C. Baker, and G. A. Billingsley.

"Ground water is used in Columbia County, Arkansas, at an estimated rate of about 3 million gallons per day. The city of Magnolia, oil fields, and oil processing industries are the principal users of ground water.

"The Sparta Sand of Tertiary age, yields moderately mineralized, generally soft, sodium bicarbonate water at a rate of about 2.7 million gallons per day. The maximum optimum perennial yield from the Sparta in the county cannot be estimated, but the decline in water levels suggests that the optimum rate of pumping in the vicinity of Magnolia is about 3 million gallons per day.

"Sediments of Quaternary age in the western part of the county might be developed as a source of fairly hard, moderately mineralized water."

ARKANSAS' GROUND-WATER RESOURCES, Arkansas Geological and Conservation Commission Water Resources Circular No. 1, 1955, by R. C. Baker.

This 16-page somewhat popularized report provides a generalized picture of the occurrence of ground water in Arkansas. Two maps of the State are used to show areas of the most important water-bearing rocks and approximate yield of wells. An appendix at the end of the report lists questions most frequently asked about obtaining water from wells and provides answers.

GROUND-WATER RESOURCES OF CHICOT COUNTY, ARKANSAS, Arkansas Geological and Conservation Commission Water Resources Circular No. 3, 1955, by F. E.Onellion and J. H. Criner, Jr.

In 1955 about 12.5 million gallons of ground water per day was being used in Chicot County for irrigation, municipal, and domestic purposes. Most of the water was obtained from the alluvium at depths of less than 150 feet with yields generally 1,000 gpm or more. One of the highest yielding wells in Arkansas (6,000 gpm) is located in the alluvium in the southeastern corner of Chicot County. The water from the alluvium generally contains more than 500 ppm dissolved solids, is hard, and much of it contains 5 ppm or more iron In parts of T.18 S., R. 3W., the water contains more than 500 ppm chloride and is unsuitable for most uses. Water also is obtained from deeper lying water-bearing formations (300 to 500 feet deep) but yields are generally less than 500 gpm. In the northern part of Chicot County, the deeper lying formations yield good quality water but in the southern part of the county the water is too mineralized for many uses. Well records, chemical quality of ground-water samples, water levels, and other related basic hydrologic data are given in 11 different tables.

GROUND-WATER RESOURCES IN A PART OF SOUTHWESTERN ARKANSAS, Arkansas Geological and Conservation Commission Water Resources Circular No. 2, 1955, by H. B. Counts, D. B. Tait, Howard Klein, and G. A. Billingsley.

This report gives information about the geography, geology, and ground-water resources of an area of about 3,900 square miles in southwestern Arkansas. The area is drained by the Red River, Little River, and the Little Missouri River. The most important aquifers are the Trinity Group, the Tokio Formation, and the Nacatoch Sand. The maximum yield to be expected from any one of these formations is less than 400 gpm. There is a considerable difference in the quality of water from the different water-bearing formations, as the saltwater contained in these rocks at the time of their deposition has not been completely flushed out of the lower parts by freshwater. Geologic maps and sections with lines showing the salt content to be expected at given locations provide a guide in locating drilling sites and depths to avoid getting into the brackish-water zones. The report is illustrated with six plates and eight figures showing various hydrologic interpretations such as pumping-test curves, geologic sections, and salt content of the water. Twelve tables list basic hydrologic data for the areas, such as well records, chemical analyses of water from wells, and pumping-test measurements.

GROUND-WATER RESOURCES OF PARTS OF LONOKE, PRAIRIE, AND WHITE COUNTIES, ARKANSAS, Arkansas Geological and Conservation Commission Water Resources Circular No. 5, 1957, by H. B. Counts.

Wells yielding about 400 to 1,700 gpm can be developed at depths of about 60 to 160 feet in the Quaternary deposits in these three counties. West of Des Arc and in southern Lonoke and Prairie Counties, water levels are lowered to such an extent that any great increase over present development would result in depletion of local ground-water resources.

Close to the Fall Line and in embayments of streams issuing from the Interior Highlands in the three Counties, the Quaternary deposits are thin, and are mostly made up of fine-grained material resulting in very low well yields. Water from the Quaternary deposits generally is chemically suitable for most purposes although it is hard and may contain considerable iron. In one area southeast of Bald Knob the water is too salty for most uses.

According to this report, little is known about aquifers at depth below the Quaternary deposits, although it is pointed out that fresh water can be expected at a minimum depth of 100 to 250 feet near the northwestern boundary to about 500 feet in the southeastern part of the area.

GEOLOGY AND GROUND-WATER RESOURCES OF DREW COUNTY, ARKANSAS, Arkansas Geological and Conservation Commission Water Resources Circular No. 4, 1956, by F. E. Onellion.

In 1956 more than 95 percent of the water used for all purposes in Drew County came from wells. The principal water-bearing formation is the alluvium that in places is as much as 200 feet thick, with wells in this material yielding as much as 2,000 gpm. Water also is obtained from formations 300 to 800 feet below the surface but yields generally are less than 900 gpm. All the ground water in the county is chemically suitable for most purposes, the deeper formations generally providing somewhat better water because the water is not as hard as that from the alluvium.

The report contains records of wells, chemical analyses of water from wells, water-level data, and several illustrations showing geologic and hydrologic conditions that will assist the reader in determining such things as drilling depths to be expected, the depth to the base of fresh water, and information needed to develop ground-water supplies.

FRESH-WATER AQUIFERS OF CRITTENDEN COUNTY, ARKANSAS, Arkansas Geological and Conservation Commission Water Resources Circular No. 8, 1961, by R. O. Plebuch.

Ground water is unquestionably one of the most important natural resources in Crittenden County. Three major aquifers are present throughout the entire county: the "1,400-foot" sand now called the lower Wilcox aquifer, the sands in the Claiborne Group which include the "500-foot" sand or what is now called the Memphis aquifer, and the alluvial deposits near the surface. All three aquifers yield water with a chemical quality suitable for nearly all purposes, although the aquifers beneath the alluvium generally contain the "best" water. Much of the water from the alluvium contains more than 5 ppm iron and generally exceeds a hardness of 250 ppm. Well yields in all three aquifers generally range from 300 to 3,000 gpm, with the alluvium consistently providing large yields to wells. The report contains 19 technically oriented illustrations useful in determining ground-water conditions at a given site. A considerable amount of basic data on well records, chemical analyses of water from wells, and water levels are given in five tables.

GEOLOGY AND GROUND-WATER RESOURCES OF DESHA AND LINCOLN COUNTIES, ARKANSAS, Arkansas Geological and Conservation Commission Water Resources Circular No. 6, 1961, by M. S. Bedinger and J. E. Reed.

Everywhere in Desha County and in all of Lincoln County except the southwest corner wells yielding 400 to 3,000 gpm can be obtained in the alluvium at depths of about 75 to 200 feet. Water, generally soft and of excellent quality, can be obtained everywhere in both counties from formations lying below the alluvium at depths of about 300 to 1,600 feet. The report is illustrated with 42 plates and figures useful in determining the probable ground-water conditions at a particular site. Tables of well records, water levels, logs of test holes, and chemical analyses of ground water for the two-county area round out the coverage.

MURFREESBORO AREA, Arkansas Geological and Conservation Commission Special Ground-Water Report Number 1, 1960, by D. R. Albin.

"The Murfreesboro area is underlain by rocks of Quaternary and Early Cretaceous age. Three aquifers are present in the area. They are alluvium and terrace deposits of Quaternary age and the Pike gravel, the basal formation of the Trinity group of Early Cretaceous age. At present (1959), only a few shallow domestic wells produce water from the alluvium and terrace deposits. This water is of good quality, and it is possible that an additional water supply for the area could be obtained from these shallow deposits.

"The Pike gravel is the principal aquifer now utilized in the Murfreesboro area. Approximately 70,000 gpd (gallons per day) is produced from it at present. Increased need for water in the area reportedly will require this production to be tripled. Wells screened in the Pike gravel in the area should yield 100 to 125 gpm (gallons per minute) if they are not spaced closer together than about half a mile, and if the present water level of the aquifer is not lowered more than 5 to 10 feet. Water from this aquifer is hard and is high in iron content. At present the city of Murfreesboro is treating the water by aeration and settling to reduce the iron concentration."

GROUND-WATER POTENTIAL OF MISSISSIPPI COUNTY, ARKANSAS, Arkansas Geological and Conservation Commission Water Resources Circular No. 7, 1960, by R. W. Ryling.

In Mississippi County, ground water is obtained from wells screened in alluvial deposits (Quaternary deposits) and from sands in the Claiborne and Wilcox Groups lying below the alluvium. The iron content of 18 samples of water from the alluvium ranged from 1.1 ppm to 26 ppm and the hardness ranged from 132 to 465 ppm. The Claiborne Group yields water with low mineralization but hard and with considerable iron. The Wilcox Group yields the "best" quality water, being low in mineralization and generally soft and low in iron. Well yields range from a few gallons per minute to a reported 3,000 gpm in the Quaternary aquifer and from 30 to 1,800 gpm in the Wilcox Group. Water levels in the alluvium are less than 10 feet below land surface in more than half the county and from 10 to 20 feet below land surface in the rest of the area. Wells in the Wilcox Group flowed to the surface in the past but now generally range from 3 to 15 feet below land surface. Cretaceous deposits at a greater depth than the Wilcox Group are not utilized at present as a source of water but potentially are a source of fresh water in northern Mississippi County.

Twenty-one illustrations are used to present hydrologic information such as depths to water, geologic conditions, and classification of the ground water for irrigation purposes. Fifteen tables list information such as well records and chemical analyses of water from wells.

GROUND-WATER SUPPLY OF THE MEMPHIS AREA, U.S. Geological Survey Circular 408, 1958, by J. H. Criner and C. A. Armstrong.

The report covers an area of about 1,000 square miles in the Coastal Plain and includes Shelby County, Tenn., a small part of Mississippi and a part of Arkansas in Crittenden County. Most of the ground water used in the area is withdrawn from the "500-foot" sand (now called the Memphis aquifer) of the Claiborne Group and the "1,400-foot" sand (now called lower Wilcox aquifer) of the Wilcox Group.

Water levels in wells penetrating these principal aquifers have declined since pumping began in 1924. The aquifers are recharged mainly by precipitation in areas where they crop out and by percolation from adjacent rocks. The Mississippi River probably contributes some water to the "500-foot" sand.

The quality of water from these two aquifers is very good. The only undesirable constituents in these waters are iron and carbon dioxide, which are easily removed by aeration and filtration.

GROUND-WATER RESOURCES OF JEFFERSON COUNTY, ARKANSAS, University of Arkansas, Institute of Science and Technology, Research Series No. 19, June 1950, by Howard Klein, R. C. Baker, and G. A. Billingsley.

The principal aquifers in Jefferson County are the deposits of Quaternary age and the Sparta Sand. The Quaternary is as much as 250 feet thick in places and yields water freely to wells. According to table 2 (well records), wells in the Quaternary yield as much as 2,000 gpm. The Sparta Sand has an average coefficient of transmissibility of about 100,000 gallons per day per foot in the vicinity of Pine Bluff. Many wells in the Sparta yield more than 1,000 gpm.

In general, ground water from the Quaternary deposits and Sparta Sand is chemically suitable for nearly all purposes. The dissolved solids in water from the Sparta Sand ranged from 60 to 138 ppm, the water was very soft, and the iron content was usually less than 2 ppm. Water from Quaternary deposits is more mineralized and varies more in composition from place to place than that from the Sparta. The dissolved solids in water from the Quaternary ranged from 195 to 851 ppm, hardness ranged from 93 to 565 ppm, and the iron content ranged from 0.03 to 28 ppm.

The total amount of ground water pumped in Jefferson County is estimated to be about 29 mgd (1950) with more than 10 mgd taken from the Sparta. Most of the withdrawals from deposits of Quaternary age (estimated at 18 mgd) are for irrigation of rice.

GEOLOGY AND GROUND WATERS OF NORTHEASTERN ARKANSAS, U.S. Geological Survey Water-Supply Paper 399, 1916, by L. W. Stephenson and A. F. Crider, *With a discussion of* The chemical character of the waters by R. B. Dole.

The geologic description of the area is covered in detail and includes a geologic map of the northeastern quarter of Arkansas for parts or all of 33 counties. A detailed geologic history also is included which describes the Mississippi River as having flowed on the west side of Crowleys Ridge.

Detailed descriptions of the physiography, geology, and water resources are given for each of 22 counties in the area. These include Arkansas, Clay, Craighead, Crittenden, Cross, Greene, Independence, Jackson, Jefferson, Lawrence, Lee, Lonoke, Mississippi, Monroe, Phillips, Poinsett, Prairie, Pulaski, Randolph, St. Francis, White, and Woodruff Counties. The chemical quality of surface and ground water in northeastern Arkansas is treated in detail in a section of the report by R. B. Dole.

SPECIAL GROUND-WATER REPORT NO. 3, JACKSONVILLE AREA, ARKANSAS, U.S. Geological Survey open-file report, 1960, by R. O. Plebuch.

"At the present time (1959) the entire municipal water supply of Jacksonville, Ark., comes from the Quaternary alluvium. The municipal system has a present maximum capacity of 2,500,000 gallons per day, and supplies both the city and the Little Rock Air Force Base. It is estimated that by 1980 the requirements will be approximately 5,000,000 gallons per day.

"This investigation disclosed that the Eocene series in the western Sand Hills area east-northeast of Jacksonville is capable of yielding several hundred gallons per minute to individual wells.

"Furthermore, it was found that the Quaternary alluvium east of Jacksonville is a potential source of large supplies of water. Irrigation wells yielding as much as 950 gallons per minute have been developed near this area. Comparison of water-level measurements in wells in the present city field indicate that, except for seasonal variations, there has been no significant change in the position of the water table since 1944.

"Water samples were collected and analyzed from both the Eocene series and the Quaternary alluvium. The results of the analyses indicate that the water from the Quaternary alluvium north of Bayou Meto is less hard and contains less calcium and dissolved solids than that from the present Jacksonville city well field."

GEOLOGY AND UNDERGROUND WATER RESOURCES OF NORTHERN LOUISIANA AND SOUTHERN ARKANSAS, U.S. Geological Survey Professional Paper 46, 1906, by A. C. Veatch.

The report includes chapters on geology, general underground water conditions, methods and costs of well making, ground-water prospects by counties, detailed well and spring records, and a dictionary of altitudes. This 422-page volume is the result of fieldwork begun by the author in the fall of 1902 and concluded in 1903. It was supplemented of course, by several years of fieldwork by other investigators, but nevertheless is an outstanding example of the excellent work done in early days of geologic and water-resources studies in the United States.

MEMORANDUM ON AVAILABILITY OF GROUND WATER FOR IRRIGATION IN CERTAIN AREAS OF EASTERN ARKANSAS, U.S. Geological Survey open-file report, November 1957, by P. E. Dennis and others.

The report contains information on the future prospects of irrigation of rice with water from wells in parts of basins of the Cache, St. Francis, and L'Anguille Rivers, Big and Dials Creeks, Bayou Meto, the Boeuf and Tensas Rivers, and Bayou Macon. From 1945 to 1955 the amount of water pumped for irrigation in Arkansas increased 100 percent. In general, a projected increase in pumpage of 38 percent over the next 10 years in the area under consideration would be feasible without serious overdraft if the wells are properly spaced.

WATER RESOURCES OF THE WINSLOW QUADRANGLE, ARKANSAS, U.S. Geological Survey Water-Supply Paper 145, 1905, by A. H. Purdue.

The Winslow quadrangle is about 28 miles wide and 34 miles long in western Arkansas with the southern border near the Arkansas River and the northern border near Fayetteville, Ark. A brief description of the topography, drainage, and geology of the area is followed by a discussion of the water resources. The Boone Formation, Pitkin Limestone, Hale Sandstone, and Winslow Formation are listed as important water producers.

WATER RESOURCES OF THE CONTACT REGION BETWEEN THE PALEOZOIC AND MISSISSIPPI EMBAYMENT DEPOSITS IN NORTHERN ARKANSAS, U.S. Geological Survey Water-Supply Paper 145, 1905, by A. H. Purdue.

The contact region discussed is a belt of land 12 to 15 miles wide along the western border of the Coastal Plain and north of the Arkansas River and includes a narrow belt of the adjacent highlands. The topography, drainage, and geology of the area are given detailed treatment. In this publication, the Mississippi River is reported to have flowed to the west of what is now Crowleys Ridge and the Ohio River to the east. In the section on water resources, the Boone Formation, Batesville Sandstone, Pitkin Limestone, and the Morrow Formation are listed as important water producers in the highlands. One item of particular interest reported refers to experiments in rice culture near Lonoke, Ark., using well water for irrigation. The report states that should the climatic and soil conditions be favorable to rice culture there is no reason why it should not become an important industry, for there is an abundance of ground water for irrigation in the lowlands (Coastal Plain). The usual depth of wells in the lowlands is reported to be 15 to 40 feet, with a few listed as 100 feet deep.

GROUNDWATER IN ALLUVIUM OF THE LOWER MISSISSIPPI VALLEY (UPPER AND CENTRAL AREAS), VOLUMES I AND II, U.S. Army Engineer Waterways Experiment Station, Corps of Engineers Technical Report Number 3-658, September 1964, by E. L. Krinitzsky and J. C. Wire.

"This report provides data on the alluvial aquifer of the Lower Mississippi Valley in the area between Cape Girardeau, Missouri, and Port Gibson, Mississippi. Maps are presented of the Tertiary surface on which the alluvial aquifer rests as well as the geology of this surface and the areas where hydrologic recharge to the alluvial aquifer may occur. A set of piezometric-surface maps, together with hydrographs of observation wells, river stages, precipitation rates, and data on the hydrologic properties of the alluvium, makes it possible to calculate changes which take place in the aquifer. Further data are presented on the chemical quality of ground-water. The relevance of these data to engineering problems is discussed."

WATER-RESOURCES RECONNAISSANCE OF THE OUACHITA MOUNTAINS, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1809-J, 1965, by D. R. Albin.

"Water for domestic and nonirrigation farm use can be obtained from wells nearly everywhere in the Ouachita Mountains, and ground-water supplies as large as 50,000 gpd (gallons per day) often can be developed. In general, the best procedure for developing ground-water supplies in the mountains is to drill wells on the flanks of anticlines (in synclinal valleys) and off the noses of plunging anticlines. Ground water for industrial or municipal use in the area may require treatment for removal of iron and calcium magnesium hardness.

"Streams are the best potential sources of water for municipal growth and economic development in the Ouachita Mountains. Although most streams in the mountains occasionally have very little or no flow, with adequate storage facilities they generally are the best sources of supply when water demands approach 50,000 gpd. The streams contain water of excellent quality that chemically is suitable for nearly all uses."

WATER RESOURCES OF PULASKI AND SALINE COUNTIES, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1839-B, 1967, by R. O. Plebuch and M. S. Hines.

"Pulaski and Saline Counties constitute an area of 1,506 square miles in the geographic center of Arkansas. The area is divided into a hilly western part, known as the Interior Highlands, and a relatively flat eastern part, known as the Coastal Plain.

"In the Interior Highlands, surface water offers greater possibilities than ground water for water supplies. Alum Fork, Middle Fork, and North Fork of the Saline River offer excellent impoundment possibilites and will yield water of good quality. In addition, with storage, many of the smaller streams are suitable for development of small supplies, "In contrast, in the Coastal Plain it is easier to develop ground water than surface water in relatively large quantities. Two aquifers, units 3 and 9, yield as much as 350 and 2,000 gallons per minute to a well south of the project area. These aquifers yield water that, with treatment, is suitable for most uses."

WATER RESOURCES OF JACKSON AND INDEPENDENCE COUNTIES, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1839-G, 1967, by D. R. Albin, M. S. Hines, and J. W. Stephens.

"The present (1965) water use in Jackson and Independence Counties is about 55.6 million gallons per day, and quantities sufficient for any foreseeable use are available. Supplies for the large-scale uses--municipal, industrial, and irrigation--can best be obtained from wells in the Coastal Plain and from streams in the highlands.

"Wells in the Coastal Plain will yield 1,000-2,000 gallons of water per minute when screened at depths from 100 to 150 feet in alluvial sand and gravel of Quaternary age. The water will require treatment for the removal of iron and the reduction of hardness to be suitable for municipal and industrial uses. Wells in the highlands generally yield less than 50 gallons per minute of water that is of good quality, though hard.

"The dependable flow of the White River at Newport is about 4.2 billion gallons per day. The dependable base flows of the small streams tributary to the White River in the Salem Plateau and Springfield Plateau sections range from 0.25 to 5 million gallons per day, and the dependable flow of Polk Bayou at Batesville is about 21 million gallons per day. These streams can be utilized for water supply with little or no artificial storage required. Streams in the Boston Mountains section and in the Arkansas Valley section recede to very low flow or to no flow during extended dry periods, but dependable supplies can be obtained from these streams by construction of storage facilities. Water from all the highland streams is of excellent chemical quality except that it generally is hard."

WATER RESOURCES OF GRANT AND HOT SPRING COUNTIES, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1857, 1968, by H. N. Halberg, C. T. Bryant, and M. S. Hines.

"In Grant and Hot Spring Counties the Ouachita, Saline, and Caddo Rivers yield large quantities of soft, good-quality water. Small streams in southeastern Hot Spring County and some of the small streams in the Ouachita Mountains have relatively high base flow; in Grant County small streams yield little water during dry periods. At times, sewage and mine drainage pollute the Ouachita River from the Garland County line to a point a few miles below Lake Catherine. At low flow, Hurricane Creek water is unfit for most uses.

"The Sparta Sand, the principal aquifer, yields as much as 850 gpm of soft water in Grant County. The Carrizo Sand and Cane River Formation are potentially important aquifers in Grant County and southeastern Hot Spring County. The Wilcox Group yields as much as 300 gpm of fresh water in southeastern Hot Spring County and southwestern Grant County; in the rest of Grant County its water is brackish. The alluvium along the principal streams and the consolidated rocks of the Ouachita Mountains yield small quantities of water that vary in quality from place to place. Some of the water from the alluvium has high nitrate content and may be a hazard to health."

WATER RESOURCES OF HEMPSTEAD, LAFAYETTE, LITTLE RIVER, MILLER, AND NEVADA COUNTIES, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1998, 1972, by A. H. Ludwig.

"Ground water occurs in sand aquifers of Cretaceous age (Tokio Formation and Nacatoch Sand), Tertiary age (Wilcox Group, Carrizo Sand, Cane River Formation, and Sparta Sand), and Quaternary age (terrace and alluvial deposits). The aquifers of Cretaceous age are the principal sources of fresh water in northern Hempstead and Nevada Counties, where wells that tap these formations yield as much as 300 gallons per minute of good-quality water from depths as great as 1,200 feet. The quality of water in these aquifers deteriorates downdip and becomes saline in northern Miller, southern Hempstead, and central Nevada Counties.

"Aquifers of Tertiary age are good sources of water in Miller and Lafayette Counties and in southeastern Nevada County. Wells that tap these formations generally do not exceed 400 feet in depth, but some wells are as much as 700 feet deep. Yields as great as 920 gallons per minute are obtained from the formations of Tertiary age; however, yields ranging from 100 to 300 gallons per minute are more common. Water from the formations of Tertiary age is suitable for municipal and industrial use; but, because of the high-sodium and high-salinity hazard, the water generally is not suitable for irrigation. Much of the water would require treatment for the removal of iron.

"Terrace deposits of Quaternary age are good sources of water in Little River and Lafayette Counties. Wells in these deposits generally yield sufficient quantities of water for domestic use and, in some places, for municipal and irrigation use. However, in parts of western Little River County, these deposits do not yield sufficient quantities of water even for domestic use. Yields of 800 gallons per minute have been measured from wells tapping terrace deposits in eastern Little River County, and a yield of 1,100 gallons per minute was reported from a well in Lafayette County.

"Wells that tap the alluvial aquifer in the Red River Valley generally yield as much as 1,200 gallons per minute; however, yields of 1,500 gallons per minute are possible. The water is used primarily for irrigation but, because of its high iron content and high degree of hardness, would require extensive treatment for other uses.

"The Red River is the largest source of surface water in the project area. It drains about 48,000 square miles upstream from the area and has an average flow of 12,180 cubic feet per second at Index. The principal reservoirs in the area are Millwood Reservoir on Little River (capacity 1,858,000 acre-feet) and Lake Erling on Bodcau Creek (capacity 49,000 acre-feet). More than 5,500 lakes and farm ponds of 5 acres or less in the study area have a combined storage capacity of more than 14,000 acre-feet.

"The tributary streams are potential sources of supply; however, depending on the need, storage facilities would be required on most of the streams to provide adequate flow during dry periods. Streams having the highest sustained flows, and consequently the greatest supply potential, include Ozan Creek, Bois d'Arc Creek, and Terre Rouge Creek. Base flows in these streams are sustained by seepage from the Tokio Formation and the Nacatoch Sand.

"Reservoirs could be constructed at many sites in the upland area. Topographic relief and an average annual runoff rate of 1.2 cubic feet per second per square mile are favorable for the construction of reservoirs, which could supply many times the amount of water used in 1969.

"Water in the Red River is high in chloride and dissolved solids and consequently is chemically unsuitable for most uses unless treated. The chemical quality of water in the tributary streams is good. The quality is similar to that of water in the geologic formations underlying the basin, unless altered by industrial or oil-field wastes. During low flow, water in Caney Creek contains as much as 2,800 milligrams per liter of chloride as the result of oil-field pollution.

"The presence of pesticides in samples of water and sediment taken from Posten Bayou, Walnut Bayou, and Ozan Creek has been established. However, the concentration of pesticides in the water does not exceed the allowable limits."

WATER RESOURCES OF RANDOLPH AND LAWRENCE COUNTIES, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1879-B, 1969, by A. G. Lamonds, M. S. Hines, and R. O. Plebuch.

"Water is used at an average rate of almost 27 million gallons per day in Randolph and Lawrence Counties, and quantities sufficient for any foreseeable use are available. Supplies for the large uses--municipal, industrial, and irrigation--can best be obtained from wells in the Coastal Plain part of the counties and from streams in the Interior Highlands part.

"The counties have abundant supplies of hard but otherwise good-quality surface water, particularly in the Interior Highlands and along the western boundary of the Coastal Plain.* * * Water supplies can be obtained without storage from the larger streams in the area. Many of the smaller streams in the Interior Highlands also have large water-supply potential because of the excellent impoundment possibilities.

"Most of the water used in the two counties is obtained from ground-water reservoirs in the Coastal Plain. Wells that tap alluvial deposits of Quaternary age commonly yield 1,000 gallons per minute. However, the water often is unsuitable for many uses unless treated to remove hardness, iron, and manganese. Water possibly may be obtained in the southeastern part of the area from the Wilcox Group of Tertiary age and the Nacatoch Sand of Cretaceous age, but these formations have not been explored in the report area.

"Wells in the Interior Highlands generally are less than 200 feet deep and yield 10 gallons per minute, or less. It may be possible to obtain greater amounts of ground water from two unexplored formations, the Roubidoux and the Gunter Sandstone Member of the Van Buren Formation, in the Interior Highlands. Ground water in the Interior Highlands is very hard and is more susceptible to local bacterial contamination than is ground water in the Coastal Plain.* * *"

WATER RESOURCES OF CLARK, CLEVELAND, AND DALLAS COUNTIES, ARKANSAS, U.S. Geological Survey Water-Supply Paper 1879-A, 1969, by R. O Plebuch and M. S. Hines.

"Although some of the streams in the area can furnish dependable water supplies without storage, the amount of water available for use can be increased by the construction of reservoirs. The average surface-water yield in the area is about 1.4 cubic feet per second per square mile, or a total of about 3,000 cubic feet per second. Generally, the water quality is good; but water from some of the streams, particularly from the smaller tributaries, may require treatment for excessive iron content and high color.* * *"

"Of the 17 geologic units present in the Coastal Plain part of the project area, 12 yield water but in varying amounts. Among the formations of Cretaceous age, the Tokio yields good-quality water in the outcrop, but the quality deteriorates downdip; the Brownstown Marl yields small amounts of water for domestic purposes, mainly in the outcrop area; the Ozan Formation yields a highly mineralized water that is generally unsuitable for most purposes; the Nacatoch Sand yields as much as 100 gallons per minute of good-quality water in and near the outcrop, but the water becomes very salty and corrosive at distances ranging from 2 miles downdip from the outcrop in northern Clark County to 17 miles downdip in the southern part of the county.

"The formations of Tertiary age offer the best possibilities for ground water, particularly in Dallas and Cleveland Counties. The Wilcox Group contains no thick widespread sands but contains thin sands locally. The quality of the water tends to deteriorate downdip, as the water becomes more mineralized and changes from a bicarbonate to a chloride type. The Carrizo Sand is undeveloped but may yield several gallons of water per minute per foot of drawdown in a large part of these two counties. High iron content may be a problem in water from the Carrizo. The Cane River Formation yields 50 gallons per minute of good-quality water to each of two wells at Sparkman. Elsewhere, high iron content of the water may be a problem. The Sparta Sand is the best aquifer in the project area, particularly east of central Dallas County. Well yields of 700 gallons per minute or more are possible. With minor treatment, the water is suitable for most purposes. The Cockfield Formation is utilized mainly for domestic supplies, but where the sands are thick, yields of as much as 300 gallons per minute are possible. The Jackson Group is utilized mainly for domestic supplies. In some areas, water from this unit contains such a high concentration of sulfate that it is unpalatable.

"The deposits of Quaternary age are thin and generally suitable only for domestic supplies. However, several wells that yield more than 200 gallons per minute have been developed in the alluvium south of Arkadelphia. Transmissibility values are highly variable, and test drilling is advisable to determine if large amounts of water are available at any specific site.* * *"

WATER-RESOURCES RECONNAISSANCE OF THE OZARK PLATEAUS PROVINCE, NORTHERN ARKANSAS, U.S. Geological Survey Hydrologic Investigations Atlas HA-383, 1972, by A. G. Lamonds.

Most of the rocks underlying the Ozark Plateaus consist of limestone, dolomite, sandstone, and shale. Nearly all the formations ranging in age from Ordovician to Quaternary yield water to wells although commonly not in excess of 10 gpm. Notable exceptions are the Roubidoux Formation and Gunter Sandstone Member (Ordovician) which are known to yield as much as 500 gpm in places. Contour maps show the elevation of the top of the Roubicoux and Gunter and can be used to estimate the depth of drilling required to penetrate these formations.

The chemical quality of ground water in the Ozark Plateaus generally is suitable for nearly all purposes. The only constituent that commonly exceeds recommended limits is iron.

The White River and its tributaries are the principal streams draining the Ozark Plateaus. Average annual runoff for all streams in the plateaus is from less than 1.0 cfs per square mile to more than 1.8 cfs per square miles. The highest runoff is in the Boston Mountains and the lowest is in the Springfield and Salem Plateaus.

Not all the streams in the area have a sufficiently high year-round flow that can be depended upon for a water supply. Low-flow data in the report can be used to determine whether or not storage would be required for a desired withdrawal and draft-storage relations provided can be used to determine the amount of storage required for a given draft.

Surface water throughout the Ozark Plateaus is chemically suitable for most municipal and industrial uses and pollution is not a serious problem at present (1969). The concentrations of chemical constituents in the water generally are well within the limits recommended by the U.S. Public Health Service.

WATER RESOURCES OF CLAY, GREENE, CRAIGHEAD, AND POINSETT COUNTIES, ARKANSAS, U.S. Geological Survey Hydrologic Investigations Atlas HA-377, 1972, by M. S. Hines, R. O. Plebuch, and A. G. Lamonds.

Ground water is available from the alluvium which covers the four counties except for Crowleys Ridge and from other formations below the alluvium. Surface water is available from the Black, Cache, St. Francis, and Little Rivers and from many ditches and laterals in the area.

The alluvium ranges in thickness from 35 to 185 feet and will yield up to 2,000 gpm in places. Deeper aquifers may yield as much as 1,000 gpm.

Water levels in the alluvium have declined as much as 55 feet in western Poinsett and Craighead Counties. The remaining saturated section ranges from 65 to 90 feet. If the present (1968) rate of decline is extrapolated at the rate of 1.0 foot per year, yields from many wells in the area will be less than 600 gpm in about 50 years.

Surface-water supplies in the area are available in large quantities but may not be as accessible in as many places as ground water. Average annual streamflow ranges from 1.2 cfs per square mile in the western part of the four counties to 1.4 cfs per suqare mile in the eastern part.

Maximum depths to the base of fresh water range from 200 to 2,600 feet. Ground water from the alluvium generally is hard and high in iron but is suitable for irrigation which is the principal use. Water from the lower Wilcox aquifer contains a high percent sodium and may not be suitable for irrigation but requires little treatment for a public supply. Surface water generally contains less total dissolved solids than the ground water and is chemically suitable for most uses.

HYDROLOGY OF THE BAYOU BARTHOLOMEW ALLUVIAL AQUIFER-STREAM SYSTEM, ARKANSAS, U.S. Geological Survey open-file report, 1973, by M. E. Broom and J. E. Reed.

"The alluvial aquifer and streams are hydraulically connected and are studied as an aquifer-stream system. Bayou Bartholomew is a principal stream of the system.* * *"

"The mean annual surface-water yield of the area that drains to the Ouachita River basin is nearly 2 million acre-feet. Flood-control projects have significantly reduced flooding in the area.* * *"

"The direction of ground-water flow generally is southward. Bayou Bartholomew functions mostly as a drain for ground-water flow from the west and as a source of recharge to the aquifer east of the bayou. As a result of navigation pools, the Arkansas River is mostly a steady-recharge source to the aquifer.

"Pumpage from the aquifer and streams increased from about 2,000 acre-feet in 1941 to 237,000 acre-feet in 1970.

"Estimates* * *indicate that recharge to the aquifer in 1970 was about 161,000 acre-feet. About 70 percent of the recharge was by capture from streams as a result of ground-water pumpage* * *"

"Stream diversion in 1970 from capture and open channel,* * * was about 110,000 acre-feet. Return flow to streams from rice irrigation and fishponds was about 60,000 acre-feet.

"The chemical quality of streamflows is excellent for irrigation. Water from the aquifer generally ranges from permissible to excellent for irrigation. The use of water from the aquifer in the flood-plain area, exclusive of irrigation, is severely limited unless it is treated to remove the iron and reduce the hardness."

GROUND WATER FOR INDUSTRIAL USE IN THE VICINITY OF LITTLE ROCK, ARKANSAS, U.S. Geological Survey open-file report, 1951, by R. C. Baker and others.

There are large undeveloped reserves of ground water in the vicinity of Little Rock that can be made available through large-capacity wells. Ground water is used in Little Rock and vicinity at an estimated rate of 10 mgd. The most productive water-bearing material consists of alluvial deposits along the Arkansas River and in a large area northeast, east, and southeast of the city.

The maximum thickness of the alluvial deposits is about 150 feet. Large capacity wells range in depth from 70 to 140 feet. The maximum capacity reported for a well tapping the alluvium in this vicinity is 2,500 gpm. Considerable variation in well yields exists from place to place. Most of the water may require limited treatment for iron and hardness for most uses.

GROUND WATER POSSIBILITIES, PULASKI AND JEFFERSON COUNTIES, ARKANSAS, Arkansas Resources and Development Commission Special Report, prepared for Charles Carpenter, New York and Pennsylvania Company, Incorporated, Lockhaven, Pennsylvania, January 1948, by N. F. Williams, H. B. Foxhall, and R. C. Baker.

The Quaternary sand and gravel deposits have been the only important source of ground water around Little Rock in the past. Four standby wells for the city of Little Rock located one-fourth to one-half mile from the edge of the Arkansas River in the northwest edge of the city are from 70 to 85 feet deep and can yield as much as 2,600,000 gallons per day per well. Surface-water resources are abundant in Pulaski County. The Arkansas River was the source for Little Rock's water supply until Alum Fork of the Saline River was dammed to form the present supply, Lake Winona. Other favorable damsites are located on Maumelle and Little Maumelle Creeks entering the northwest part of the county.

From data available, it seems evident there is a good possibility of developing a reliable supply of ground water from deep (Eocene) sands in the vicinity of Pine Bluff at depths from 700 to 1,000 feet. Wells in operation in the area drawing water form Eocene sands yield from 600 to 800 gpm.

Quaternary deposits also yield large quantities of water to wells in Jefferson County but generally the water is of inferior quality as compared with water from Eocene sands.

WATER RESOURCES AND THE MISSISSIPPI EMBAYMENT PROJECT, U.S. Geological Survey Circular 471, 1963, by E. M. Cushing.

Based on available streamflow records, the quantity of water which originated within the region and which leaves it as streamflow during an average year is about 90 million acre-feet. In addition, about four times this amount of water enters the embayment from adjacent areas. Thus, about 450 million acre-feet of water leaves the embayment as streamflow during an average year.

The amount of ground water stored in the subsurface in the embayment is estimated to be sufficient to cover the entire embayment to a depth of 80 feet.

The Mississippi embayment project in progress (1963) is designed to define the geologic environment and provide management analysis water-resources information.

AVAILABILITY OF WATER IN THE MISSISSIPPI EMBAYMENT, U.S. Geological Survey Professional Paper 448-A, 1970, by E. M. Cushing, E. H. Boswell, P. R. Speer, R. C. Hosman, and others.

"The Mississippi embayment is part of a vast geologic and hydrologic province. Most of the region is underlain by aquifers that will yield large quantities of water to wells, so that ground water is the most readily available source of fresh water.

"Ground water having a dissolved-solids content of less than 500 ppm (parts per million) is generally available at depths of less than 1,000 feet, and water having a dissolved-solids content of less than 1,000 ppm is available in some places to depths of more than 2,000 feet. Iron is the most common troublesome chemical constituent in the ground water.

"The potential yield of the aquifers that underlie the region is estimated to be about 30,000 mgd (million gallons per day), of which about 3,000 mgd is presently being withdrawn.

"Water in varying amounts is also available from streams within the region. The amount of water which originates within the region and which leaves it as streamflow during a year averages about 90 million acre-feet (about 80,000 mgd). An additional 400 million acre-feet (about 360,000 mgd) leaves the region as streamflow during an average year, this amount having originated outside the region. The present withdrawals (1965) from streams within the region are about 1,700 mgd."

WHITE RIVER BASIN, ARKANSAS AND MISSOURI, COMPREHENSIVE BASIN STUDY, White River Basin Coordinating Committee, in six volumes, June 1968.

This study was reviewed and accepted by the White River Basin Coordinating Committee composed of representatives of the Departments of Agriculture; Army; Commerce; Health, Education, and Welfare; and the Interior; the Federal Power Commission; and the States of Arkansas and Missouri.

The report presents a proposed plan for the development and management of the water and related land resources of the White River Basin. Volume I, titled "Main Report," contains an 11-page summary of the six volumes. Volume II contains two appendixes, A and B, titled, respectively, "History of Investigation" and "Area Economic Study." Appendixes C and D in Volume III are titled "Hydrology" and Geohydrology." Volume IV contains five appendixes, E through F, respectively, titled "Mineral Resources and Mineral Industry," "Land Use and Watershed Protection," "Flood Problems and Losses," "Flood Control and Flood Prevention," and "Drainage." Appendixes J through O in Volume V are titled "Outdoor Recreation," "Fish and Wildlife," "Hydroelectric Power," "Navigation," "Water Supply and Water Quality Control," and "Irrigation." The last appendix, P, is in volume VI and is titled "Plan Formulation."

The White River basin contains about 27,765 square miles of which 17,143 square miles is in Arkansas. About 62 percent of the basin is in forest and the remainder is principally in agricultural lands. Flood losses are estimated to average $97,000,000 annually and about 3,400,000 acres have a wetness hazard.

Considering the availability of water for the basin as a whole, there is sufficient water to serve all purposes. In 1965 approximately 48 mgd was used for municipal and industrial purposes. This use is expected to increase to 140 mgd by 1980 and to 257 mgd by 2020. In the Coastal Plain part of the basin, there will be sufficient water to meet the projected irrigation and water-supply requirements to the year 2020.

Water-resources problems in the area are flooding, potential pollution of water, crooked alinement of White River and low stages restricting navigation, and lack of an adequate hydrologic instrumentation system for data collection. A comprehensive plan of development includes reservoir construction at 7-main-stem or major tributary locations, installation of hydroelectric-power generating units, 13 levee projects, navigation improvements, construction of 860 structures for flood retardation, water supply, and recreation, and extensive fish, wildlife, and recreation measures.

ARKANSAS WATER RESOURCES, University of Arkansas, Industrial Research and Extension Center, June 1959, by N. H. Wood.

The State of Arkansas includes an area of about 53,100 square miles divided into two areas of about equal size called the

Interior Highlands and the Coastal Plain. Rainfall in the State is normally abundant (an average of 48.6 inches per year) with the heaviest usually occurring in March, April, and May and the least during July, August, and September.

All of Arkansas' major drainage basins empty into the Mississippi River. The Arkansas, White, and St. Francis Rivers enter the Mississippi River from Arkansas, whereas the Ouachita River flows into the Red River in Louisiana and then into the Mississippi. The average annual flow of the Arkansas at Little Rock is about 30 million acre-feet; the White River at Clarendon, 23 million acre-feet; the Red River at Fulton, 13 million acre-feet; the Ouachita River at Camden, 5 million acre-feet; and the St. Francis River near Marked Tree, 3 million acre-feet.

The variations in topography between the Coastal Plain and the Interior Highlands are due principally to the characteristics of the rocks underlying these areas. The rocks also control the availability of ground water in the two regions. Ground water in the Highlands is relatively scarce throughout most of the area as compared with the Coastal Plain. Well yields in the Highlands seldom exceed 300 gpm, whereas in the Coastal Plain wells yielding 300 to 1,000 gpm are common, with some wells yielding more than 2,000 gpm.

The quality of surface water in Arkansas varies from excellent to good with two exceptions, namely, the Arkansas River and the lower Ouachita River. The water of the Arkansas River at times is high in chloride and dissolved solids. The concentrations of dissolved solids at Van Buren sometimes approaches 6,000 ppm, whereas during periods of high runoff at downstream locations the dissolved solids may be as low as 100 ppm. The quality of water in the Arkansas is controlled principally by influences out of the State. Water quality on the upper Ouachita River is very good. Downstream from Camden the influences of industrial activity and oil-field operations have a pronounced effect on the quality of water of the Ouachita River and several of its tributaries, principally Smackover and Hurricane Creeks.

Water quality from Cretaceous deposits is varied and downdip the water progressively becomes more mineralized. Water from Tertiary aquifers generally is the sodium bicarbonate type, is good quality and soft, although at depth, it may be of the sodium chloride type. Quaternary deposits generally yield water of the calcium bicarbonate type that is hard and often high in iron.

The industrial water requirement for Arkansas is estimated to be about 261 mgd by 1975. Water consumption for domestic purposes is increasing. The estimated 1975 domestic water need will be about 162 mgd, of which 126 is for urban use, 24 mgd for rural nonfarm use, and 12 mgd for rural household use. Assuming that the acreage-control program is removed, it is estimated that by 1975 about 1,148 mgd of water will be used for rice irrigation, 512 mgd will be used for irrigation of other crops, 33 mgd will be used for livestock production, and about 222 mgd will be required for fish culture. Thus, total water needs in 1975 are estimated to be 2,342 mgd, an increase of 104 percent over 1957.

ARKANSAS WATER RESOURCES: SUPPLY, USE, AND RESEARCH NEEDS, University of Arkansas, Water Resources Research Center, Publication No. 2, 1967 by Jared Sparks.

"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."

NEGLECTED RICHES IN THE ARKANSAS BASIN AWAIT A RIVER AT WORK, A Pictorial Story of National Assets in a Great Southwestern Area.

This report, probably published in 1944, was prepared by an Interstate Committee appointed by the Honorable Ben Laney, Governor of Arkansas, and the Honorable Robert S. Kerr, Governor of Oklahoma. The report, prepared for presentation to Congress, strongly supports the comprehensive plan of the U.S. Army Corps of Engineers, for development of the Arkansas River for navigation and related benefits. According to the report, recreational benefits will exceed $8,000,000 annually, power and flood-control benefits will earn $6,720,200 per year from five dams, and annual public benefits of navigation to coal will be $1,621,521. Many other benefits and earnings are listed, resulting in a ratio of $1 in cost to $1.97 in benefits.

WATER AND LAND RESOURCES, OUACHITA RIVER BASIN IN ARKANSAS, Arkansas Soil and Water Conservation Commission, July 1970, by R. G. Andrews, E. A. McRae, and Albert Nyitrai.

This report constitutes an appraisal of the water and related land resources of the Ouachita River basin in south-central Arkansas. Included in the appraisal are: (1) The available water supply in terms of quantity and quality; (2) the extent and nature of present water use and pollution; (3) the estimated probable future water needs and availability to meet the needs; (4) the available land resources in terms of food and fiber production and mineral resources; and (5) the capability of the land resources to meet future needs.

The area comprises 11,548 square miles and has a population (1960) of about 367,000 with about 60 percent of the population urban. The basin is rich in water resources with an average annual precipitation of 52 inches and an average annual runoff of 17 inches. The best aquifers are in the Coastal Plain part of the basin and although the ground-water resources are large, overdevelopment has occurred near El Dorado and Magnolia.

Generally, the quality of the water in the basin is excellent. However, manmade pollution has seriously depleted the quality in some areas. Action by the Arkansas Pollution Control Commission and cooperation of the industries creating the pollution problem has cleared up much of the problem, but further effort is needed.

With proper management, water supplies are adequate to meet all foreseeable needs. Quality of water in future years may well be more of a problem than quantity and constant vigilance will be required to protect the water resources.

More information is needed on streamflow characteristics of small drainage areas. Ground-water investigations should be expanded to determine more clearly yields of aquifers. Detailed soil surveys should be made to determine best use of lands. A continuing investigation and assessment of mineral resources of the region should be made.

WATER AND LAND RESOURCES, BARTHOLOMEW-BOEUF-MACON BASIN IN ARKANSAS, Arkansas Department of Commerce, Division of Soil and Water Resources, January 1972, by R. G. Andrews and Albert Nyitrai.

This basin comprises an area of 2,889 square miles in south-eastern Arkansas. The principal economic activities in the basin are related to agriculture and forest products. The basin is rich in water resources; precipitation averages 52 inches and the average annual runoff is 16 inches. Large quantities of ground water are available in Quaternary and Tertiary aquifers. The basin is subject to extremes of floods and droughts and there is a need for surface-water management.

Although the basin's water resources are abundant there will be a need for the utilization of surface-water storage and an orderly development of ground water.

Many small reservoir sites are available in the area west of Bayou Bartholomew. More information is needed on streamflow characteristics of small watersheds. Ground-water investigations should be expanded to define more accurately potential yield of aquifers. Detailed soil surveys should be completed on all areas not adequately covered. More data should be collected on pollution loads including sediment, pesticides, and herbicides.

WATER RESOURCES OF THE BLUE, MUDDY BOGGY, KIAMICHI, AND LITTLE RIVER BASINS IN THE LOWER RED RIVER VALLEY, ARKANSAS AND OKLAHOMA, U.S. Geological Survey administrative report, November 1965, by A. H. Ludwig.

Abundant supplies of ground water are available for future development in the area of this study. The greatest potential lies in river basins underlain by sediments of the Gulf Coastal Plain and limestones in the upper Blue River basin. The principal aquifers in decreasing order of potential are: 1) the outcrop area of the Paluxy Sand, 2) terrace and alluvial deposits along the reaches of all the rivers, especially Little River and along the Red River, 3) limestone in the Arbuckle Mountains, and 4) sandstone and shale in the Arbuckle and Ouachita Mountains.

The rivers in the study area are a good potential source of water and may be the only source where the water demand exceeds 50,000 gpd.

In general, both the ground water and surface water are of good quality. Exceptions are in southern McCurtain County and in Little River County where water in the Paluxy Sand is highly saline. Water in the Blue and Muddy Boggy Rivers is considered to be hard.

AREAS OF PRINCIPAL GROUND-WATER INVESTIGATIONS IN THE ARKANSAS, WHITE, AND RED RIVER BASINS, U.S. Geological Survey Hydrologic Investigations Atlas HA-2, 1953, by S. W. Lohman and V. M. Burtis.

GENERAL AVAILABILITY OF GROUND WATER AND DEPTH TO WATER LEVEL IN THE ARKANSAS, WHITE, AND RED RIVER BASINS, U.S. Geological Survey Hydrologic Investigations Atlas HA-3, 1953, by S. W. Lohman, V. M. Burtis, and others.

CONSERVATION OF WATER AND RELATED LAND RESOURCES, BUFFALO RIVER BASIN, ARKANSAS, INTERIM REPORT, White River Basin Comprehensive Study, Missouri and Arkansas, U.S. Army Engineer District, Little Rock Corps of Engineers, Volumes I, II, III, December 1964.

This report in three volumes, contains appendixes A through H. The appendixes cover hydrology and hydraulic analyses, economic base study, supplemental economic data, detailed cost estimate, geology and soils data, hydroelectric power, reports of other agencies and comments of other agencies. As indicated by the subject matter of the appendixes, the report describes water-resources problems and needs in the Buffalo River basin, with a recommendation for construction of a multiple-purpose dam and reservoir at Gilbert, Ark. Flood control, hydroelectric power, and water-related recreation are listed as benefits. The initial cost is estimated to be $55,300,000 and an annual cost of $380,000 for operation, maintenance, major replacement, and pumping energy.

REGIONAL TRENDS IN WATER-WELL DRILLING IN THE UNITED STATES, U.S. Geological Survey mimeographed report, May 1966, by Gerald Meyer and G. G. Wyrick.

The report provides estimates of the number of water wells drilled in the United States during the period 1960-64. In the tally of wells in the appendix, by States, Arkansas is shown to have had an estimated 5,000 wells drilled in 1960 and 5,000 wells drilled in 1964.

Approximately 435,700 wells were drilled in the United States in 1964--an average of 1,400 well starts each working day. An estimated 13,000 contractors operate about 27,000 drilling machines. The national investment in water wells is estimated to be about one-half to three-quarters of a billion dollars annually. The overall growth rate in wells drilled is about 5,000 wells per year.

WATER WITCHING, U.S. Geological Survey brochure, 14 pages, 1965.

This brochure describes water witching as the use of a forked twig or a pendulum for locating underground water. Dowsers, as they are called, also may be used to attempt to locate gold, silver, lead, uranium, coal, and most other valuable minerals. The origin of the divining rod is not known; the first description of it is found in a description of German mines published in 1556.

According to the brochure, controlled experiments have shown conclusively that water witching is not a reliable method of locating ground water but that a competent hydrologist can show where water can be obtained, its chemical composition, and in a general way, how much is available.

THE DIVINING ROD, A HISTORY OF WATER WITCHING, U.S. Geological Survey Water-Supply Paper 416, 1938, by A. J. Ellis.

A PLAN FOR WATER-RESOURCES INVESTIGATIONS IN ARKANSAS, WITH DEFINITION OF HYDROLOGIC UNITS, U.S. Geological Survey open-file report, October 1970, by R. T. Sniegocki and M. S. Bedinger.

Most of the questions about Arkansas' water resources, such as where, how much, and what kind of water is available, can be answered as a result of descriptive qualitative studies made over the last several years. However, the demands for information about Arkansas' water resources are undergoing a change and include, more and more frequently, such questions as what effect will certain water-development projects have on water quality or on the ground-water levels, what is the time frame for the effects, how can we conserve and preserve our water, and what are the water interrelationships. To answer water management questions of these types, new tools and methods must be utilized. Detailed and quantitative cause-effect models have been developed and have demonstrated their capability in providing answers to complex water-management questions. To effectively apply these modeling tools, Arkansas has been subdivided into hydrologic units isolated as nearly as possible into independent entities.

Four types of hydrologic units can be recognized in Arkansas. There are alluvial aquifer-stream, Cretaceous-Tertiary-Quaternary aquifer-stream, stream-aquifer, and aquifer sub-systems. Each of these types of subsystems is described in detail and through application of the criteria for each type, 23 subsystems can be delineated in Arkansas.

An appendix provides a detailed description of selected sub-systems, data available within the subsystem, and the principal problems to be solved.

A PLAN FOR WATER-RESOURCES INVESTIGATIONS IN ARKANSAS, U.S. Geological Survey administrative report, October 1964.

"The State of Arkansas is in an era of expanding water use and water development, a considerable amount of which is taking place without adequate knowledge of the water resources of the State. This is because the rate of obtaining knowledge is not keeping pace with development. Toward this goal, a long-range plan for water-resources investigations in Arkansas has been developed to keep the rate of providing water knowledge equal to or ahead of the rate of growth of water problems. This long-range plan contemplates studies, and research as required, to serve as a proposed course of action. Some phases of the plan include investigations which will be completed within a short period of years, some phases include descriptive areal coverage of the water resources of specific areas and will require reanalysis and reevaluation of those water resources in light of constant changing use and development, and some phases will continue indefinitely to provide a continuing inventory of the water as it occurs in its natural and man-modified environment in and on the earth.

"From a Statewide point of view, no serious water problems have arisen, and competition for water is slight. Relatively small areas of overdevelopment of ground water, some stream pollution, and a few conflicts of water use have developed. These problems are minor and have been infrequent because of the great abundance of water in the State. However, these problems further indicate that continued development without the application of water facts will lead to more severe and widespread water problems.

"Future water problems in Arkansas can be divided into three major categories: (1) water supply for various uses, (2) floods, and (3) water management.

"Solutions to the foregoing water problems require a thorough knowledge of the State's water resources. This long-range plan serves as a proposed course of action for developing and presenting water information in a form most useful to decision makers for selecting the best solution or combination of solutions to any future water problems."

Details of the plan are presented in tabular form having been categorized as to purpose, information currently (1964) available, information needed, study unit, priority, and method of disseminating the information.

A PROPOSED STREAMFLOW DATA PROGRAM FOR ARKANSAS, U.S. Geological Survey open-file report, 1969, by J. L. Patterson.

"An evaluation of the streamflow data available in Arkansas was made to provide guidelines for planning future programs. The basic steps in the evaluation procedure were (1) definition of the long-term goals of the streamflow data program in quantitative form, (2) examination and analysis of all available data to determine which goals have already been met, and (3) consideration of alternate programs and techniques to meet the remaining objectives. It was found that many of the goals could be met by generalization of the data for gaged basins by regression analysis. This fact indicates that significant changes could be made in the present data program that would allow emphasis to be placed on attaining the goals that have not been met. A streamflow data program based on the guidelines developed in this study is proposed for the future."

PROPOSED GROUND-WATER PROGRAM FOR ARKANSAS, U.S. Geological Survey administrative report, September 1960, by R. T. Sniegocki.

"Water constitutes the major portion of practically all living things. As such, it is a necessity for the maintenance of life, and its importance cannot be overemphasized. Ample water of suitable quality and reasonably priced is essential to the continual growth and prosperity of Arkansas. The ground-water resources of the State have a tremendous potential and if wisely developed, the water needs will be met.

"In broad terms, Arkansas has four major ground-water problems. These are, in order of their importance, supply, availability, and development; chemical quality; pollution; and distribution.

"Reconnaissance, appraisal, research studies, and maintenance of water records, along with proper support studies, can provide answers for the major part of these problems. Basic appraisal studies should receive high priority in long-range planning so that residents of Arkansas can develop the ground-water resources of the State and formulate water policies of their own choosing based on modern scientific investigations."

ARKANSAS WATER PLAN, PHASE I: PRELIMINARY WATER USE, Arkansas Division of Soil and Water Resources, by Gulf South Research Institute.

This report assesses the future water-use needs of Arkansas for the purpose of providing a basis for developing a water and land-resources management plan. Future water requirements were determined using the growth index by category from previous study methods. Total projected water use for Arkansas, based on forecasts by the Water Resources Council, was 3,798.01 million gallons per day for 1980, 6,409.09 million gallons per day for 2,000, and 9,245.12 million gallons per day for 2,080.

ARKANSAS WATER PLAN, PHASE II: OUTLINE OF STUDY PROCEDURE, Arkansas Division of Soil and Water Resources, by Gulf South Research Institute.

Recommendations for a procedure to follow in creating a comprehensive water-development plan for Arkansas include determining (1) water and land-resources planning procedures, (2) present water use and needs by category, (3) present instream requirements, (4) present water-oriented recreation needs, (5) future water requirements by category and source of supply, (6) future in-stream requirements, (7) future water-oriented recreation needs, (8) developing an inventory of surface-water supply sources, (9) an inventory of ground-water supply sources, (10) supply and demand profiles, (11) an inventory of water-deficit areas, and (12) alternate solutions for providing water in water-deficit areas, and (13) developing needed legislation.

ARKANSAS, A PRELIMINARY PLAN, 1980, Prepared for the Arkansas Planning Commission, July 1964, by Associated Planners, Little Rock, Ark.

This report is a summary of a very detailed inventory dealing with all aspects of physical, social, and economic growth in Arkansas. Water resources are covered in a section under land use.

According to the report, the surface water of Arkansas presently encompasses about 370,000 acres or about 1 percent of the State's total area. The acreage is shared almost equally between lakes more than 40 acres in size and rivers and streams more than one-eighth of a mile or more in width. The use and control of water and pollution are listed as the most important water problems confronting the State.

PINE BLUFF METROPOLITAN AREA, ARKANSAS URBAN WATER MANAGEMENT STUDY, PLAN OF STUDY, Department of the Army, Vicksburg District Corps of Engineers, August 1973.

The objective of the Pine Bluff Metropolitan Area, Arkansas, Study is to provide a realistic program for the timely and efficient development of water and related land resources in the Pine Bluff area.

The study will include needs for flood protection, wise use of flood-plain lands, navigation facilities, water supply, waste-management facilities systems, general recreation facilities, enhancement of water quality, and enhancement of fish and wildlife recources.

A list of participating agencies in the study is given as well as cost allocation and a schedule of completion dates for various phases of the work.

GOVERNOR'S SEMINAR ON LAND RESOURCE MANAGEMENT, Compiled and published by John Saxton, Chairman, Steering Committee, May 15-17, 1973.

Nine areas of concern and recommendation are expressed as a summary of this conference.

These areas of concern are:

1. Preservation of a quality life.
2. Lack of understanding of impact and inter-relationship of land-use planning.
3. Lack of a coordinated comprehensive land-use management information system.
4. Lack of coordination between large or intensive private and public development programs.
5. Protection of individual property rights.
6. Lack of State growth goals that will include a rational balance of environmental, economic, and social factors.
7. Established state-wide goals to include a balance of environmental, economic, and social factors.

8. Failure to fully implement existing land-use legislation at both the State and local levels.

9. Failure to recognize the intrinsic land capabilities in land-use planning.

Recommendations for action to meet these areas of concern are given. The report also contains the speeches given by 11 speakers, including the remarks by then-Governor Dale Bumpers.

REGIONAL WATER DISTRIBUTION PROPOSAL, Central Arkansas Planning Development District, Lonoke, Arkansas.

The report includes a proposal for preparation of a plan for development, treatment, and distribution of water supplies to meet projected water needs in all or parts of Pulaski, Lonoke, White, Faulkner, and Cleburne Counties. The total project cost is estimated to be $103,000.

PRELIMINARY REPORT OF THE ROCKWIN FUND WATER MANAGEMENT STUDY FOR ARKANSAS, Winrock Farms, June 1961, by L. E. Mack.

The most serious water-management needs in Arkansas are for formal unified water management at the State level; accessibility to more water data; improvement in distribution, storage, and quality of the State's water; basic and applied water-resources research studies; public education in water management; inquiry into forms of statutory water law; and reorganization of the State agencies working in water resources. A chart showing the present (1961) and proposed organization of State agencies dealing with Arkansas' water resources concludes this report.

ARKANSAS WATER RESOURCES, Arkansas State Planning Board, June 1939.

A complete study of the entire problem of flood control and stream regulation in the western Arkansas River basin is suggested as urgently necessary. A study of power markets and possible development of power in the upper White River basin is recommended. Additional hydroelectric-power development is recommended in the Ouachita River basin. Flood-reduction works are recommended in the Red River basin and the lower Mississippi River basin. Recommendations for recreational development in many of the basins also are given.

To promote the State government in taking an active technical part in the solution of water problems and planning for water development, it is recommended that there be established a permanent Water Resources Commission. The Commission should consist of recognized authorities in the various fields to be covered and should be provided with legal and financial advisors and with funds necessary to conduct its work in an intelligent and efficient manner.

A map showing inundation of land during the 1927 flood shows that at least 15 counties in the Coastal Plain had half or more of their areas covered by water.

WATER, PULASKI COUNTY, ARKANSAS, Pulaski County Planning Board, December 1940.

Flood control, land drainage, soil erosion, stream pollution, and mosquito control are listed as problems that must be solved. Recommendations for action to solve each problem are given in a 12-point summary in the report. The recommendations cover promotional consideration, such as emphasizing climate and water-resources advantages that exist in the county; navigation on the Arkansas River; pollution control and flood control.

The lowest recorded temperature in 60 years in Pulaski County was 12°F below zero on February 12, 1899. The highest recorded temperature was 110°F on August 10, 1936. The growing season through the 60-year record ranged from 186 days to 282 days, the average frost-free growing season being 241 days. Average rainfall through the 60-year record ranged from 31.57 inches in 1924 to 75.54 inches in 1882, with an average of 47.70 inches for the period of record. The average annual snowfall for a 55-year period was 4.8 inches.

The ground-water section of the report, by A. D. Hoagland, Arkansas Geological Survey, contains information on locations, depths, and yields of wells in deposits of Paleozoic, Tertiary, and Quaternary age. Of 127 springs examined, 84 were noted to be in deposits of Paleozoic age and 34 in deposits of Tertiary age.

Uses of water given in the report in order of their importance are domestic water supply, drainage works, recreation and wildlife conservation, hydroelectric-power development, and navigation.

PROPOSED BUFFALO NATIONAL RIVER, ARKANSAS, U.S. Department of the Interior, National Park Service, 1968.

The Buffalo River deserves national attention, not for any single quality but for an outstanding combination of qualities. Among these are clean flowing water that supports a notable sports fishery, opportunities for boating and swimming, interesting and spectacular scenery, a remarkable collection of features illustrating geology, botany, wildlife, archeology, and history, and the area is within an easy day's drive of nearly 15 million people.

A general development map shows 16 locations of interest including caves, a mining camp, water mills, campgrounds, picnic areas, scenic trails, and conservation education centers.

FIELD INVESTIGATION REPORT, SUGGESTED BUFFALO NATIONAL RIVER, ARKANSAS, U.S. Department of the Interior, National Park Service, April 1963.

"The Buffalo River's natural scenic beauty, abundant supply of clear unpolluted water, and important scientific and historic sites adapt it well to an increasing volume of recreational opportunities for the Nation. The adjacent extensive land area is also particularly suitable for outdoor recreational activities.* * *"

"It is recommended that the Buffalo River area be favorably considered for administration by the National Park Service as a National River.* * *"

THE STATES OF ARKANSAS AND OKLAHOMA PRESENT ADDITIONAL BENEFITS IN THE PROPOSED COMPREHENSIVE IMPROVEMENT OF THE ARKANSAS RIVER BASIN, Arkansas-Oklahoma Interstate Water Resources Committee, May 1945.

The committee report indicates that unit construction costs used in the Corps of Engineers planning documents are much too high and that public benefits are much too low. Also the committee report indicates that collateral benefits such as commercial fish production, pollution control, and recreational benefits have been omitted from the Corps of Engineers documents. The total benefits listed in the Corps of Engineers report are $26,366,200. Additional benefits listed in the committee report are valued at $43,585,426.

SOUTHWEST ARKANSAS RESOURCE CONSERVATION AND DEVELOPMENT PROJECT, A PLAN FOR CONSERVING AND DEVELOPING THE RESOURCES OF THE AREA, Southwest Arkansas Planning and Development District, 1970.

The project area consists of Calhoun, Columbia, Dallas, Hempstead, Howard, Lafayette, Little River, Miller, Nevada, Ouachita, Sevier, and Union Counties. The greatest needs in the area are prevention of forest fires, construction of drainage ditches, land leveling, pasture renovation, development of watersheds to enhance water management, improvement in fish and wildlife habitat, development of outdoor-recreation facilities, improvement in solid waste and sewage systems and removal of junk, litter, and unsightly vegetation. The steering committee approved 125 project measures to meet these needs.

ARKANSAS RIVER VALLEY RESOURCES CONSERVATION AND DEVELOPMENT PROJECT, A PLAN FOR DEVELOPMENT, U.S. Department of Agriculture, Soil Conservation Service, May 1966.

One hundred and twenty-two project measures are proposed in the project area comprised of Crawford, Franklin, Johnson, Logan, Pope, Sebastian, and Yell Counties. Project proposals include development for recreation, water supply, flood detention and strip-mine reclamation. The total cost of the project measures is estimated to be $118 million and the gross income of the area increased by $210 million.

STREAM PRESERVATION IN ARKANSAS, REPORT OF THE STATE COMMITTEE ON STREAM PRESERVATION, Arkansas Planning Commission, February 1969.

The General Assembly of the State of Arkansas established a 16-member State Committee on Stream Preservation which held its first organizational meeting November 28, 1966. The committee was to (1) study, locate, and designate selected high quality streams in Arkansas, (2) make preliminary surveys of these streams to define their character, quality, and other values to be retained, (3) evaluate and describe potentials of such designated streams in accordance with recognized classification systems, (4) prepare a report on the streams selected, and (5) prepare recommendations for preservation of streams.

Initial studies were centered on five streams. These were the Buffalo, Eleven Point, Kings, and Mulberry Rivers and Big Piney Creek. Each of these streams is described in general terms regarding origin, length, and beauty and unique recreational potentials. Technical sections in the report give information on the acrheology, geology, plant life, economics, water quality, and other features of the mountain country through which these streams flow. Technical data are available that cover a wide range of subjects such as geologic time scale and a list of ligneous plants in the Ozark and Ouachita Mountains in Arkansas.

In summary, the report makes a strong plea to preserve and protect an environment for man which will have diversity and quality, as well as quantity, and further states that the proposal to preserve streams in Arkansas for their economic, esthetic, historic, recreational, and intangible values is in keeping with these high purposes.

HOT SPRINGS TOMORROW, A Conceptual Master Plan, Hot Springs National Park, National Park Service, 1971, by Planning Team, Rock Comstock, Team Captain.

This planning report is an effort to establish a firm direction in revitalization of a declining tourist industry brought on by a lack of renewal or renovation of tourist and commercial service facilities along "Bathouse Row."

The plan recommends rerouting of traffic along Central Avenue through a tunnel through West Mountain to avoid congestion, noise, air pollution, and safe pedestrian conditions. The resort theme envisioned in this plan includes international bathing, hiking, fishing, horseback riding, dancing, scenic tours, boating, biking, camping, swimming, amusement rides, outdoor games, sidewalk cafes, theater, and puppet shows. Folk arts and crafts, folk dancing and music, performing arts, fine arts center, and museums are included. Modern medical rehabilitation and physical therapy centers are indicated along with cosmetic courses, diet and weight programs, and physical culture.

A pedestrian mall along Central Avenue is described in detail. The plan recommends that a tower be constructed on West Mountain. The tower should be about 200 feet high with observation decks, a restaurant, and a souvenir shop.

Water displays are contemplated, principally through opening the now-sealed hot springs and allowing the water to cascade down Hot Springs Mountains as it no doubt did in the past.

ARKANSAS RIVER REGION COMPREHENSIVE DEVELOPMENT PLAN 1980, Arkansas Planning Commission, December 1966, by Associated Planners Incorporated, Little Rock, Arkansas.

NAVIGATION-RELATED SITES ON THE ARKANSAS RIVER WATERWAY, University of Arkansas, Industrial Research and Extension Center, Publication D-14, February 1969, by M. H. Sonstegard and J. C. Lilly, Jr.

COMPREHENSIVE DEVELOPMENT PLAN, PULASKI COUNTY METROPOLITAN AREA, Metropolitan Area Planning Commission, 216 Pulaski County Courthouse, Little Rock, Arkansas, June 1964, Howard Eichenbaum, Chairman.

OUTDOOR RECREATION IN ARKANSAS, 1969, Arkansas Planning Commission, July 1969.

ARKANSAS STATEWIDE COMPREHENSIVE OUTDOOR RECREATION PLAN, 1969, Arkansas Planning Commission, December 1968.

ARKANSAS STATEWIDE COMPREHENSIVE OUTDOOR RECREATION PLAN, 1969, ACQUISITION AND DEVELOPMENT SCHEDULE, FISCAL YEARS 1969 THROUGH 1973, Arkansas Planning Commission, 1969.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, CANAL 18 WATERSHED, DESHA AND DREW COUNTIES, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, October 1963.

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WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, REDFORK WATERSHED, DESHA COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, December 1963.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, ARK-LA WATERSHED, CHICOT COUNTY, ARKANSAS, AND EAST CARROLL PARISH, LOUISIANA, U.S. Department of Agriculture, Soil Conservation Service, July 1964.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, CROOKED LAKE BAYOU WATERSHED, MISSISSIPPI COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, January 1964.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, MUD CREEK WATERSHED, INDEPENDENCE COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, December 1962.

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WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, GARRET BRIDGE WATERSHED, LINCOLN COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, November 1964.

WORK PLAN FOR WATERSHED PROTECTION AND FLOOD PREVENTION, WEST-FORK POINT REMOVE CREEK WATERSHED, CONWAY, POPE, AND VAN BUREN COUNTIES, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, April 1959.

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WORK PLAN FOR WATERSHED PROTECTION AND FLOOD PREVENTION, UPPER CROOKED CREEK WATERSHED, BOONE AND NEWTON COUNTIES, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, October 1964.

WORK PLAN FOR WATERSHED PROTECTION AND FLOOD PREVENTION, TUPELO BAYOU WATERSHED, FAULKNER COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, July 1962.

ARKANSAS WATERSHED PROGRESS REPORT, U.S. Department of Agriculture, Soil Conservation Service, October 1968.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, MUNICIPAL WATER SUPPLY, POTEAU RIVER WATERSHED, SCOTT COUNTY, ARKANSAS, AND LEFLORE COUNTY, OKLAHOMA, U.S. Department of Agriculture, Soil Conservation Service, March 1963.

PRELIMINARY WATERSHED WORK PLAN, WAR EAGLE CREEK WATERSHED, MADISON, WASHINGTON, AND BENTON COUNTIES, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, October 1955.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL WATER MANAGEMENT, CHICOT WATERSHED, CHICOT COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, March 1967.

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WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, AGRICULTURAL MANAGEMENT, CAMP BAYOU WATERSHED, ASHLEY COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, March 1958.

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WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, MUNICIPAL AND INDUSTRIAL WATER SUPPLY, FISH AND WILDLIFE RESOURCE IMPROVEMENT, GALLA CREEK WATERSHED, POPE COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, October 1968.

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WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, MUNICIPAL AND INDUSTRIAL WATER SUPPLY, AND RECREATION, UPPER OUACHITA RIVER WATERSHED, POLK COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, March 1969.

WORK PLAN FOR WATERSHED PROTECTION, FLOOD PREVENTION, NONAGRICULTURAL WATER MANAGEMENT AND FISH AND WILDLIFE DEVELOPMENT, MUDDY FORK OF ILLINOIS RIVER WATERSHED, WASHINGTON COUNTY, ARKANSAS, U.S. Department of Agriculture, Soil Conservation Service, September 1960.

Group 6C--Cost allocation, cost sharing, pricing/repayment

ECONOMIC STUDY OF THE PROPOSED BUFFALO NATIONAL RIVER, by the Industrial Research and Extension Center, University of Arkansas, May 1963.

From 1950 to 1960 the Buffalo River study area (five counties) experienced a 17-percent decrease in population and an estimated out-migration rate of over 32 percent. Per capita income in 1960 was about $1,100 and is about 20 percent lower than the State average. This report indicates that the 1970 personal income in the five counties would be increased by $7.3 million, or 12 percent higher as a result of creating a national river.

REVISED ECONOMIC STUDY OF THE PROPOSED BUFFALO NATIONAL RIVER, University of Arkansas, College of Business Administration, February 1968, by R. W. Bell, Alan Cook, Don Helms, and Jerry Johnson.

A national public-use area tends to produce widespread beneficial economic effects, especially on its surrounding region. This fact is particularly true when the area is substantial and has a variety of attractions, and is easily accessible to large numbers of people. The proposed Buffalo National River would have all the above-mentioned desirable characteristics. In addition, the river is one of the few remaining free-flowing and largely undeveloped streams of its size and character in the United States. As such, together with nearby land areas, it merits preservation as a unique section of mid-America in its near-natural condition.

Per capita income in the area in 1960 was about $1,100; and average family income amounted to approximately $2,500. It is estimated that tourist spending in the area, which could be attributed to the presence of the proposed national river, would reach an annual level of nearly $34 million in 1972. It also is estimated there would be an increase of 3,500 jobs in nonfarm occupations.

THE FINANCIAL FEASIBILITY OF THE REGIONAL APPROACH TO PUBLIC WATER SUPPLY: A CASE STUDY OF NORTHWEST ARKANSAS, University of Arkansas Agricultural Experiment Station, Bulletin 788, June 1974, by N. C. Williams and J. M. Redfern.

The regional system is feasible as measured by the anticipated rate of return on the system and the amortization periods of the bond issues supporting the investment. This analysis should provide municipal officials with criteria for investment decisions concerning the expansion of existing facilities versus merging facilities into a single unit.

AN ECONOMIC SURVEY OF THE OZARK REGION, U.S. Department of Agriculture, Economic Research Service, Agricultural Economic Report Number 97, July 1966.

Group 6D--Water demand

USE OF WATER IN ARKANSAS, 1960, Arkansas Geological Commission Special Ground-Water Report Number 4, 1961, by J. W. Stephens and H. N. Halberg.

The average daily rate of water use in Arkansas increased steadily from 525 mgd in 1945 to 1.5 billion gpd in 1960. Of this amount, 59 percent was ground water, 33 percent was surface water and 8 percent was unclassified. Most of the use was for irrigation (56 percent), followed by industrial use (26 percent), public supply (5 percent), and rural-domestic-livestock use (5 percent).

USE OF WATER IN ARKANSAS, 1965, Arkansas Geological Commission Water Resources Summary Number 5, 1966, by H. N. Halberg and J. W. Stephens.

"In 1965, Arkansas used an average of 2,142 mgd (million gallons per day) of ground and surface water, 35 percent more than the use in 1960. The quantity used in 1965 does not include more than 8,700 mgd used in the production of hydroelectric power. The principal categories of use are public supply, self-supplied industrial use, rural domestic and livestock use, irrigation, fish and minnow farming, water for wildlife impoundments and fish hatcheries, and fuel-electric-power production. More than half the State's total was used for irrigation and 80 percent of the irrigation water was ground water.

"Cooling water for fuel-electirc-power production required 423 mgd, 20 percent of the State's total. Practically all of it was surface water. Fish and minnow farming, a rapidly expanding activity, used 179 mgd, 8 percent of the State's total.

"More than half the water used was withdrawn from the ground; streams and reservoirs supplied the rest. Surface-water supplies are commonly used in the northwestern half of the State; ground-water supplies are more common in the southeastern half or Coastal Plain where the two principal underground reservoirs, the alluvium of Quaternary age, and the Sparta Sand, of Tertiary age, furnished practically all the ground water used. The deposits of Quaternary age provided most of the ground water used for irrigation; the Sparta Sand provided much of the ground water used for industry."

USE OF WATER IN ARKANSAS, 1970, Arkansas Geological Commission Water Resources Summary Number 7, 1972, by H. N. Halberg.

"Arkansas used an average of 3,061 mgd (million gallons per day) of surface water and ground water in 1970, 28 percent more than in 1965. This total does not include the 24,700 mgd used in the production of hydroelectric power. Half the water supplied was ground water and half was drawn from streams and reservoirs. The principal categories of use are public supply, self-supplied industrial use, rural domestic and livestock use, irrigation, fish and minnow farming, water for wildlife impoundments, and fuel-electric-power production. The principal use was irrigation, which used 1,293 mgd, or a little less than half the total, and 82 percent of which was ground water. Cooling water for fuel-electric power production required 956 mgd, 31 percent of the total. Practically all of it was surface water. Fish and minnow farming, a rapidly growing industry, used 314 mgd, 10 percent of the total. Consumption of water was 1,226 mgd, 40 percent of withdrawals.

"Surface-water supplies are commonly used in the northwestern half of the State; ground-water supplies are more common in the southeastern half, or Coastal Plain, where the two principal underground reservoirs, the deposits of Quaternary age, and the Sparta Sand, of Eocene age, furnished practically all the ground water used. The deposits of Quaternary age provided most of the ground water used for irrigation; the Sparta Sand provided much of the ground water used for industry."

WATER USAGE IN RICE IRRIGATION, Arkansas Farm Research, Volume XV, Number 4, July-August 1966, by H. N. Halberg.

In 1940, the average quantity of water applied to irrigate rice in the Grand Prairie region was determined to be 1.8 acre-feet (22 acre-inches). To determine whether or not there had been any change in the quantity presently (1965) being applied, checks were made at two farms in 1964 and 1965. The water application was found to be well within the range established in 1940. Thus, when rice is irrigated with ground water, an average of 1.8 acre-feet applied to the rice-acreage figure continued to provide a reliable estimate of the amount of ground water pumped for rice irrigation.

PROJECTED WATER UTILIZATION IN WASHINGTON AND BENTON COUNTIES, University of Arkansas, Industrial Research and Extension Center, March 1959, by Ralph Gray.

In this report the Industrial Research and Extension Center developed projections of between 161 and 256 mgd as a reasonable range of estimates based on two different methods of projection of the demand for municipal and industrial water by the year 2010 for Benton and Washington Counties.

Current (1958) water use is about 6.8 mgd. This is more than three times the total water use in 1940 of 2.0 mgd.

PROJECTED WATER DEMAND: NORTHWEST ARKANSAS, 1975, University of Arkansas, Industrial Research and Extension Center, December 1959, by Ralph Gray.

Total industrial and domestic water demand in the area is currently about 17.61 mgd, which is a per capita rate of 147 gpd. Projected total nonfarm water demand for 1975 is 32.33 mgd. This projection anticipates population growth and an increase in per capita rate of use to 169 gpd.

INDUSTRIAL WATER DEMAND: POINT REMOVE CREEK WATERSHED, University of Arkansas, Industrial Research and Extension Center, December 1960, by Ralph Gray.

A series of flood-control dams are to be constructed on the East and West Forks of the Point Remove Creek. It is possible to raise the height of one or several of these floodwater-retarding structures to store water for industrial users in the area.

Projections of manufacturing growth, assuming sufficient industrial water, justify raising the Isabella Dam. The projections indicate that the water assured by storage in the Isabella Reservoir will be fully utilized by the year 1975. Accordingly, revenues from the sale of water should, over the life of the project, fully offset capital plus interest costs.

COLD WATER FOR INDUSTRY, University of Arkansas, Industrial Research and Extension Center, February 1962, by L. E. Mack.

"With little discharge from Lake Ludwig, over 100 million gallons of water colder than 50°F are in storage during late summer and early autumn. With heavy discharge, there was as much as 400 million gallons of water in storage colder than 60°F. Cold water in reservoir storage is a renewable natural resource from which Arkansas should benefit.

Lake Ludwig is a relatively small lake, but this study would lead to the conclusion that Arkansas' larger lakes provide a tremendous quantity of potential cooling water for industry. A plant located below a federal dam requires no contract for water. In organized water districts, where proper agreements have been made with the U.S. Corps of Engineers or the Soil Conservation Service, industrial water supplies can be obtained directly from the impoundments."

IRRIGATION OF ARABLE CROPS ON A RICE SOIL, University of Arkansas, Agricultural Experiment Station Bulletin 455, June 1945, by R. P. Bartholomew, L. C. Kapp, and Martin Nelson.

Highly significant increases in yields of cotton, seed cotton, soybeans, corn, lespedeza hay, and lespedeza seed resulted from irrigation. The best yields were obtained from the combination of application of fertilizer and subsequent irrigation.

The report contains details on how much water and fertilizer was applied, the time when water was applied, and yields for irrigated and nonirrigated crops.

SUBSURFACE IRRIGATION RESEARCH IN ARKANSAS, University of Arkansas, Water Resources Research Center Publication Number 3, June 1969 by J. P. Hoskyn and B. B. Bryan.

A pilot study conducted in 1963 indicated that cotton yields could be increased by subirrigation. The objectives of this study were to determine and evaluate the hydraulic problems involved in distributing water subterraneously at low pressure in small-diameter, perforated plastic pipe and to develop criteria for design of subirrigation systems that approach the optimum in efficiency of water use.

It was concluded that a pressure head of 6 feet of water is preferable to 10 feet, 38-inch lateral spacing is preferred over 76-inch spacing, and an orifice spacing of 30 inches is preferable to a spacing of either 12 or 48 inches.

The major problem was internal plugging of orifices from iron precipitated from the water. The system should include facilities for flushing and for periodically applying a higher than normal pressure to purge the system.

WATER POWERS OF ARKANSAS, A PRELIMINARY REPORT ON WHITE RIVER AND SOME OF ITS TRIBUTARIES, The Geological Survey of Arkansas, 1911, by W. N. Gladson.

The work covered by this report was the first systematic effort made to determine and locate possible sites for the development of hydroloelectric power in Arkansas. Surveys were made on three streams, the White River from near Fayetteville (Habberton, Ark., not now in existence) to Buffalo City, Arkansas; the Buffalo River from Boxley, Ark., to the mouth; and the North Fork River from Henderson, Ark., to the mouth. The intention of each survey was to locate the principal hydropower sites in as much detail as possible by section, township, and range. The fall of the streams was determined and maps were prepared on a scale of 1,000 feet to the inch with contours of 10 feet on land and 5 feet on the water surface. Drainage areas and discharge data are available for several locations on the three streams mapped.

WATER REQUIREMENTS OF THE ALUMINUM INDUSTRY, U.S. Geological Survey Water-Supply Paper 1330-C, by H. L. Conklin, 1956.

Group 6E--Water law and institutions

ARKANSAS RIVER BASIN COMPACT, ARKANSAS-OKLAHOMA, 1970, Office of Representative, United States, 300 East 8th St., Austin, Tex., March 16, 1970.

The State of Arkansas and the State of Oklahoma, acting through their duly authorized Compact representatives have agreed to 13 articles dealing with equitable apportionment of the waters of the Arkansas River and a means of administering this apportionment. Article IV contains the following provisions.

A. The State of Arkansas shall have the right to develop and use the waters of the Spavinaw Creek Sub-basin subject to the limitation that the annual yield shall not be depleted by more than fifty percent (50%).

B. The State of Arkansas shall have the right to develop and use the waters of the Illinois River Sub-basin subject to the limitation that the annual yield shall not be depleted by more than sixty percent (60%).

C. The State of Arkansas shall have the right to develop and use all waters originating within the Lee Creek Sub-basin in the State of Arkansas, or the equivalent thereof.

D. The State of Oklahoma shall have the right to develop and use all waters originating within the Lee Creek Sub-basin in the State of Oklahoma, or the equivalent thereof.

E. The State of Arkansas shall have the right to develop and use the waters of the Poteau River Sub-basin subject to the limitation that the annual yield shall not be depleted by more than sixty percent (60%).

F. The State of Oklahoma shall have the right to develop and use the waters of the Arkansas River Sub-basin subject to the limitation that the annual yield shall not be depleted by more than sixty percent (60%).

ARKANSAS RIVER BASIN COMPACT, ARKANSAS-OKLAHOMA, 1970, WITH SUPPLEMENTAL INTERPRETIVE COMMENTS, SUPPLEMENT NO. 1, Office of Representative, United States, 300 East 8th St., Austin, Tex., March 16, 1970.

This supplement to the 1970 Compact contains interpretive statements regarding the 13 articles of agreement concerning apportionment of waters of the Arkansas River between the States of Arkansas and Oklahoma. The interpretive statements are for the purpose of establishing intent of the Compact Committee.

RURAL WATER SUPPLIES, Arkansas State Board of Health, Bureau of Sanitary Engineering, Bulletin Number 12.

This bulletin was prepared to acquaint individuals, school boards, and sanitarians with the recommendations of the State Board of Health concerning the proper protection and development of water supplies for individuals and small schools. Regardless of the type of ground-water supply, experience has demonstrated that the safety of the supply depends upon its proper location, construction, and operation. The location of the source of supply should be adequately drained on the surface, should not be subject to flooding, and should not be near sewers.

Privies, septic tanks, sewers, and barnyards should be at least 100 feet from the well and must not be closer than 50 feet. Seepage pits and subsurface disposal fields should be at least 100 feet away, and cesspools should not be closer than 150 feet. Water should not be taken from depths of less than 10 feet.

Disinfection chemicals and dosage for wells and water-supply systems are given at the end of the report. The report is well illustrated with diagrams that show properly constructed dug wells, drilled wells, driven wells, pumps and pumphouses, and springhouses.

WATER LAW IN ARKANSAS, University of Arkansas, Industrial Research and Extension Center, Little Rock, Arkansas, October 1963, by L. E. Mack.

This report provides a condensed descriptive summary of the statutory and case law on the development and use of water in Arkansas. Because of the abundance of water in Arkansas, litigation of water rights has been relatively limited.

The Arkansas Supreme Court has accepted the riparian doctrine of reasonable use. In addition to the riparian doctrine, the Arkansas Legislature has adopted some aspects of the appropriation doctrine whereby a State agency may allocate a fair share of water to persons where there is a shortage. The State has enabled legally-responsible organizations to enter into contracts with Federal agencies for use of water from Federal reservoirs. The State may enter compacts with other States concerning interstate rivers.

A proprietor whose land is bordered by a non-navigable stream has title to the thread of the stream but if the land is bordered by a navigable water course, he takes only to the high-water mark. Where a tract of land is bounded by a navigable or non-navigable stream, the boundary changes with the gradual change in the course of the stream but, where the stream suddenly seeks a new channel, the boundary lines do not change. Any person causing injury to another by pollution may be sued for damages or enjoined from further pollution.

WATER QUALITY AND WATER QUANTITY CONTROL IN ARKANSAS AS OF AUGUST 1971: A LEGAL OVERVIEW, University of Arkansas, Agricultural Experiment Station, Bulletin 782, June 1973, by W. W. Nixon, J. M. Redfern, A. M. Witte, and N. C. Williams.

The questions this report seeks to answer are: What are the laws of water-quality control and water-quantity control, and by whom and how are these laws implemented and enforced?

The bulk of Federal legislation on the subject of water pollution and water-quality control is found in the Federal Water-Quality Improvement Act of 1970 and the "Refuse Act" of 1899.

An Arkansas industry desirous of making a discharge into any watercourse which runs into or is itself a navigable stream, must comply with the Refuse Act and the Water-Quality Improvement Act, as well as with State pollution-control legislation. In doing so, the industry may be required to confer with the U.S. Army Corps of Engineers, the Environmental Protection Agency, the U.S. Fish and Wildlife Service, the Arkansas Department of Pollution Control and Ecology, and perhaps other Federal and State agencies.

The Arkansas Water Pollution Control Commission, created in 1949, and now (1973) called the Arkansas Department of Pollution Control and Ecology, was the first agency in this State to be charged with detailed and comprehensive authority to control pollution in all waters in Arkansas.

In Arkansas, water rights are deemed to be vested property rights. With regard to watercourses and surface water, Arkansas clearly adheres to the riparian reasonable-use doctrine. The Arkansas Soil and Water Conservation Commission has been given the power to make allocations among persons taking water from streams during periods of shortage. In 1969, the Arkansas Legislature granted the Soil and Water Conservation Commission power to issue annual certificates of registration of water diverted from streams. The registration requirement provides that any person diverting water from any stream, lake, or pond (except natural lakes or ponds in exclusive ownership of one person), should register the diversion with the Commission.

WATER QUALITY CRITERIA AND PLAN FOR IMPLEMENTATION, STATE OF ARKANSAS, Arkansas Pollution Control Commission, May 1967.

"In compliance with the Federal Water Quality Act of 1965, the Governor of the State of Arkansas designated the Arkansas Pollution Control Commission as the agency to establish water quality criteria for interstate streams by June 30, 1967. This Commission is empowered by law to establish and alter standards for any waters of the State.* * *"

"By 1975, the population of the State is expected to have increased by 26% to 2.44 million, domestic water use by 28% to 161 mgd, industrial water use by 52% to 263 mgd, and irrigation water by 40% to 1,920 mgd, exclusive of the Mississippi River.* * *"

"Temperature - The maximum temperature shall not be elevated above 20° centigrade in trout streams, 30° centigrade in smallmouth bass streams, and 35° centigrade in other streams.* * * The temperature of a stream as determined by natural conditions shall not be increased or decreased more than 5° centigrade by discharges thereto.

"Color - True color shall not be increased to the extent that it will interfere with present usage and projected future use of the streams.

"Turbidity - There shall be no distinctly visible increase in turbidity due to waste discharges to the stream.

"Taste and Odor - Taste and odor producing substances shall be limited to concentrations in the stream that will not interfere with the production of potable water by reasonable water treatment processes, or impart unpalatable flavor to food fish, or result in offensive odors arising from the stream or otherwise interfere with the reasonable use of the water.

"Solids, Floating Material, and Deposits - The stream shall have no distinctly visible solids, scum, or foam of a persistent nature, nor shall there be any formation of slimes, bottom deposits of sludge banks, attributable to waste discharges.

"Oil and Grease - The stream shall be essentially free of the relatively nonvolatile liquid components that contribute to the formation of oil films, deposits, and emulsions.

"pH - The pH of water in the stream must not fluctuate in excess of 1.0 pH unit, within the range of 6.0-9.0, over a period of 24 hours. The pH shall not be below 6.0 or above 9.0 due to wastes discharged to the receiving stream.

"Dissolved Oxygen (D.O.) - The dissolved oxygen in the stream shall not be less than 4 ppm* * *and this shall be the critical deficit point of the dissolved oxygen profile. The only exception will be when periodic lower values are of natural origin and therefore beyond control of the water user. For trout stream waters the minimum dissolved oxygen content shall not be less than 5.0 mg/l. The dissolved oxygen sample shall be taken at mid-depth and the middle of the stream on the smaller streams and rivers. On the larger rivers the dissolved oxygen shall be determined by the average of concentrations in samples collected at quarter points across the river, and at two-tenths and eight-tenths of the depth at each point.

"Radioactivity - The Rules and Regulations for the Control of Sources of Ionizing Radiation, of the Division of Radiological Health, Arkansas State Board of Health, shall apply as to the limits established for radiation levels in uncontrolled areas.

"Bacteria - The Arkansas State Board of Health has the responsibility of approving or disapproving surface waters for swimming and drinking water supply, and it has issued rules and regulations pertaining to such uses.

"For purposes of this Regulation, the coliform group shall not exceed 1,000/100 milliliters as a monthly average value (either Most Probable Number or membrane filter count) for waters substantially used for body contact aquatic sports; nor exceed this number in more than twenty percent of samples examined during any one month; nor exceed 2,400/100 milliliters on any day except during periods of storm water runoff; provided, however, that no fecal contamination is known to be present. In other waters, the coliform bacteria group shall not exceed 5,000/100 milliliters as a monthly average value (either Most Probable Number of membrane filter count); nor exceed this number in more than twenty percent of the samples examined during any month; nor exceed 20,000/100 milliliters in more than 5% of such samples. Arithmetic averages will be used.

"Toxic Substances - Toxic materials, organic or inorganic, shall not be present in such quantities as to cause the waters to be toxic to human, animal, plant, or aquatic life or to interfere with the normal propagation of aquatic life. For aquatic life and using bioassay techniques, the level of toxic materials in the stream shall not exceed one-tenth (0.1) of the forty-eight (48) hour Median Tolerance Limit.

"Mineral Quality - Waste discharges shall not affect existing mineral quality so as to interfere with other beneficial uses. Recognizing that the present water quality of the Arkansas and Red Rivers is less than desirable from natural as well as man-made sources, additional mineral discharges will be limited with the intent of improving the quality as plans for removing major natural salt sources are implemented. In the Lower Ouachita River Basin it is recognized that water quality is low due primarily to manmade sources, but constantly improving under existing controls. Numerical mineral criteria will be set and implemented within the next 5 years as existing quality and results of present controls are evaluated.* * *"

PRIVATE SEWAGE DISPOSAL SYSTEMS, Arkansas State Board of Health, Bureau of Sanitary Engineering, Bulletin Number 9.

This bulletin sets forth minimum uniform standards to be followed by individuals and the plumbing industry in the construction of private sewage-disposal systems for one-family residences only.

No portion of the disposal system should be upgraded from a water supply. A septic tank shall be located not less than 5 feet from a building, 10 feet from property lines, and 50 feet from any water supply. Other requirements include a range of septic tank capacity from 500 gallons for 2 or less bedrooms to 160 gallons per bedroom for more than four bedrooms. The minimum liquid capacity of the septic tank must be increased if household garbage grinders are used.

Many other construction details and requirements are included in the bulletin. Assistance of the Bureau of Sanitary Engineering should be sought in designing and constructing facilities to serve schools and commercial buildings.

RULES AND REGULATIONS PERTAINING TO PUBLIC WATER SUPPLIES, Arkansas State Board of Health, Little Rock, Arkansas Act 96 of 1913, Arkansas Statutes of 1947, Section 82-110, 1971.

This pamphlet, reprinted periodically by the Arkansas State Board of Health as needed, specifies the rules and regulations that must be followed by an owner to develop and operate a public water supply. An owner is defined as any person, firm, corporation, institution, or governmental agency owning or operating any water supply, distribution system, or water-treatment plant. The purpose of the rules and regulations is to safeguard public health. Both ground- and surface-water supplies are covered and include specifications concerning the location of the water supply, pumps, bacterial and chemical quality, water-treatment plants, and distribution systems. All operators of municipal public water supplies from which water is sold, distributed, or otherwise offered for human consumption, whether such water supplies be public or privately owned and operated, shall be duly licensed and certified as competent by the Arkansas State Board of Health.

An older (undated) pamphlet published by the State Board of Health covers public water supplies and includes sewer systems. The title of this pamphlet is "Rules and Regulations Pertaining to Public Water Supplies and Sewer Systems." Pamphlets on rules and regulations pertaining to public swimming pools and bathing places also are available from the Arkansas State Department of Health.

AIR CODE AND WATER QUALITY CRITERIA FOR INTERSTATE STREAMS FOR STATE OF ARKANSAS, Arkansas Pollution Control Commission, August 1969.

The report sets forth rules and regulations of the Arkansas Pollution Control Commission, adopted pursuant to Part II of the Arkansas Water and Air Pollution Control Act (Arkansas Statues, Section 82-1901).

WATER QUALITY STANDARDS SUMMARY, Arkansas Pollution Control Commission, October 1969.

This report contains virtually the same material in summary form as the report entitled "Water Quality Criteria and Plan for Implementation, State of Arkansas" dated May 1967.

Group 6F--Nonstructural alternatives

No entries.

Group 6G--Ecologic impact of water development

QUANTITATIVE COMPARISON OF SOME AESTHETIC FACTORS AMONG RIVERS.

For primary bibliographic entry see 7B.

A PROCEDURE FOR EVALUATING ENVIRONMENTAL IMPACT.

For primary bibliographic entry see 7B.

ENVIRONMENTAL CHANGES PRODUCED BY COLD-WATER OUTLETS FROM THREE ARKANSAS RESERVOIRS, University of Arkansas, Water Resources Research Center Publication Number 5, 1970, by C. E. Hoffman and R. V. Kilambi.

"Water qualities of two natural streams (Buffalo and Kings Rivers) one new cold-tailwater (Beaver), and two old cold-tailwaters (Norfork and Bull Shoals) in northwestern Arkansas were studied from July 1965 through October 1968.

"The essential difference between the old cold-tailwaters and natural streams is a change in water quality which allows the development of a new productive ecological environment. Features which typify the cold tailwaters are as follows: (1) relatively homoithermal temperatures; (2) stream beds scoured by strong hydroelectric power generation currents; (3) abundant phytoplankton, and benthic macroinvertebrates; and (4) absence of warm water game fish.

"Environmental factors characterizing natural streams are as follows: (1) high summer temperatures; (2) seasonal and individual current fluctuations at the various stations; (3) a greater variety of benthic macroinvertebrates and ichthyofauna; (4) abundant zooplanktons; and (5) a tendency toward an equal distribution of the phyla Chrysophyta, Cyanophyta, and Chlorophyta.

"By October 1968, the new Beaver cold-tailwater had lost all of its warm-water characteristics but had not developed the biotic features of the old tailwaters."

A NEW TROGLOBITIC CRAYFISH OF THE GENUS CAMBARUS (DECAPODA, ASTACIDAE) FROM ARKANSAS WITH A NOTE ON THE RANGE OF CAMBARUS CRYPTODYTES HOBBS, Proceedings of the Biological Society of Washington, Volume 77, pages 9-16, June 26, 1964, by H. H. Hobbs, Jr., and M. S. Bedinger.

This paper describes a new species of troglobitic crayfishes from the Ozark region. The species, known from a single locality, is the third species described from the region and first from Arkansas. The crayfish were collected from a stream in Hell Creek Cave, Stone County, Arkansas, about 150 feet from the cave entrance.

This part of the cave is in perpetual darkness. The crayfish have albinistic eyes and showed no response to the light of lanterns. However, they apparently are sensitive to turbid water and are aware of disturbances in the water made when being approached. The crayfish are sensitive to touch and swim quickly if not captured on first contact.

DARDANELLE RESERVOIR ILLINOIS BAYOU EMBAYMENT BACKGROUND SURVEY, PROGRESS REPORT NO. 9, January 1973, by C. B. Sinclair.

DARDANELLE RESERVOIR ILLINOIS BAYOU EMBAYMENT BACKGROUND SURVEY, PROGRESS REPORT NO. 12, June 1974, by C. B. Sinclair.

Field 7--RESOURCES DATA

Group 7A--Network design

A PROPOSED STREAMFLOW DATA PROGRAM FOR ARKANSAS.

For primary bibliographic entry see 6B.

Group 7B--Data acquisition

MAPPING TRANSMISSIBILITY OF ALLUVIUM IN THE LOWER ARKANSAS RIVER VALLEY, ARKANSAS.

For primary bibliographic entry see 2F.

LAKES OF ARKANSAS.

For primary bibliographic entry see 2H.

THERMAL SURVEY OF DARDANELLE RESERVOIR.

For primary bibliographic entry see 2H.

APPROXIMATE METHODS OF MEASURING THE YIELD OF FLOWING WELLS, Geological Survey Water-Supply Paper 110, 1905, by M. L. Fuller.

Charles S. Slichter on pages 37 through 42 of this report describes a simple, quick method for determining with fair accuracy the amount of water flowing from a full and partly full pipe. Chiefly, this is done by measuring the diameter of the pipe and then the vertical distance from the center of the opening of the pipe vertically downward 6 inches, then from this point horizontally to the center of the stream. These data, referred to table 1, page 39, will provide the flow, in gallons per minute.

PROJECTING THE EFFECT OF CHANGED STREAM STAGES ON THE WATER TABLE, Journal of Geophysical Research, Volume 66, Number 8, August 1961, by J. E. Reed and M. S. Bedinger.

"The position and shape of the water table under certain conditions may be considered to be the sum of two components of head, namely the boundary component and the accretion component. In an aquifer of given hydraulic characteristics, the boundary component of the head is determined by the stream stage and areal shape of the aquifer, the accretion component of head is determined by vertical gain or loss of water to the aquifer and by the areal shape of the aquifer. The boundary component may be obtained by electric-analog methods. By subtracting the boundary component from the observed position of the water table, the accretion component can be obtained. A change in river stage imposes a new boundary component on the system. The effect of changed stream stages on the water table may be obtained by adding the accretion component to a new boundary component caused by changed stream stages."

RELATION BETWEEN MEDIAN GRAIN SIZE AND PERMEABILITY IN THE ARKANSAS RIVER VALLEY, ARKANSAS, U.S. Geological Survey Professional Paper 424-C, Geological Survey Research, 1961, Short Papers in the Geologic and Hydrologic Sciences, paper 157, 1961, by M. S. Bedinger.

The transmissibility of unconsolidated earth materials in alluvium along the Arkansas River in Arkansas can be estimated by multiplying a field coefficient of permeability for a given grain size times the thickness of the section of material of that given grain size.

The range in field coefficient of permeability was found to be from 15,000 gallons per day per square foot for very coarse sand and very fine gravel to 10 gallons per day per square foot for very fine sand.

COMPUTING STREAM-INDUCED GROUND-WATER FLUCTUATION, U.S. Geological Survey Professional Paper 501-B, Geological Survey Research, 1964, Chapter B, pages B177-B180, 1964, by M. S. Bedinger and J. E. Reed.

"Changes in ground-water level induced by fluctuating surface-water boundary can be analyzed by separating the surface-water stage hydrograph into a sequence of steady stages separated by instantaneous changes. Each change in ground-water level is considered to be the net effect of antecedent changes in surface-water stage weighted according to the drain function."

METHODS AND APPLICATIONS OF ELECTRICAL SIMULATION IN GROUND WATER STUDIES IN THE LOWER ARKANSAS AND VERDIGRIS RIVER VALLEYS, ARKANSAS AND OKLAHOMA, U.S. Geological Survey Water-Supply Paper 1971, 1970, by M. S. Bedinger, J. E. Reed, C. J. Wells, and B. F. Swafford.

"Analysis and projections of ground-water conditions were made by use of electrical analog models. These models use the analogy between the flow of electricity in a resistance-capacitance circuit and the flow of a liquid in a porous and permeable medium.

"Verification provides a test of the validity of the analog to perform as the aquifer would, within the range of historic forces. The verification process consists of simulating the action of historic forces which have acted upon the aquifer and of duplicating the aquifer response with the analog.

"The areal distribution of accretion can be treated as an unknown and can be determined by analog simulation of the piezometric surface in an aquifer. Comparison of accretion decreases with decreasing depth to water level. The decrease in accretion is attributed mostly to the increase in evapotranspiration from the aquifer, and where water levels are very near the land surface, to the rejection of recharge. The maximum accretion and the decrease in accretion with the decrease in depth to water are dependent upon the climate and the thickness and lithology of the fine-grained material overlying the aquifer.

"Dams on the Arkansas and Verdigris Rivers will impose a direct change in water levels in the aquifers adjacent to the rivers. This change will be attenuated by the resultant change in accretion to the aquifer. The analogs of aquifers in the valleys were used to determine the change in ground-water level from preconstruction to postconstruction conditions."

HYDROGEOLOGICAL MAPPING OF QUANTITATIVE PROPERTIES OF AN ALLUVIAL VALLEY BY USE OF LABORATORY DATA, International Association of Hydrogeologists, Congress of Istanbul [Turkey], September 10-22, 1967, by A. I. Johnson and M. S. Bedinger.

"Hydrogeologic studies of alluvial valleys usually require that the quantitative properties of the alluvial materials be mapped over large areas. An example of such a study is the areal mapping of the quantitative properties of alluvium in the Arkansas River Valley of Oklahoma and Arkansas, U.S.A. This was done prior to construction of an electrical resistance-capacitance-type analog model of that valley.

"Lithologic logs of many test holes were available and samples from some of these test holes were analyzed in the laboratory to determine permeability, specific yield, and particle-size distribution. Textural classification triangles on which contours of equal permeability and specific yield have been drawn, and graphs relating these two properties to statistical measures of particle-size--such as median diameter--were used to provide permeabilities or specific yields for weighting each lithologic unit according to its thickness as shown in the test hole log. The weighted lithologic logs were used to map properties such as transmissibility.

"The hydrogeologic maps resulting from such techniques have been checked by detailed aquifer tests. Although use of laboratory data proved satisfactory in the Arkansas Valley, the relations of hydrologic properties to particle size as determined for this area should not be applied directly to other areas without a similar study of data obtained from laboratory analysis of the properties of lithologic samples from the area."

ELECTRIC-ANALOG STUDY OF CAVE FORMATION, National Speleological Society Bulletin, Volume 28, Number 3, pages 127-132, July 1966, by M. S. Bedinger.

"This study of limestone solution leading to cavern development is based on the following conditions: (1) the permeability of the limestone is low, but it contains and transmits water in joints, fractures, bedding-plane partings, and solution-channels; (2) at depth, the limestone aquifer is underlain by impermeable rock; (3) ground water in the limestone is under water-table conditions; (4) recharge to the limestone is by infiltration of precipitation through the overlying rock to the zone of saturation; (5) discharge from the aquifer is by seeps and springs; (6) ground water dissolves the limestone through which it flows, continuously modifying the flow pattern and the hydraulic properties of the medium. These conditions commonly are found in terrains of limestone of Paleozoic age in the eastern and central United States. An electrical analog conforming to these conditions has been constructed and used to define the pattern and density of ground-water flow and the relative length of time that water is in contact with the aquifer. Successive models are used to illustrate progressive limestone solution and changes in ground-water flow in the aquifer. The initial analog indicates a strongly convex water table with the greatest density of flow at shallow depth beneath the water table near the point of discharge. Successive models indicate greater concentration of flow near and on the level of ground-water discharge, and overall lowering of the water table, and a pronounced flattening of the water table near the discharge point.

"Results of the analog study support the following conclusions: (1) solution channels generally decrease in size with depth and with lateral distance from the point of ground-water discharge; (2) the larger solution channels are above or near the elevation of the point of discharge and have greater lateral than vertical extent. This second observation supports the theory that the major zone of cave formation is at shallow depth beneath the water table."

DIGITAL-COMPUTER PROGRAMS FOR ANALYSIS OF GROUND-WATER FLOW, U.S. Geological Survey open-file report, 1973, by M. S. Bedinger, J. E. Reed, and J. D. Griffin.

Ground-water flow, river-induced fluctuations, and evapotranspiration digital-computer programs presented in this report can be used (1) to compute the head response in an aquifer to various boundary conditions, (2) to compute the steady-state relation between evapotranspiration and depth to water as a function of thickness and layering of fine-grained materials overlying the aquifer, and (3) to compute the head fluctuations in an aquifer induced by changes in river stage. Sufficient information is available in this report so that anyone familiar with digital computers can solve a wide variety of hydrologic problems. Preparation of input data for the three programs is described in detail and sample outputs from each program show the results to be expected.

METHODS FOR THE ANALYSIS OF ROCKS FROM THE POTASH SULFUR SPRINGS AREA OF ARKANSAS, University of Arkansas, Institute of Science and Technology, March 1953, by R. A. Schroeder.

"The rocks of the Potash Sulfur Springs area of Arkansas offer unusual and extraordinarily difficult problems in chemical analysis. Fusion of samples with sodium carbonate is not complete either with or without the addition of sodium nitrate and the use of long fusion. Fusion with NaOH and Na_2O_2 in nickel, although it gives excellent results, is not satisfactory for cation analysis because nickel and large quantities of sodium salts are introduced. This method was used for anion analysis. For cation analysis the rock sample was treated with HNO_3 and HF. This method removes silica from the analysis in the first operation. Small amounts of platinum produce the only contamination.

"Qualitative analysis by spectrographic methods resulted in the following determinations:

"Elements present in quantities larger than one percent: aluminum, calcium, iron, niobium, titanium, sodium, potassium, phosphorus, and fluoride. Elements present in quantities from one tenth of one percent to one percent: uranium, vanadium, and zirconium. Elements present in quantities less than one tenth of one percent: lead, manganese, chromium, zinc, rare earths, and barium."

QUANTITATIVE COMPARISON OF SOME AESTHETIC FACTORS AMONG RIVERS, U.S. Geological Survey Circular 620, 1969, by L. B. Leopold.

"This report is a preliminary attempt to quantify some elements of aesthetic appeal while eliminating, insofar as possible, value judgments or personal preferences.* * *"

"Quantitative evaluation of river and valley characteristics was made on 12 sites in Idaho. These were analyzed without introduction of any personal preference or bias. Hells Canyon of the Snake River was shown to be unique and comparable only to the Grand Canyon of the Colorado River.* * *"

SHORTCUTS AND SPECIAL PROBLEMS IN AQUIFER TESTS, U.S. Geological Survey Water-Supply Paper 1545-C, 1963, by Ray Bentall.

AQUIFER-TEST DESIGN, OBSERVATION, AND DATA ANALYSIS, Techniques of Water-Resource Investigations of the U.S. Geological Survey, Book 3, Chapter B1, 1968, by R. W. Stallman.

COMPUTATION OF RATE AND VOLUME OF STREAM DEPLETION BY WELLS, Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 4, Chapter D1, 1970, by C. T. Jenkins.

ELECTRIC ANALOG OF THREE DIMENSIONAL FLOW TO WELLS AND ITS APPLICATION TO UNCONFINED AQUIFERS, U.S. Geological Survey Water-Supply Paper 1536-H, 1963, by R. W. Stallman.

METHODS OF COLLECTING AND INTERPRETING GROUND-WATER DATA, U.S. Geological Survey Water-Supply Paper 1544-H, 1963, by Ray Bentall.

APPLICATION OF ELECTRICAL AND RADIOACTIVE WELL LOGGING TO GROUND-WATER HYDROLOGY, U.S. Geological Survey Water-Supply Paper 1544-D, 1963, by E. P. Patten, Jr., and G. D. Bennett.

THEORY OF AQUIFER TESTS, U.S. Geological Survey Water-Supply Paper 1536-E, 1962, by J. G. Ferris, D. B. Knowles, R. H. Brown, and R. W. Stallman.

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A PROCEDURE FOR EVALUATING ENVIRONMENTAL IMPACT, U.S. Geological Survey Circular 645, 1971, by L. B. Leopold, F. E. Clarke, B. B. Hanshaw, and J. R. Balsey.

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Group 7C--Evaluation, processing, and publication

QUANTITATIVE ANALYSIS OF STREAM FLOW RATE EXTREMES.

For primary bibliographic entry see 2E.

STREAM FLOW QUANTITY AND QUALITY CORRELATIONS AND STATISTICAL ANALYSES.

For primary bibliographic entry see 2E.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1935, U.S. Geological Survey Water-Supply Paper 777, 1936.

The report contains a tabulation of water levels measured in 25 States. The section on Arkansas (pages 5 through 17) is a tabulation of measurements made in 18 wells in the Grand Prairie region. A brief introductory statement to the tabulations by D. G. Thompson describes the history of the water-level program and water-level declines in the Grand Prairie region caused by pumping ground water for rice irrigation. Measurements cover the period from 1927 through 1935.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1936, U.S. Geological Survey Water-Supply Paper 817, 1937.

Water-level measurements are tabulated for 28 States. In 1936 the water-level program for the Grand Prairie region of Arkansas was expanded to include measurements for 238 wells. However, water levels are tabulated for only nine wells (p. 5). According to D. G. Thompson, in the introductory statements, the successive lowering of water levels in the Grand Prairie each year was evident. Comparison of measurements a year apart in the same wells showed declines of 1.20 to 1.50 feet.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1937, U.S. Geological Survey Water-Supply Paper 840, 1938.

The report contains a tabulation of water levels for 28 States. The section on Arkansas for the Grand Prairie region (p. 7 through 22) lists measurements for 32 wells. According to D. G. Thompson, in the introductory statements, the most critical information showing the trend of water levels in the Grand Prairie can be obtained by annual measurements made in the spring before pumping for rice irrigation. The continuous downward trend of water levels in the Grand Prairie was again reflected in the 1937 water-level measurements. The decline is dramatically emphasized by graphs on page 9 of the report showing the lowest water level reached each day in four wells. Well number 280 in the graph shows a decline in water level of about 8 feet in 8 years.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1938, U.S. Geological Survey Water-Supply Paper 845, 1939.

Water-level measurements made in 32 States are listed in the report. The section on Arkansas, prepared by D. G. Thompson (p. 6 through 11), covers only the Grand Prairie region and measurements for 37 wells are tabulated. Changes in water level in a given well of as much as 0.8 foot are noted as being caused by changes in atmospheric pressure. High atmospheric pressure causes depressed water levels whereas low atmospheric pressure causes water levels to rise. After correction for barometric influence, the 1938 measurements show the drop in water level was more than 1 foot for most of the Grand Prairie region.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1939, U.S. Geological Survey Water-Supply Paper 886, 1940.

This report contains records of water-level measurements in about 5,500 wells in 36 States. The section on the Grand Prairie region in Arkansas, by D. G. Thompson, pages 7 through 16, lists water levels for 50 wells. The measurements showed water-level declines of a foot or more in several parts of the Grand Prairie region in 1 year. The greatest decline, more than 6 feet, occurred in a small area at the extreme southeastern part of the region. Presumably, the declines in water level would stop if rice irrigation was restricted to only 58,000 to 67,000 acres per year.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1940, PART 4. SOUTH-CENTRAL STATES, U.S. Geological Survey Water-Supply Paper 909, 1941.

By 1940 the number of water-level measurements made in the United States had increased to such a large number it was impractical to publish them in one volume. Consequently, beginning in 1940, water levels were published in six volumes, the practice being followed to the present time. Arkansas is included in the volume titled "South-Central States," along with Oklahoma, Texas, and Louisiana. Pages 6 through 21, by D. G. Thompson and R. G. Kazmann, list water levels made in the Grand Prairie region of Arkansas in 81 wells. There was an average net decline of water level of about 0.5 foot in 1 year in the Grand Prairie.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1941, PART 4. SOUTH-CENTRAL STATES, U.S. Geological Survey Water-Supply Paper 939, 1943.

This report covers Arkansas, Louisiana, Oklahoma, and Texas, and gives records of water levels for about 1,413 wells in these States. The section on Arkansas, pages 5 through 9, by D. G. Thompson and R. G. Kazmann, gives water levels in 81 wells in the Grand Prairie region. The measurements indicate that the general slow decline in water level in the Grand Prairie had continued in 1941.

WATER LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN 1942, PART 4. SOUTH-CENTRAL STATES, U.S. Geological Survey Water-Supply Paper 947, 1944.

This volume covers Arkansas, Louisiana, Oklahoma, and Texas, and gives records of water-level measurements in about 1,320 wells in these States. The section on Arkansas, pages 7 through 10, by R. G. Kazmann, gives records of water levels for 75 wells in the Grand Prairie region. The water levels in the Grand Prairie continued to reflect a downward trend in 1942.

A series of Water-Supply Papers with a master title, Water LEVELS AND ARTESIAN PRESSURE IN OBSERVATION WELLS IN THE UNITED STATES IN (year), has been published since the one described in the foregoing reference. To avoid undue lengthy repetition, a table summarizing water-level information pertaining to Arkansas that is contained in each Water-Supply Paper follows.

WSP No.	Number of wells measured in Arkansas and listed in the WSP	Counties in which water levels were measured	Page numbers in report on which water levels are listed	Year water-level measurements made	Remarks
989	24	Arkansas Jefferson Lonoke Monroe Prairie	6-12	1943	
1019	27	Arkansas Jefferson Lonoke Monroe Prairie	5-11	1944	
1026	29	Arkansas Jefferson Lonoke Monroe Prairie	5-11	1945	
1074	34	Arkansas Ashley Lonoke Monroe Prairie	5-12	1946	
1099	50	Arkansas Ashley Lonoke Monroe Prairie	5-12	1947	
1129	61	Arkansas Ashley Jefferson Lonoke Monroe Prairie	5-11	1948	
1159	56	Arkansas Ashley Jefferson Lonoke Monroe Prairie	5-10	1949	

WSP No.	Number of wells measured in Arkansas and listed in the WSP	Counties in which water levels were measured	Page numbers in report on which water levels are listed	Year water-level measurements made	Remarks
1168	56	Arkansas Ashley Jefferson Lonoke Monroe Prairie	3- 6	1950	
1194	86	Arkansas Ashley Clay Columbia Craighead Cross Jackson Jefferson Lonoke Monroe Poinsett Prairie Randolph St. Francis Union Woodruff	3-22	1951	Includes maps showing the locations of observation wells and graphs of water levels in nine wells for the period of record.
1224	25	Arkansas Ashley Columbia Jefferson Lonoke Prairie Union	3-12	1952	Includes two maps, one for northeast and one for southeast Arksas, showing the differences in water levels in observation wells measured in 1951 and 1952. Also includes a map of the Grand Prairie region and the changes in water levels from 1951 to 1952 in about 275 wells.
1268	24	Arkansas Ashley Columbia Jefferson Lonoke Prairie Union	3-11	1953	Includes maps of Arkansas showing the locations of wells measured in 1953. Also includes a map of the Grand Prairie region showing changes in water levels from 1952 to 1953 in about 325 wells.

WSP No.	Number of wells measured in Arkansas and listed in the WSP	Counties in which water levels were measured	Page numbers in report on which water levels are listed	Year water-level measurements made	Remarks
1324	29	Arkansas Ashley Chicot Columbia Desha Drew Jefferson Lincoln Lonoke Prairie Pulaski Union	3-20	1954	Contains maps showing locations of wells measured in 1954 in northeast and south Arkansas, and a map of the Grand Prairie region showing the changes in water levels from 1953 to 1954 in 180 wells. The changes in water levels from 1953 to 1954 in 113 wells in northeast and south Arkansas are shown in two tables. Water levels in the six wells for period of record are illustrated as graphs; the period of record for one well in the Grand Prairie is from 1928 to 1954.
1407	32	Arkansas Ashley Chicot Desha Drew Jefferson Lafayette Lincoln Lonoke Ouachita Prairie Pulaski Union	3-18	1955	Contains maps showing the locations of wells measured in 1955 in northeast and south Arkansas and a map of the Grand Prairie region showing the changes in water levels from April 1954 to April 1955 in 220 wells. The changes in water levels in 111 wells in northeast and south Arkansas are given in two tables. Water levels in five wells are illustrated as graphs.

WSP No.	Number of wells measured in Arkansas and listed in the WSP	Counties in which water levels were measured	Page numbers in report on which water levels are listed	Year water-level measurements made	Remarks
1549	59	Arkansas Ashley Chicot Clay Columbia Craighead Crittenden Cross Desha Drew Hempstead Howard Jackson Jefferson Lafayette Lee Lincoln Little River Lonoke Mississippi Monroe Ouachita Pike Poinsett Prairie Pulaski Sevier Union White Woodruff	3-22	1956-59	Includes two maps showing the locations of wells measured in northeast and south Arkansas, 1956-59.

WSP No.	Number of wells measured in Arkansas and listed in the WSP	Counties in which water levels were measured	Page numbers in report on which water levels are listed	Year water-level measurements made	Remarks
1824	50	Arkansas Ashley Chicot Clay Columbia Craighead Crittenden Cross Desha Drew Hempstead Howard Jackson Jefferson Lafayette Lee Lincoln Little River Lonoke Miller Mississippi Ouachita Pike Poinsett Prairie Pulaski Sevier Union White Woodruff	3-14	1960-64	Includes a map of Arkansas showing the locations of wells measured, 1960-64.

WSP No.	Number of wells measured in Arkansas and listed in the WSP	Counties in which water levels were measured	Page numbers in report on which water levels are listed	Year water-level measurements made	Remarks
1979	68	Arkansas Ashley Calhoun Chicot Clay Cleveland Columbia Craighead Crittenden Cross Dallas Desha Drew Greene Jackson Jefferson Lafayette Lee Lincoln Little River Lonoke Miller Mississippi Monroe Ouachita Phillips Prairie Pulaski St. Francis Union Woodruff	4-28	1965-69	Contains a map of Arkansas showing the locations of wells measured, 1965-69.

DEPTH TO WATER MEASUREMENTS IN WELLS IN THE ALLUVIUM OF THE ARKANSAS RIVER VALLEY BETWEEN LITTLE ROCK, ARKANSAS, AND THE MISSISSIPPI RIVER, U.S. Geological Survey open-file report, Volumes I through IV, February 1965, by J. R. May, J. J. Yanchosek, '. S. Bedinger, and L. F. Emmett.

Water-level measurements in wells tabulated in the four volumes are grouped on a county basis.

Volume I contains measurements made in 17 wells in Arkansas County. The measurements for the period 1957-64 were made monthly, and range from 30 to 90 feet below land surface.

Volume II contains measurements made in 26 wells in Desha County, with most of the records covering the period 1957-64, made monthly. The measurements range from 3 to 37 feet below land surface.

Volume III contains water-level measurements made in wells in Jefferson and Lincoln Counties. Most of the measurements were made monthly and cover the period 1957-64, with 32 wells tabulated for Jefferson County and 7 for Lincoln County. The measurements range from 3 to 37 feet below land surface in the two counties.

Volume IV contains water-level measurements made in 6 wells in Lonoke County, 26 wells in Pulaski County, and 1 well in Saline County. Most of the measurements cover the period 1958-64, were made monthly, and range from 3 to 44 feet below land surface.

CHANGES IN WATER LEVELS IN DEPOSITS OF QUATERNARY AGE IN EASTERN ARKANSAS FROM 1938 TO 1953, University of Arkansas, Agricultural Experiment Station, Report Series 42, June 1954, by H. B. Counts and Kyle Engler.

This report covers an area of about 8,800 square miles in the Coastal Plain of Arkansas. The changes in ground-water levels noted from 1938 to 1953 are the result of natural conditions and withdrawal of water from wells. In 1938 pumpage in the area was about 320 mgd and in 1952 was about 685 mgd.

The area of greatest decline of water levels was in Lonoke and Prairie Counties and was caused by pumping. Declines ranged from more than 10 to more than 20 feet.

Four areas show slight rises in water levels from 1938 to 1953. The largest of these rises is along the Cache River in east Jackson County, northwest Poinsett County, west Craighead County and east Lawrence County. Other smaller areas of ground-water rise are in White and Woodruff Counties, Monroe and Lee Counties, and along Bayou Meto in southwest Arkansas County.

GROUND-WATER LEVELS IN OBSERVATION WELLS IN ARKANSAS, SPRING 1973, U.S. Geological Survey open-file report, 1973.

More than 500 water-level measurements made in wells in the spring of 1973 are tabulated in this report. Ten aquifers, the Quaternary alluvium, Cockfield Formation, Sparta Sand, Cane River Formation, Carrizo Sand, Wilcox Group, Nacatoch Sand, Tokio Formation, Trinity Group, Pike Gravel, and the Jackfork Sandstone are included.

GROUND-WATER LEVELS IN DEPOSITS OF QUATERNARY AND TERTIARY AGE, SPRING 1965, Arkansas Geological Commission, Water Resources Summary Number 4, 1967, by D. R. Albin, J. W. Stephens, and Joe Edds.

Two maps of the Coastal Plain of Arkansas use contour lines to show the shape of the water-level surface in the water-bearing deposits of Quaternary age and the Sparta Sand below in the spring of 1965. A comparison of the 1961 and 1965 maps (Quaternary) shows that the cone of depression centered in Lonoke, Prairie, and Arkansas Counties is not as deep in 1965 as in 1961 but that the cone covers a larger area. Overall, there has been little change in water levels in Quaternary deposits since 1961, indicating little change in the amount of ground water in storage.

The map of water levels in the Sparta Sand in 1965 shows three distinct cones of depression centered around Pine Bluff, Magnolia, and El Dorado. These cones reflect heavy industrial withdrawals. At Magnolia, the water level in the Sparta Sand has declined almost to the top of the aquifer. At the present rate of withdrawal, about 4 feet per year, a significant part of the aquifer will be dewatered by approximately 1970.

DECLINE OF WATER LEVELS IN THE PINE BLUFF AREA, Arkansas Geological and Conservation Commission, Special Ground-Water Report Number 2, 1960, by M. S. Bedinger, J. W. Stephens, and Joe Edds.

The industrial growth and consequent increased use of ground water from the Tertiary deposits in the Pine Bluff area have been accompanied by accelerated declines in ground-water levels. Most of the increase in pumping began in 1958 and declines of as much as 115 feet have been recorded in wells near the center of ground-water development. The declines in water level are significant but in the absence of hydrologic data it is not possible to determine whether or not an overdraft is occurring.

CHANGES IN GROUND-WATER LEVELS IN DEPOSITS OF QUATERNARY AGE IN NORTHEASTERN ARKANSAS, Arkansas Geological Commission, Water Resources Summary Number 3, 1962, by R. O. Plebuch.

This report shows the changes in ground-water levels from 1953 to 1961 in deposits of Quaternary age in the Coastal Plain west of Crowleys Ridge and north of the Arkansas River. Also, changes in ground-water levels from 1955 to 1962 in deposits of Quaternary age east of Crowleys Ridge are shown.

The cone of depression in the Grand Prairie region enlarged northwestward (1953 to 1961). A second area of lowered water levels for the same period includes parts of western Cross and Poinsett Counties where declines were from 5 to 16 feet. A rise in water levels was noted in White County south of Searcy, Arkansas, and in St. Francis, Lee, and Phillips Counties, the rise generally being less than 5 feet.

East of Crowleys Ridge there was a general net rise of water levels (1955-62). The low water levels in 1955 probably were the result of deficient precipitation and increased pumpage.

ESTIMATED DEPTH TO WATER IN STATES WEST OF THE MISSISSIPPI RIVER, U.S. Geological Survey Technical Letter, Special Projects - 3, April 16, 1962, by S. L. Schoff.

This report contains a map showing where the estimated depth to water is greater than 1,000 feet below the land surface in States west of the Mississippi River. The map also shows areas where no well-defined zone of saturation exists because rocks--such as intrusive rocks or thick shale--may contain little or no free water. The report was prepared for the U.S. Atomic Energy Commission for information on localities where the rocks might be expected to be dry to great depths.

Arkansas, Missouri, Washington, Nebraska, Iowa, and Kansas have no areas where the depth to water exceeds 1,000 feet below land surface. Arizona, California, Colorado, and Idaho are the States containing the largest areas where the depth to water is greater than 1,000 feet.

WATER LEVELS IN RICE IRRIGATION WELLS IN THE GRAND PRAIRIE REGION, University of Arkansas, Arkansas Farm Research, Volume 7, Number 3, May-June, 1958, by Kyle Engler.

GROUND-WATER TREND STILL DOWN IN 1963, University of Arkansas, Arkansas Farm Research, Volume 12, Number 5, September-October 1963, by Kyle Engler.

GROUND-WATER LEVELS IN WELLS IN THE GRAND PRAIRIE AND EASTERN ARKANSAS, University of Arkansas, Arkansas Farm Research, Volume 14, Number 3, May-June 1965, by Kyle Engler.

LOGS AND WATER-LEVEL MEASUREMENTS OF SELECTED TEST HOLES AND WELLS IN THE ALLUVIUM OF THE ARKANSAS RIVER VALLEY BETWEEN LITTLE ROCK AND FORT SMITH, ARKANSAS, U.S. Geological Survey open-file report, Volume I through XI, June 1964, by J. R. May and L. F. Emmett.

Volumes I through XI contain water-resources data (principally logs of test holes) that were collected by the U.S. Geological Survey in cooperation with the U.S. Army Corps of Engineers. Many of the logs also have a water-level measurement that was made in the test hole. The location of each log and the elevation of the land surface at each location is given. Nearly all of the logs also have a water level and the date of measurement listed. Most of the holes penetrate the entire thickness of the alluvium. All of the logs are of holes drilled in the alluvium along the Arkansas River.

Volume I contains 109 logs of test holes in Conway County. The depths of the holes range from 9 to 82 feet.

Volume II contains 75 logs of test holes in Crawford County. The depths of the holes range from 5 to 52 feet.

Volume III contains 44 logs of test holes in Faulkner County. The depths of the holes range from 10 to 80 feet.

Volume IV contains 18 logs of test holes in Franklin County. The depths of the holes range from 10 to 64 feet.

Volume V contains 15 logs of test holes in Johnson County. The depths of the holes range from 6 to 55 feet.

Volume VI contains 51 logs of test holes in Logan County. The depths of the holes range from 30 to 67 feet.

Volume VII contains 23 logs of test holes in Perry County. The depths of the holes range from 5 to 77 feet.

Volume VIII contains 54 logs of test holes in Pope County. The depths of the holes range from 10 to 65 feet.

Volume IX contains 55 logs of test holes in Pulaski County. The depths of the holes range from 11 to 97 feet.

Volume X contains 28 logs of test holes in Sebastian County. The depths of the holes range from 12 to 50 feet.

Volume XI contains 56 logs of test holes in Yell County. The depths of the holes range from 8 to 73 feet.

LOGS AND WATER-LEVEL MEASUREMENTS OF SELECTED TEST HOLES AND WELLS IN THE ALLUVIUM OF THE ARKANSAS RIVER VALLEY BETWEEN LITTLE ROCK AND FORT SMITH, ARKANSAS, U.S. Geological Survey open-file report, Volume XII, June 1964, by J. R. May and L. F. Emmett.

This report is one of a series of 12 volumes containing water-resources data collected by the U.S. Geological Survey in cooperation with the U.S. Army Corps of Engineers as a part of the study of ground water in water-bearing material next to the Arkansas River between Little Rock and Fort Smith. Volume XII, contains only lists of water-level measurements made in wells in Conway, Crawford, Faulkner, Johnson, Logan, Perry, Pope, Pulaski, Sebastian, and Yell Counties, Arkansas. The period of record for most of the monthly measurements for the 80 wells tabulated is 1957-61. The elevation of the land surface at each well is also given.

RECORD OF DEEP WELL DRILLING FOR 1905, U.S. Geological Survey Bulletin 298, 1906, by M. L. Fuller and Samuel Sanford.

Gives an account of progress in collection of well records, and samples; contains tabulated records of wells in Arkansas, Colorado, Kansas, Kentucky, Louisiana, Mississippi, Missouri, New Mexico, Oklahoma, Tennessee, and Texas, and detailed records of wells in Hempstead County, Arkansas.

LIST OF ARKANSAS WATER WELLS, DATA TO JUNE 30, 1937, Arkansas Geological Survey Information Circular 11, 1937.

The report contains information on 2,141 water wells in Arkansas. Well depths range from 70 to 3,810 feet. George C. Branner, State Geologist, who directed the compilation, estimated that ground-water use in Arkansas in 1936 by municipalities, self-supplied industries, bottled-water firms, and rice growers was 117,247,484,000 gallons valued at $4,379,000, which is about 23 percent of the value of all other minerals produced.

LIST OF ARKANSAS OIL AND GAS WELLS, DATA TO OCTOBER 31, 1936, Arkansas Geological Survey Information Circular 10, 1937.

Information Circular 10 contains data on 2,109 oil and gas wells and dry holes drilled in Arkansas to October 31, 1936. The data are tabulated by county with the location of each hole given and where the log of the hole may be obtained.

LIST OF ARKANSAS OIL AND GAS WELLS, Arkansas Geological and Conservation Commission, Supplement to Information Circular 10, 1956, by W. L. Dobie and H. D. Hughes.

Information Circular 10 contains a list of oil and gas wells drilled in Arkansas to October 31, 1936. This supplement is an update of Information Circular 10 and lists "wildcat wells" and oil and gas wells drilled from November 1, 1936, to January 1, 1955. The data are tabulated by county with the location of each hole given and where the logs of the hole may be obtained.

RECORD OF DEEP-WELL DRILLING FOR 1904, U.S. Geological Survey Bulletin 264, 1905, by M. L. Fuller, E. F. Lines, and A. C. Veatch.

Discusses the importance of accurate well records to the driller, to owners of oil, gas, and water wells, and to geologists, describes the general methods of work and gives tabulated records of wells in Arkansas, Colorado, New Mexico, Oklahoma, Kansas, Missouri, Tennessee, and Texas.

WELL RECORDS, DEPTH-TO WATER MEASUREMENTS AND LOGS OF SELECTED WELLS AND TEST HOLES, AND CHEMICAL ANALYSES OF GROUND WATER IN THE ARKANSAS VALLEY REGION, ARKANSAS, U.S. Geological Survey open-file report, 1962, by R. M. Cordova.

The data in this report were collected as a part of a ground-water reconnaissance of the Arkansas Valley region. This compilation can be helpful in predicting drilling conditions, quality of ground water, and yields of wells at prospective well sites.

Measurements of the depth to water are tabulated for 108 wells for a period of record generally covering August 1960-March 1961. During this period, water levels in the various wells measured ranged from 0 to 86 feet below land surface.

Records of the character of the 108 wells are given in table 3 and include the location, depth, and the kinds of rocks in which the well is drilled. Well depths range from 13 to 134 feet.

Table 4 is a compilation of the results of chemical analyses of 64 water samples from different wells in the Arkansas Valley region. Information listed includes the location of the well samples, water temperature, and the amount of silica, iron, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, fluoride, nitrate, and dissolved solids in the water. Hardness, conductance, and pH of the water are also given. In general, these analyses indicate the water is of usable quality but may in some areas exceed recommended limits of dissolved substances.

Logs of 102 gas and oil test holes and wells drilled in the Arkansas Valley region are given in table 5. At the date of the compilation of table 5 (1960) all water wells drilled in the study area were less than 500 feet deep. Consequently, even though the gas and oil test holes may have been several hundreds of feet deeper, the log below 500 feet is not given.

An interpretive report on the Arkansas Valley region also has been prepared. (See WSP 1669-BB.)

WELL RECORDS, DEPTH-TO-WATER MEASUREMENTS AND LOGS OF SELECTED WELLS AND TEST HOLES, AND CHEMICAL ANALYSES OF GROUND WATER IN BRADLEY, CALHOUN, AND OUACHITA COUNTIES, ARKANSAS, U.S. Geological Survey open-file report, 1963, by D. R. Albin.

The data in this report were collected from January 1958 through June 1961, in Bradley, Calhoun, and Ouachita Counties.

Included are records of 163 wells, measurements of water levels in 207 wells, logs of 38 test holes and wells, chemical analyses of water samples from 194 wells, and graphs of water levels in two wells.

Well depths range from 60 to 1,059 feet, and well yields range from 2 to 817 gallons per minute. Depths to water in wells range from 1 to 191 feet for the period of record.

An interpretive report (WSP 1779-G) covering Bradley, Calhoun, and Ouachita Counties also contains a limited amount of basic water-resources data.

WELL RECORDS, DEPTH-TO-WATER MEASUREMENTS, STREAMFLOW DATA, AND CHEMICAL ANALYSES OF WATER IN THE OUACHITA MOUNTAINS, ARKANSAS, U.S. Geological Survey open-file report, 1963, by D. R. Albin and J. W. Stephens.

This report is a compilation of the water-resources data collected during a water-resources reconnaissance of the Ouachita Mountains. A short interpretive report (WSP 1809-J) on the same area also contains some basic data. The period of record for most of the data is from July 1961 through June 1963.

Included are records for 172 wells, water-level measurements in 45 wells, chemical analyses of water samples from 49 wells, measurements of streamflow at 14 gaging stations, and chemical analyses of water samples from streams at 17 locations.

Well depths range from 14 to 627 feet and yields are reported to range from 5 to 550 gpm with most of the yields being less than 10 gpm. Depths to water in the wells ranged from 2 to 45 feet below land surface and fluctuated widely. The water in the wells was found to be suitable for most purposes although many samples contained excessive iron and hardness.

Streams in the area are the best potential source for developing large quantities of water. The water quality is excellent, even during periods of poorest quality when the flow of the stream is low.

WELL RECORDS, DEPTH-TO-WATER MEASUREMENTS, STREAMFLOW AND PRECIPITATION DATA, CHEMICAL ANALYSES OF WATER, AND LOGS OF TEST HOLES IN JACKSON AND INDEPENDENCE COUNTIES, ARKANSAS, U.S. Geological Survey open-file report, 1965, by J. W. Stephens, D. R. Albin, and M. S. Hines.

This report is a compilation of water-resources data collected during an appraisal of the water resources of Jackson and Independence Counties. (See WSP 1839-G for additional information.) Most of the data were collected between July 1962 and July 1965. Included are records of 147 wells, water-level measurements in 32 wells, graphs of water levels in 4 wells, logs of 16 test holes, discharge measurements of 40 wells, chemical analyses of water samples from 33 wells, measurements of streamflow at 20 locations, chemical analyses of water samples from streams at 10 locations, and precipitation records for Newport, Ark.

WELL RECORDS AND DEPTH-TO-WATER MEASUREMENTS IN THE VICINITY OF RANDOLPH AND LAWRENCE COUNTIES, ARKANSAS, U.S. Geological Survey open-file report, 1967, by A. G. Lamonds, M. S. Hines, and R. O. Plebuch.

Tabulated in this report are records for 2 wells in Craighead County, 1 well in Jackson County, 1 well in Greene County, 64 wells in Lawrence County, and 50 wells in Randolph County. Water-level measurements are listed for 44 wells, with most of the measurements made in 1966. An interpretative report, WSP 1879-B, also covers Randolph and Lawrence Counties and contains additional water-resources data.

WATER-RESOURCES DATA, GRANT AND HOT SPRING COUNTIES, ARKANSAS, U.S. Geological Survey open-file report, 1967, by Joe Edds, C. T. Bryant, H. N. Halberg, and M. S. Hines.

This report contains basic data collected as a part of an appraisal of the water resources of Grant and Hot Spring Counties. (See WSP 1857.) Records of 598 wells and 4 springs are listed according to the water-bearing materials from which the water is obtained. Chemical analyses of ground-water samples from 108 wells and 3 springs are listed. Logs of 138 wells and test holes ranging from 17 to 1,788 feet deep are given.

Twelve water-bearing formations were tested for yield by making specific-capacity tests on 44 wells. The drawdown and yield of each well for the test period are also given. Data for five pumping tests are tabulated. Periodic water-level measurements were made on four wells for about a 3-year period and are listed in the report.

Tables 7 and 8 in the report contain a list of streamflow data for the Caddo, Ouachita, Antoine, and Saline Rivers in the two-county area. Table 9 contains a summary of the chemical and physical quality of water samples collected from the Ouachita and Saline Rivers and Hurricane Creek during a period of record from 3 to 15 years long. Low-flow measurements of 22 smaller streams, tributary to larger streams in the area, are listed in table 10. One to five water samples at each location were collected from 18 streams during 1960-65 in the study area and the results of the chemical analyses of these samples are given in table 11.

WATER-RESOURCES DATA FOR ARKANSAS, GROUND-WATER RECORDS FOR ARKANSAS COUNTY, U.S. Geological Survey open-file report, 1968, by J. R. May.

This report was prepared to assemble under one cover the water-resources data in file in the U.S. Geological Survey office in Little Rock that had been collected in Arkansas County from August 1928 through December 1967. The report includes records of 393 wells, measurements of the depth to water in 386 wells, logs of 62 wells, and chemical analyses of water samples from 76 wells.

WATER-RESOURCES DATA FOR THE OZARK PLATEAUS PROVINCE, ARKANSAS, U.S. Geological Survey open-file report, 1969, by A. G. Lamonds and J. W. Stephens.

Discharge measurements for 31 springs in the Ozarks are listed. The discharge ranged from a low of 0.12 cfs (54 gpm) for Abwatt Spring to 309 cfs (139,000 gpm) for Mammoth Spring. Records for 209 wells are tabulated. Well depths listed range from 14 to 642 feet and water levels were from 3 to 344 feet below land surface at the time of measurement. The thicknesses of the water-bearing rocks and depths to their tops are given for 30 test holes and wells. The depths of these holes and wells range from 350 to 4,996 feet. Water samples from 88 wells and springs representing water from 9 types of rocks were collected and analyzed for chemical concentration. According to table 4, in which the results are tabulated, the water is suitable for most purposes although much of it is high in iron and tends to be hard. Fifty-five water samples from 39 streams in the area were collected and analyzed for chemical concentration. The water is exceptionally good quality and suitable for nearly all uses. Other information may be found in an interpretative report prepared on the area (See HA-383.)

WELL RECORDS, WATER-LEVEL MEASUREMENTS, CHEMICAL ANALYSES OF WATER, AND WELL HYDROGRAPHS IN CLAY, GREENE, CRAIGHEAD, AND POINSETT COUNTIES, ARKANSAS, U.S. Geological Survey open-file report, 1969, by M. S. Hines.

Records for 99 wells in the four-county area are tabulated. Well depths are reported to range from 15 to 400 feet and yields range from 250 to 2,500 gpm with most of the listed yields being greater than 1,000 gpm.

Chemical analyses of water from 62 wells are given in table 2. The most noticeable undesirable constituent is iron, which was as high as 13 ppm and exceeded 2 ppm in more than half the samples. Water-level measurements for 10 wells are listed and are from less than 1 foot to 88 feet below land surface. The maximum change in water level in a given well is about 20 feet and the minimum about 5 feet for the period of record listed. Water samples were collected at 11 locations on 10 streams in the area for chemical analyses. Table 4, listing the results of these analyses, shows that the water generally is of good chemical quality suitable for most purposes. Graphs of water levels in two wells are shown, one for January 1957 through November 1966, and one for June 1955 through November 1966. An interpretative report, HA-377, contains additional water-resources information.

WELL RECORDS, DEPTH-TO-WATER MEASUREMENTS, CHEMICAL ANALYSES OF GROUND WATER, DRILLERS LOGS, AND ELECTRIC-LOG INFORMATION IN HEMPSTEAD, LAFAYETTE, LITTLE RIVER, MILLER, AND NEVADA COUNTIES, ARKANSAS, U.S. Geological Survey open-file report, 1970, by J. W. Stephens.

Most of the data in this report were collected between January 1967 and October 1968 as a part of an appraisal study of the water resources of the five-county area. (See WSP 1998 for additional information.) The report includes records of 479 wells, results of chemical analyses of water samples from 197 wells, electric-log information from 131 locations, logs of 126 wells and test holes, and measurements of water levels in 149 wells. The data are grouped by county and by the particular water-bearing formation associated with the water.

HYDROLOGIC DATA FOR HORSESHOE LAKE, ARKANSAS, AND VICINITY, U.S. Geological Survey open-file report, 1971, by A. G. Lamonds.

This report contains data collected during a study of the hydrology of Horseshoe Lake. Most of the data were collected between July 1969 and May 1971. Included in the report are measurements of water levels in 56 wells, logs of 11 wells and test holes, elevations of the water surface in Goose and Brushy Lakes, elevation of the water surface in Fish Bayou, and the average daily water temperature at Horseshoe Lake. Additional information is available in the interpretive report "Hydrology of Horseshoe Lake, Arkansas," U.S. Geological Survey open-file report, 1971, by A. G. Lamonds.

PETROLEUM EXPLORATION IN EASTERN ARKANSAS WITH SELECTED WELL LOGS, Arkansas Resources and Development Commission Bulletin 14, 1949, by C. A. Renfroe.

This report covers 20 counties in northeast Arkansas, with the principal content of the report being lithologic logs of 60 oil tests. In addition, there is a table for each of the counties, listing a total of 166 oil tests in which the hole location, total depth, and availability of the log are indicated. A generalized columnar section is given in figure II to assist in picking formation names and to define stratigraphic relationships of the rocks.

Although the report principally is designed to assist in oil exploration, it should be useful in developing a subsurface concept of the nature and extent of rocks that might serve as aquifers.

CONTRIBUTIONS TO THE HYDROLOGY OF THE EASTERN UNITED STATES, 1903, U.S. Geological Survey Water-Supply Paper 102, 1904, by M. L. Fuller.

Pages 374 through 388 of this report, written by A. H. Purdue, deals with well records and springs in Arkansas. The location, owner, depth, yield, and other pertinent statistics are given for 96 wells, most of which are north of the Arkansas River. The exceptions are a few wells reported for Clark, Hot Spring, Little River, Polk, Scott, and Sevier Counties. Records also are given for 33 springs. This information includes the location, owner, temperature, flow and a description of the rocks from which the water flows. Mammoth Spring, the largest listed, has an estimated flow of 150,000 gpm. Blanchard Springs, the second largest listed, is reported to have a flow of 2,100 gpm.

PRELIMINARY LIST OF DEEP BORINGS IN THE UNITED STATES, SECOND EDITION, WITH ADDITIONS, U.S. Geological Survey Water-Supply Paper 149, 1905, by H. N. Darton.

This report provides a list of deep borings in 48 States, the District of Columbia, and one table of deep borings for the Indian Territory.

Coverage is given for Arkansas on pages 11 through 14 of the report, with the location, depth, diameter,yield, and depth to water given in 134 holes in 37 counties.

SURFACE WATER SUPPLY OF THE UNITED STATES, 1961-65, PART 7. LOWER MISSISSIPPI RIVER BASIN, VOLUME 1. LOWER MISSISSIPPI RIVER BASIN EXCEPT ARKANSAS RIVER BASIN, U.S. Geological Survey Water-Supply Paper 1920, 1969.

This volume is one of a series of 37 reports giving records of stage, discharge, and content of streams, lakes, and reservoirs in the United States during the water years 1961-65. Data are available for 34 stations in the White River basin in Arkansas and for 25 stations in the Red River basin in Arkansas.

SURFACE WATER SUPPLY OF THE UNITED STATES 1961-65. PART 7. LOWER MISSISSIPPI RIVER BASIN, VOLUME 2. ARKANSAS RIVER BASIN, U.S. Geological Survey Water-Supply Paper 1921, 1969.

This volume is one of a series of 37 reports giving records of stage, discharge, and content of streams, lakes, and reservoirs in the United States during the 1961-65 water years. Data are available for 33 stations on the Arkansas River and its tributaries in Arkansas

COMPILATION OF RECORDS OF SURFACE WATERS OF THE UNITED STATES, OCTOBER 1950 TO SEPTEMBER 1960, PART 7. LOWER MISSISSIPPI RIVER BASIN, U.S. Geological Survey Water-Supply Paper 1731, 1964.

Monthly and yearly summaries of streamflow and reservoir data collected during the period October 1, 1950, to September 30, 1960, are listed for 88 stations in Arkansas. Data are available for 49 streams and eight reservoirs in four river basins.

COMPILATION OF RECORDS OF SURFACE WATERS OF THE UNITED STATES, THROUGH SEPTEMBER 1950, PART 7. LOWER MISSISSIPPI RIVER BASIN, U.S. Geological Survey Water-Supply Paper 1311, 1955.

This report makes available all the surface-water records collected in the lower Mississippi River basin up to September 30, 1950. The data consist of records of discharge of streams and contents of reservoirs summarized on a monthly and yearly basis. Records are available in this report for 63 stations in Arkansas.

STREAM-GAGING STATIONS AND PUBLICATIONS RELATING TO WATER RESOURCES, 1885-1913, U.S. Geological Survey Water-Supply Paper 340, 1916, by B. D. Wood.

Pages 83 through 93 of this report contain water-resources information for the lower Mississippi River basin. Nine of the gaging stations listed are in Arkansas, with seven in the White River basin and two on the Ouachita River in the Red River basin. The report also contains a list of publications covering a wide range of hydrologic subjects in the lower Mississippi River valley and includes a brief description of the content of each report.

MAXIMUM DISCHARGES AT STREAM-MEASUREMENT STATIONS, THROUGH DECEMBER 31, 1937, WITH A SUPPLEMENT INCLUDING ADDITIONS AND CHANGES THROUGH SEPTEMBER 30, 1938, U.S. Geological Survey Water-Supply Paper 847, 1940, by G. R. Williams and L. C. Crawford, supplement by W. S. Eisenlohr, Jr.

This report is a compilation of the highest known discharges at most gaging stations in the United States and at several places on boundary streams in Canada and Mexico. Information for Arkansas is given in table 7, pages 120 through 128, for 26 locations.

SURFACE WATER RECORDS OF ARKANSAS, 1961, U.S. Geological Survey open-file report, 1961 (also 1962 through 1971; however, 1965 through 1971 reports are titled WATER RESOURCES DATA FOR ARKANSAS, PART 1. SURFACE WATER RECORDS, followed by the year for which the records are appropriate).

Through September 30, 1960, records of discharge and stage of streams, and contents and stage of lakes or reservoirs collected by the U.S. Geological Survey were published in an annual series of water-supply papers entitled SURFACE WATER SUPPLY OF THE UNITED STATES. The records for Arkansas are contained in Part 7 of that series.

The 1961 report, listed above, marks the beginning of a new method of presenting annually by States basic data on surface-water records. Each of the annual reports (1961 through 1971) contains a description of the gaging stations, the daily discharges, and monthly and yearly discharges of streams. In addition, reservoir content, low-flow, crest-stage, and miscellaneous records are listed.

The following is an example of the coverage to be expected. In the 1961 report, records are listed for 86 gaging stations covering 54 streams in five river basins in Arkansas. Included in these 86 records are data on the content of seven reservoirs. In addition 93 low-flow, 55 crest-stage, and nine miscellaneous stream measurements are listed. Subsequent reports contain greater coverage.

SURFACE WATER SUPPLY OF THE UNITED STATES, 1960, PART 7. LOWER MISSISSIPPI RIVER BASIN, U.S. Geological Survey Water-Supply Paper 1711, 1962.

Part 7, one of 20 volumes in this series listing records of streamflow, covers Arkansas, Colorado, Kansas, Kentucky, Louisiana, Mississippi, Missouri, New Mexico, Oklahoma, Tennessee, and Texas. This particular report was the last one of the annual WSP series to be published and was replaced by annual reports on a State-boundary basis.

The first report in the foregoing WSP series to list records of streamflow in Arkansas was entitled "REPORT OF PROGRESS OF STREAM MEASUREMENTS FOR THE CALENDAR YEAR 1904," U.S. Geological Survey Water-Supply Paper 131, 1905. Discharge measurements and gage heights of the Ouachita River near Malvern, Arkansas, for 1903 and 1904 are listed on pages 190 and 191 of Water-Supply Paper 131.

Since that time, through water year 1960, records of streamflow in Arkansas can be found in the following Water-Supply Papers.

WSP Number	Year	WSP Number	Year
131	1904	877	1939
173	1905	987	1940
209	1906	927	1941
267	1909	957	1942
287	1910	977	1943
547	1922	1007	1944
567	1923	1037	1945
587	1924	1057	1946
607	1925	1087	1947
627	1926	1117	1948
647	1927	1147	1949
667	1928	1177	1950
687	1929	1211	1951
702	1930	1241	1952
717	1931	1281	1953
732	1932	1341	1954
747	1933	1391	1955
762	1934	1441	1956
787	1935	1511	1957
807	1936	1561	1958
827	1937	1631	1959
857	1938	1711	1960

Early measurements of streamflow in Arkansas were on the Ouachita River (1904-6). By 1909 measurements had been made on the White, Buffalo, Little River, and North Fork Rivers. Beginning in 1930 data were available on the White, St. Francis, Arkansas, Red, Little, Little Missouri, and Ouachita Rivers. Streamflow data were available for most of the larger streams in Arkansas by 1940.

From 1922 to the present (1973) there has been no interruption of measurements of one or more streams in Arkansas.

For those years in which records were not collected in Arkansas, data are available on the Arkansas River and tributaries to the Mississippi River from gaging stations in States through which those streams run. These data may be found in the following Water-Supply Papers.

WSP Number	Year	WSP Number	Year
169	1905	407	1915
205	1906	437	1916
247	1907-8	457	1917
307	1911	477	1918
327	1912	507	1919-20
357	1913	527	1921
387	1914		

ARKANSAS STREAM GAGING REPORT 2, 1929 and 1930, U.S. Geological Survey, 1930, by J. H. Gardiner.

This report contains records for 32 stream-gaging stations. The Arkansas River at Van Buren had a minimum flow of 2,380 cfs in the period 1927-30 and a maximum flow of 315,000 cfs. The Red River at Garland City had a minimum flow of 2,740 cfs and a maximum flow of 119,000 cfs during the period from 1927-30. The White River at DeValls Bluff ranged in flow from 4,900 cfs to 140,000 cfs from 1927 to 1930. An oblique areal view of the Arkansas River at the mouth of Lee Creek near Van Buren shows innundation caused by the Arkansas River flood of May 1929, where the flow was measured at 301,000 cfs.

STAGES OF THE MISSISSIPPI RIVER AND TRIBUTARIES IN THE MEMPHIS DISTRICT, (year given for which the records are available), U.S. Army Engineer District, Memphis, Corps of Engineers.

STAGES AND DISCHARGES OF THE MISSISSIPPI RIVER AND TRIBUTARIES IN THE MEMPHIS DISTRICT, (year given for which the records are available), U.S. Army Engineer District, Memphis, Corps of Engineers.

STAGES AND DISCHARGES OF THE MISSISSIPPI RIVER AND TRIBUTARIES IN THE VICKSBURG DISTRICT, (year given for which the records are available), U.S. Army Engineer District, Vicksburg, Corps of Engineers.

OBSERVED AND DAILY DISCHARGE FOR THE RED AND OUACHITA RIVER BASINS IN THE VICKSBURG ENGINEER DISTRICT, (inclusive period given for which records are available), War Department, Corps of Engineers, U.S. Army Vicksburg, Mississippi.

STAGES AND DISCHARGES OF THE MISSISSIPPI RIVER AND TRIBUTARIES AND OTHER STREAMS AND WATERWAYS IN THE NEW ORLEANS DISTRICT (inclusive period given for which records are available), Corps of Engineers, U.S. Army, New Orleans District.

STAGES AND DISCHARGES FOR MISCELLANEOUS STATIONS, (inclusive period given for which records are available), U.S. Army Engineer District, New Orleans, Corps of Engineers.

RESULTS OF DISCHARGE OBSERVATIONS FOR MISCELLANEOUS STATIONS, (inclusive period given for which records are available), U.S. Army Engineer District, New Orleans, Corps of Engineers.

RIVER STAGES IN ARKANSAS, U.S. Weather Bureau, 1920, by H. S. Cole.

The first table in the report gives the low-water plane of the Arkansas River at Little Rock. The second table gives the names of the river stations and the streams on which they are located, information concerning river gages, and highest and lowest stages. A subsequent series of tables include mean monthly stages at each station, then a series giving the highest monthly and annual stages, one giving the lowest monthly and annual stages, and a table giving the number of days with navigable stages in the Arkansas River.

DIVISION OF FLOOD CONTROL AND SOIL CONSERVATION OF THE ARKANSAS RESOURCES AND DEVELOPMENT COMMISSION, ANNUAL REPORT, 1946, Arkansas Resources and Development Commission, January 2, 1947.

The stream-gaging program in 1946 was operated by the U.S. Geological Survey in cooperation with the Division of Flood Control and Soil Conservation and consisted of 47 stations with 23 additional stations proposed for installation. Completed projects, those under construction, and those proposed by the U.S. Army Engineers are included in the report. It is indicated that the Comprehensive Plan for Flood Control, Navigation, and Hydroelectric Development, at a cost of about $500 million, had received Congressional approval.

INDEX OF WATER-RESOURCES DATA FOR ARKANSAS, Arkansas Geological Commission Water Resources Summary Number 6, 1968, by L. D. Reid and B. W. Vines.

This index identifies all surface-water data-collection stations in Arkansas and shows graphically the periods for which streamflow, stage, reservoir contents, chemical quality, water temperature, and sediment load are available. Information collected by State and Federal agencies, including the U.S. Geological Survey, are included. Two lists, an alphabetical list of streams and reservoirs (p. 47-74) and an alphabetical list by cities and towns (p. 75-105) and a map (fig. 1) make it very easy to determine if information is available on a particular stream or near a given town in Arkansas.

STREAM GAGING IN ARKANSAS FROM 1857 TO 1928, Arkansas Geological Survey Arkansas Stream Gaging Report 1, 1930, by W. S. Frame.

This report was compiled to make available in convenient form all the information relating to the flow of streams in Arkansas that had been collected by 1928. The report also contains records of streamflow collected as a part of the first State-Federal cooperative program of water-resources studies in Arkansas that began in 1927. The program, arranged by the State Geologist, George C. Branner, and the Director of the U.S. Geological Survey, included operation of 19 gaging stations. Records, grouped into five drainage basins, (St. Francis, White, Arkansas, Ouachita, and Red Rivers) include discharge of the streams on a daily, monthly, and yearly basis, and runoff.

SURFACE-WATER RESOURCES OF ARKANSAS, Arkansas Resources and Development Commission, Division of Geology Bulletin No. 17, June 1950, by J. L. Saunders and G. A. Billingsley.

More than 800 station years of streamflow data at 67 gaging stations on Arkansas streams are covered in this report. Also included are results of chemical analyses of water samples collected at most of the gaging stations. Primarily, the report is a condensed statistical inventory with tables listing daily discharge, mean annual runoff, average discharge, maximum recorded discharge, information on major floods, and minimum mean discharge for a day, 7 days, calendar month, and water year.

INDEX TO RIVER SURVEYS MADE BY THE UNITED STATES GEOLOGICAL SURVEY AND OTHER AGENCIES, REVISED TO JULY 1, 1947, U.S. Geological Survey Water-Supply Paper 995, 1948, by B. E. Jones and R. O. Helland.

This report is a descriptive list of surveys of rivers in the United States. A river survey generally results in a map showing the river in plan and profile view and the adjacent topography sufficiently high above the water surface to include areas of proposed reservoir sites, possible canal or conduit locations, and other structures related to water utilization.

Descriptions of surveys of the White and Ouachita Rivers in Arkansas are given on pages 11 and 12 of the report.

ANNUAL REPORT OF THE STATE GEOLOGIST, THE MINERAL INDUSTRIES OF ARKANSAS IN 1942, Arkansas Geological Survey Bulletin 10, January 1, 1943, by R. J. Anderson.

A historical review of stream gaging in Arkansas, beginning with the first records collected in 1903, is covered in this report. The program in 1942 consisted of operation of 48 stations. Cooperative agreements for the fiscal year ending June 30, 1943, show that the Arkansas Highway Commission contributed $7,500; the Arkansas Flood Commission $1,500; and the Arkansas Geological Survey $250. These amounts were matched by equal allotments of Federal funds by the U.S. Geological Survey.

Other activities of the Arkansas Geological Survey are covered in the report.

ANNUAL ADMINISTRATIVE REPORT OF THE STATE GEOLOGIST, FROM DECEMBER 1, 1935, TO NOVEMBER 30, 1936, Arkansas Geological Survey, 1936, by G. C. Branner.

During the fiscal year 1935-36, 17 stream-gaging stations were maintained cooperatively by the U.S. Geological Survey, the Arkansas Geological Survey, and other interested agencies. The total cost of the program was approximately $7,500 per year, with the Arkansas Geological Survey contributing $800 per year.

Other work done by the Arkansas Geological Survey also is included in the report.

ANNUAL ADMINISTRATIVE REPORT OF THE STATE GEOLOGIST OF ARKANSAS, DECEMBER 1, 1926-December 1, 1927, Arkansas Geological Survey, February 17, 1928, by G. C. Branner.

"Stream gaging work has been undertaken as a cooperative measure. The cooperative funds of the Water Resources Branch of the U.S. Geological Survey, however, were available only to the extent of $500 at the time the request for them was made. In order to get the work started, the State Survey agreed to contribute $2,500 for this purpose. Up to the present time the Arkansas Power and Light Company has contributed $300 toward stream gaging work.* * *"

"Under the cooperative arrangement the installation of gaging stations, their reading and maintenance and the making of rating curves for each gaging station is in charge of Dr. H. C. Beckman, U.S. District Engineer, Rolla, Mo. He is assisted by Mr. V. L. Austin of the Water Resources Branch of the U.S. Geological Survey.* * *Fourteen stations were in operation and six new installations were recommended.* * *"

The report also covers other work accomplished by the Arkansas Geological Survey.

ARKANSAS STREAM GAGING REPORT II, STREAM GAGING IN ARKANSAS FROM 1929 TO 1930, Arkansas Geological Survey, 1930, by J. H. Gardiner.

INDEX OF SURFACE-WATER RECORDS TO SEPTEMBER 30, 1955, PART 7, Lower Mississippi River Basin, U.S. Geological Survey Circular 387, 1956, by J. S. Gatewood.

QUALITY OF SURFACE WATERS OF THE UNITED STATES, 1946, U.S. Geological Survey Water-Supply Paper 1050, 1950.

This volume is the sixth in a series of reports giving chemical analyses, concentrations, and loads of suspended sediment, and temperatures of the surface waters of the United States. This is the first volume that contains records for Arkansas. Descriptive statements are given for each sampling station for which regular series of chemical analyses or sediment determinations have been made. These statements include the location of the stream-sampling station, drainage area, length of time for which records are available, extremes of dissolved solids, total hardness, sediment discharge, water temperature, and other pertinent data. Records of water discharge of the streams for the sampling period are included in most tables of analyses.

Water-supply papers published since this report that contain records of the quality of surface waters in Arkansas are listed in the following table.

WSP Number	Year	WSP Number	Year
1102	1947	1644	1959
1133	1948	1744	1960
1163	1949	1884	1961
1188	1950	1944	1962
1199	1951	1950	1963
1252	1952	1957	1964
1292	1953	1964	1965
1352	1954	1994	1966
1402	1955	2014	1967
1452	1956	2096	1968
1522	1957	2146	1969
1573	1958		

WATER QUALITY RECORDS IN ARKANSAS, 1964, U.S. Geological Survey open-file report, 1961 (also, 1965 through 1970; however, 1965 through 1970 reports are titled WATER RESOURCES DATA FOR ARKANSAS, PART 2. WATER QUALITY RECORDS, followed by the year for which the records are appropriate).

The Geological Survey began publishing annual basic records of chemical quality, water temperatures, and suspended sediment in 1941 in the water-supply paper series QUALITY OF SURFACE WATERS OF THE UNITED STATES. Records for Arkansas were first published in this series in 1946 (WSP 1050) when records were being published in a single volume for the entire country. In 1948 and 1949 the records were published in two volumes and beginning in 1950 in four volumes. Since 1959 these records have been published in five volumes, each volume covering an area where boundaries coincide with those of natural-drainage areas. The records for Arkansas are contained in Parts 7 and 8 of the water-supply paper series.

This report marks the beginning of presenting annually, records of chemical quality of surface water in Arkansas. Each of the annual reports (1964 through 1970) contains a description of the location of the site for which the records are applicable (usually at a gaging station), the discharge of the stream at the time of collection of the quality record, the chemical content of the water for from 10 to 30 different constituents, and frequently, temperature, pH, specific conductance, color, and suspended sediment data.

The following is an example of the coverage to be expected. In the 1964 report, records are listed for 10 regular stations operated in the White, Arkansas, and Red River basins with most of the common inorganic constituents given generally on a monthly basis.

In addition, miscellaneous samples were collected at 62 locations on streams in the White and Red River basins and the results of these analyses are listed. Subsequent reports contain much greater coverage of Arkansas streams. For example, the 1964 report contains 49 pages and the 1970 report contains 153 pages. A large part of the increased coverage in later reports is because results of analyses of surface-water samples by other agencies also are published.

CHEMICAL COMPOSITION OF ARKANSAS SURFACE WATERS, 1949, University of Arkansas, Institute of Science and Technology, Fayetteville, Arkansas, U.S. Geological Survey, February 1951, by J. W. Guerin.

The U.S. Geological Survey in cooperation with the University of Arkansas began water-quality studies in Arkansas in 1945. This report contains the results of chemical analyses of surface waters for the period October 1, 1948, to September 30, 1949. Samples of water were collected daily at 12 stations and periodically at 53 stations during the year ending September 30, 1949.

The data tables generally include analyses for silica, iron, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, fluoride, nitrate, and dissolved solids. Results are given for 45 streams in Arkansas representing the White, Arkansas, Red, and St. Francis River basins.

SUMMARY OF ANNUAL RECORDS OF CHEMICAL QUALITY OF WATER OF THE ARKANSAS RIVER IN OKLAHOMA AND ARKANSAS, 1945-52, U.S. Geological Survey Circular 361, 1955, by T. B. Dover and J. W. Guerin.

"The Arkansas River is subject to many types of pollution downstream from the Oklahoma-Kansas State line, and its inferior quality together with its erratic flow pattern has caused it to be largely abandoned as a source of municipal and industrial water supply. Currently, the Arkansas River is not directly used as a source of public supply in any part of the basin in either Oklahoma or Arkansas.

"In general, the chemical concentration of the river water increases downstream from the Oklahoma-Kansas State line to Tulsa because of tributary inflow from the Salt Fork Arkansas River and the Cimarron River, both streams being sources of large amounts of natural salts and industrial wastes. A decrease in concentration of dissolved solids is noted downstream from Tulsa due to tributary inflow from the Verdigris, Neosho, and Illinois Rivers; another increase in concentration occurs with tributary inflow from the Canadian River, which is largely oilfield wastes. A progressive decrease in concentration is noted as the river flows through Arkansas to the Mississippi River, because all major tributaries below the Canadian River have a dilution effect upon the chemical concentration of the Arkansas River water.

"Proposals for storage and regulating reservoirs on the Arkansas River in both Oklahoma and Arkansas have been made by the Corps of Engineers and others. Additional proposals are being considered in the present Arkansas-White-Red River Basin Inter-Agency Sub-Committee studies. If constructed, these reservoirs will provide an opportunity for control of flow and beneficial use of Arkansas River water both at and downstream from these sites. Impoundment alone will greatly reduce the extremes in water quality, and by reasonable control of municipal and industrial wastes, the water at some points on the river should be comparable in quality to many existing municipal and industrial supplies in the basin."

CHEMICAL QUALITY OF SURFACE WATERS OF ARKANSAS, 1945-55— A SUMMARY, University of Arkansas, Engineering Experiment Station, Bulletin No. 25, July 1957, by J. W. Geurin and H. G. Jeffery.

During the period October 1945 to September 1955 daily samples of water were collected from the Arkansas, White, Ouachita, and Red Rivers at seven index stations. Daily samples also were collected at 33 short-term stations, principally on tributaries to the aforementioned rivers. In addition, samples were collected monthly at 16 locations and semiannually at 43 locations on streams in Arkansas. This report contains a summary of the results of chemical analyses of these samples.

The water of the St. Francis River in Arkansas is hard and has concentrations of dissolved solids averaging slightly more than 200 ppm.

The quality of water of the Arkansas River is influenced by many factors outside the State. All tributaries of the Arkansas in the State are low in mineral content but do not reduce appreciably the concentration of dissolved materials in the Arkansas because of the high concentration already present.

Waters in the upper White River basin are low in dissolved solids but are moderately hard. Impoundment of the waters in Bull Shoals Reservoir has not changed the chemical composition but has resulted in smaller day-to-day variations in the mineral content. Quality of the White River at Newport, Arkansas, is about the same as at Cotter, and the water becomes less mineralized from Newport to the mouth.

Tributaries of the main stem of the Red River in Arkansas are low in dissolved solids and have a diluting effect on water of the Red River. All tributaries of the Ouachita River upstream from Camden and the main stem of the Ouachita River as far downstream as Camden have waters low in dissolved materials. Downstream from Camden, a significant increase in concentration of dissolved solids of the Ouachita River is caused by inflow from Smackover Creek and Bayou Lapile.

CHEMICAL COMPOSITION OF ARKANSAS SURFACE WATERS, 1950, University of Arkansas, Institute of Science and Technology, Fayetteville, Arkansas, U.S. Geological Survey, July 1952, by J. W. Geurin.

This report contains the results of chemical analyses of samples of water which were collected from streams in Arkansas during the period October 1, 1949, through September 30, 1950.

Samples of water were collected for chemical analysis daily at 28 stations and periodically at 44 stations during the year ending September 30, 1950. Discharge records are included for those stations which are located at or near stream-gaging stations maintained by the U.S. Geological Survey and the U.S. Army Corps of Engineers.

The data tables generally include analyses for the common inorganic constituents, and measurements of temperature, color, pH, and specific conductance.

A STUDY OF THE CHEMICAL QUALITY OF STREAMFLOW IN ARKANSAS, U.S. Geological Survey open-file report, October 1971, by T. D. Steele.

"Historical records of streamflow, chemical quality for 16 Arkansas water-quality stations representing more than 102 station-years of data, and over 6,200 composite samples are analyzed graphically and statistically.* * *Preliminary simulation studies revealed that monthly mean values could be estimated to within 15-25 percent of actual determinations for an independent period of record or set of data. Annual mean concentration and loads for dominant ions estimated from the regression relationships seldom exceeded 15 percent in error relative to comparable values computed from actual data.* * *"

Other procedures in data analyses include examples for transferring information on streamflow chemical quality both in time and space, for assessing long-term trends in streamflow salinity, and for evaluating the tradeoffs between increased errors and reduction in frequency of sample collection.

WATER QUALITY STUDIES FOR ARKANSAS STREAMS, University of Arkansas, Engineering Experiment Station, Research Report Series No. 11, October 1967, by H. M. Jeffus, J. A. Proctor, and L. R. Heiple.

The report consists of a statistical treatment of water-quality data for Arkansas streams for a period of record from 1946 through 1961. Statistical measures of interest are coefficients of variation; arithmetic means and the standard deviation; and geometric means and geometric standard deviation.

From this analysis, correlations can be made between dissolved solids and specific conductance. The temperature of water in Arkansas streams can be estimated on the basis of percentage of time a certain temperature can be expected. Other uses of the derived relations include a means whereby the water quality in a reservoir can be controlled based on river discharge and at what discharge rate the water should be collected or bypassed.

The statistical data are arranged in tables by river basins in Arkansas. A glossary and computer programs for handling regressions and correlations are covered in sections near the end of the report.

RESERVOIR TEMPERATURES, YAZOO RIVER BASIN, MISSISSIPPI, AND OUACHITA RIVER BASIN, ARKANSAS, 1967, U.S. Army Engineer District, Vicksburg, Corps of Engineers, April 1967.

The water-temperature logs assembled in this report are supplementary material to the "Reservoir Water Quality Investigations" report published in March 1967 by the Corps of Engineers. The reservoirs in Arkansas included in the report are Blakely Mountain and Narrows.

The temperatures of water in Blakely Mountain Reservoir above the dam on the west side of the intake structure were as low as 7.0°C at depths from 16 through 25 metres on September 1, 1965, and as high as 30.0°C at depths from 1 to 2 metres on July 22, 1965. The temperatures of water in Narrows Reservoir above the dam on the west end of the trashrack deck were as low as 6.0°C at depths from 24 to 38 metres on February 18, 1966, and as high as 31°C at depths from 1 to 4 metres on July 15, 1965.

RESERVOIR TEMPERATURES, YAZOO RIVER BASIN, MISSISSIPPI AND OUACHITA RIVER BASIN, ARKANSAS, 1967, U.S. Army Engineer District, Vicksburg Corps of Engineers, March 1968.

The water-temperature logs assembled in this report are supplementary material to the "Reservoir Water Quality Investigations" report published in March 1968, by the Corps of Engineers. The reservoirs in Arkansas included in the report are Blakely Mountain and Narrows.

The temperatures of water in Blakely Mountain Reservoir above the dam on the west side of the intake structure were as low as 7.0°C at depths of 1 through 16 metres on January 20, 1967, and as high as 27.0°C at depths of 1 through 5 metres on August 21, 1967. The temperatures of water in Narrows Reservoir above the dam on the west end of the trashrack deck were as low as 6.0°C at depths from 35 to 38 metres on February 17, 1967, and as high as 29.0°C at depths from 1 to 5 metres on August 4, 1967.

GROUND-WATER TEMPERATURES IN THE COASTAL PLAIN OF ARKANSAS, Arkansas Geological and Conservation Commission Water Resources Summary Number 2, 1962, by R. O. Plebuch.

Ground-water temperatures and well depths (fig. 1) in deposits of Cretaceous age show the water temperatures range from 62° to 98°F with unusually high temperatures occurring near Hope, Ark.

Ground-water temperatures and well depths (fig. 2) in deposits of Tertiary age show the water temperatures depend primarily on well depth and range from 62° to 83°F.

Ground-water temperatures in deposits of Quaternary age shown in figure 3 range from 61° to 69°F and exceed the mean annual air temperature at a given location by 1° to 4°F.

ARKANSAS MUNICIPAL WATER SUPPLIES CHEMICAL DATA, Arkansas State Department of Health, Bureau of Environmental Engineering.

The chemical-quality data on public water supplies in Arkansas contained in this report are from analyses of water samples collected for the most part in 1969 and 1970. A lesser number of analyses also are reported for 1960 through 1968 and about 15 for 1971. Data for most of the inorganic constituents of water are tabulated with the results given in milligrams per liter for more than 300 public water supplies.

A report published in 1965, with the same title as above, by the Arkansas State Department of Health, contains chemical-quality data for 263 public-water supplies. Chemical-quality data on public-water supplies in Arkansas for earlier and succeeding years than those indicated above also are available in published form from the Arkansas State Department of Health.

CHEMICAL ANALYSES OF THE WATER FROM SELECTED WELLS IN THE ARKANSAS RIVER VALLEY FROM THE MOUTH TO FORT SMITH, ARKANSAS, U.S. Geological Survey open-file report, June 1964, by J. R. May, J. J. Yanchosek, and H. G. Jeffery.

This basic-data report is a tabulation of the results of chemical analyses of ground-water samples collected from wells in the alluvium along the Arkansas River during the period 1949-1960. More than 1,600 analyses are given from samples collected in 16 counties.

CITY WATER SUPPLIES OF ARKANSAS, University of Arkansas, Engineering Experiment Station, Fayetteville, Arkansas, Bulletin No. 2, Volume 20, Number 18, November 1926, by Harrison Hale.

Principally this report is the "basic-data type," inasmuch as the information presented is a listing of the results of chemical and bacteriological analyses of water samples from 82 city water supplies in Arkansas. A brief description of the water system for each town generally includes the town population, source of the water, amount of water used, type of water treatment, and water rates.

More than 65 percent of the cities utilized ground water, about 25 percent utilized surface water from rivers or lakes, and the rest obtained their water from springs. The two largest cities in the State, Little Rock and Fort Smith, used surface water. Little Rock reportedly pumped almost 2 billion gallons of water from the Arkansas River in 1924 and the average daily pumpage for Fort Smith from the Poteau River was reported as 206,902 gallons for a yearly total of 1,394,348,900 gallons.

The chloride, iron-aluminum, and total dissolved solids concentration of the waters analyzed showed great variation. Chloride ranged from 1.82 ppm at Rector, Arkansas, to 405.48 ppm at Bauxite, with Hope, Little Rock, Morrilton, and Prescott also exceeding the 1925 official limit of 250 ppm. The iron-aluminum concentration ranged from a low of 0.45 ppm at El Dorado to a high of 20.5 ppm at Bauxite followed by 11.8 ppm at Springdale. Total dissolved solids (the 1925 limit was 1,000 ppm) ranged from 40 ppm at Mena and Hot Springs to 1,313.75 ppm at Morrilton followed by 1,032.50 ppm for Hope, and 1,018.5 ppm for Prescott. Eighteen towns had less than 100 ppm total dissolved solids in their water supplies, an unusually low amount.

In general the analyses showed that Arkansas city water supplies are reasonably satisfactory and most are exceptionally good with a relatively low mineral content.

PUBLIC WATER SUPPLIES OF ARKANSAS, University of Arkansas, Bureau of Research, Research Series No. 11, June 30, 1947, by Harrison Hale, R. C. Baker, I. W. Walling, D. M. Parrish, and G. A. Billingsley.

This report is the basic-data type, listing analyses of water samples for 178 public water supplies in Arkansas.

"In general, the quality of Arkansas' water is good; in many cases very good. Hardness ranges from one to 704 parts per million, but averages 94 parts per million for all public supplies analyzed. Of the 178 supplies tested, 45 percent had a hardness of below 50 parts per million and 58 percent less than 100. Based on volume of water actually used, the hardness is lower than the above figures suggest, for, in general, the larger cities have the softer supplies. Little Rock, Fort Smith, and Hot Springs have hardness of 26, 38, and 42, respectively. The improvement in the quality of water supplies of Little Rock and Fort Smith occurred when these cities changed from river supplies to impounded reservoirs about 10 years ago. This change in hardness does not mean that all Arkansas streams contain hard water; analyses of most public supplies obtained from streams reveal that the water is soft."

ANNUAL REPORT OF THE GEOLOGICAL SURVEY OF ARKANSAS FOR 1891, THE MINERAL WATERS OF ARKANSAS, Volume I, 1892, by J. C. Branner.

For the most part, the report contains the results of chemical analyses of water from springs in Arkansas. An interesting analysis of sediment in Arkansas River water collected in 1888 is given on page 24 of the report, and chemical quality of the Arkansas River at high and low stage is given on succeeding pages. Chapter V deals with what is called sanitary water analysis and includes data on Little Rock's water supply drawn from wells.

Some of the earliest information on the chemical quality of waters from the hot spring at Hot Springs, Arkansas, are found in Chapter II. The heat source is suggested to be underlying Silurian rocks. Most of the results are given in terms common to the time--that is, in grains per gallon.

FLUORIDE CONTENT OF GROUND WATER IN THE COTERMINOUS UNITED STATES, U.S. Geological Survey Miscellaneous Geological Investigations Map I-387, 1962, by Michael Fleischer.

According to the map, the fluoride concentration of ground water in Arkansas is from 0 to 1.5 ppm or higher. Clark, Hempstead, Nevada, and Drew Counties are indicated as having the higher values. Twelve counties are shown as having no data on fluoride concentration available, and 59 counties are shown as having fluoride concentrations ranging from 0 to 1.4 ppm.

DRAINAGE AREA DATA, ARKANSAS WHITE AND RED RIVER BASINS, Corps of Engineers, U.S. Army, Arkansas-White-Red Office, Tulsa, Oklahoma, November 1954.

This report is a compilation of drainage areas for the Arkansas, White, and Red River basins. Procedures used in delineations of watershed boundaries and the breakdown and determination of drainage areas are given. River mileages are also a part of the compilations.

The Arkansas River is shown as heading on East Fork in Colorado near Leadville, 1,459.2 river miles upstream from the mouth. The total drainage area of the main stem is listed as 160,645 square miles. The White River is shown as heading on West Fork, 684.6 river miles upstream from the mouth, with a main-stem total drainage area of 27,765 square miles.

The Red River is listed as heading on Tierra Blance Creek near Hereford, Texas, 1,222 river miles upstream from the mouth with a total main-stem drainage area of 93,450 square miles.

DRAINAGE AREAS OF STREAMS IN ARKANSAS, ST. FRANCIS RIVER BASIN, U.S. Geological Survey open-file report, 1967, by R. C. Christensen, R. C. Gilstrap, and J. N. Sullavan.

The St. Francis River drains 1,700 square miles at the Missouri-Arkansas State line and 8,416 square miles at its mouth. The principal tributaries of the St. Francis and their drainage areas are Little River, 2,590 square miles; Tyronza River, 561 square miles; and the L'Anguille River, 938 square miles.

DRAINAGE AREAS OF STREAMS IN ARKANSAS, ARKANSAS RIVER BASIN, U.S. Geological Survey open-file report, 1970, by J. N. Sullavan and J. E. Terry.

The drainage area of a stream is one of the most significant parameters used in computations for the design of hydraulic structures or in hydrologic investigations of river basins. This report lists the drainage area of the Arkansas River and tributaries in downstream order, starting at the Arkansas-Missouri State line with Lime Kiln Hollow Creek whose flow eventually reaches the Arkansas River. The drainage area of the Arkansas River at its mouth is 160,576 square miles.

Principal tributaries of the Arkansas River in Arkansas and their drainage areas are Frog Bayou, 267 square miles; Mulberry River, 511 square miles; Six Mile Creek (through diversion channel), 274 square miles; Big Piney Creek, 537 square miles; Illinois Bayou, 391 square miles; Petit Jean River, 1,083 square miles; Point Remove Creek, 530 square miles; Cadron Creek, 753 square miles; Fourche La Fave River, 1,116 square miles; Little Bayou Meto, 430 square miles; and Bayou Meto, 998 square miles.

DRAINAGE AREAS OF STREAMS IN ARKANSAS, WHITE RIVER BASIN, U.S. Geological Survey open-file report, 1974, by J. N. Sullavan.

The total drainage area of the White River is 27,818 square miles (72,049 sq km). The elevation at the source of the White River is about 2,050 feet (625 m) above mean sea level and the low-water elevation at the mouth is about 107 feet (32.6 m) above mean sea level. Principal tributaries of the White River are the Kings, Black, Little Red, and Cache Rivers, and LaGrue Bayou.

ELEVATIONS IN ARKANSAS, Arkansas Geological Survey Information Circular 6, Volumes 1 through 9, 1936.

Information Circular 6 contains 14,421 elevations at various locations in Arkansas. A special effort was made to include the elevation of all towns, community centers, and mountains. For convenience in publication and use, Information Circular 6 has been divided into nine volumes, each of which contains elevations for a group of counties, with all 75 counties covered.

LEVELING IN ARKANSAS, U.S. Coast and Geodetic Survey Special Publication Number 188, 1934, by H. S. Rappleye.

"This publication contains the descriptions and elevations of bench marks in the State of Arkansas, the elevations of which have been determined by first- or second-order leveling executed by the Coast and Geodetic Survey. Other lines have been included, the elevations of which were determined by first-order leveling run by the Corps of Engineers, United States Army.

Approximately 2,000 miles of first-order leveling and 550 miles of second-order leveling have been run within the limits of this State."

Field 8--ENGINEERING WORKS

Group 8A--Design, construction, and operation

WATER POWERS OF ARKANSAS, A PRELIMINARY REPORT ON WHITE RIVER AND SOME OF ITS TRIBUTARIES.

For primary bibliographic entry see 6D.

REPORT TO WAR DEPARTMENT ON DEVELOPMENT OF THE OUACHITA RIVER AND TRIBUTARIES IN ARKANSAS, U.S. Corps of Army Engineers, Vicksburg District, April 10, 1939.

The total losses accounted for in the flood plains of the Ouachita and tributaries downstream from Remmel Dam are estimated to be $231,000 annually. If flood protection of these lands should be provided, the net appreciation would be $4,472,130.

It is estimated that by 1943 there will be 78,521 electric utility customers in the State, and total power requirements in that year will be approximately 1,000,000,000 kilowatt hours. Unless Blakely Mountain dam is constructed, 700,000,000 kilowatt hours of power will be imported annually by 1943.

A map of the Ouachita River basin shows that 32 cities utilized wells to develop a public water supply, 6 utilized water from streams, and 1 utilized a spring. According to a map showing ground-water provinces, in the southeastern end of the Ouachita River basin abundant supplies of ground water are obtainable from shallow wells, whereas, in the northwestern part, ground-water supplies are very limited.

WATER RESOURCES DEVELOPMENT BY THE CORPS OF ENGINEERS IN ARKANSAS, Mississippi River Commission and Lower Mississippi Valley Division, January 1953.

Work in Arkansas by the Memphis, New Orleans, Tulsa, and Little Rock Districts in Arkansas includes construction of navigation projects and flood control projects, as well as emergency flood control activities such as levee repairs, snagging and clearing, and emergency bank protection.

The report includes descriptions of projects completed and those authorized. Examples of completed projects are Blue Mountain Dam in Yell County, Arkansas, or the Petit Jean River. The dam is an earthfill structure about 2,800 feet long and 115 feet high. The reservoir provides storage capacity for about 258,000 acre-feet of water, covers an area of about 11,000 acres, and has a shoreline of about 89 miles. The estimated cost of the project is $4,775,000. Benefits that have accrued to the project through June 1952 amount to $2,313,200. An example of an authorized project is DeGray Dam on the Caddo River, near Arkadelphia, Arkansas. This dam will be an earthfill structure 9,700 feet long and 216 feet high. The project is estimated to cost $25,495,000 and total annual estimated benefits are $728,000.

WATER RESOURCES DEVELOPMENT BY THE U.S. ARMY CORPS OF ENGINEERS IN ARKANSAS, U.S. Army Engineer Division, Lower Mississippi Valley, Corps of Engineers, Vicksburg, Mississippi, January 1, 1959.

"Water resources development by the U.S. Army Corps of Engineers in the State of Arkansas includes the investigations and development of its rivers and waterways for the control of floods, hydroelectric power, navigation, drainage, irrigation, and for other uses, all as authorized and directed by the Congress of the United States, and as funds are appropriated for the work.* * *"

"The water resources development program for the State of Arkansas is extensive in scope and effect. While all of the authorized projects are not complete, many are sufficiently well advanced as to be partially effective. The further progress of construction on projects now authorized, and the planning and construction of future civil work projects will proceed in accordance with Congressionsl appropriations, authorizations, and directives."

WATER RESOURCES DEVELOPMENT IN ARKANSAS BY THE U.S. ARMY CORPS OF ENGINEERS, U.S. Army Engineer Division, Lower Mississippi Valley, Corps of Engineers, Vicksburg, Mississippi, 1965.

Corps of Engineers flood control, navigation, and multiple-purpose projects completed and authorized in Arkansas are covered in detail. Project locations, costs, and specifications of structures and equipment are listed. The type of information given in this report may be seen in the following example: "Blakely Mountain Dam, which forms Lake Ouachita, is located on the Ouachita River at the upstream end of Lake Hamilton and about 10 miles northwest of Hot Springs in Garland County, Arkansas. It is a compacted earthfill dam, 1,100 feet long and 231 feet above the stream bed. The exterior of the dam is covered with a blanket of riprap to prevent wavewash and erosion. Two penstocks, each 16 feet in diameter, deliver water to the two 37,500-kilowatt generating units installed in the power plant.

"The reservoir has a storage capacity of 2,768,000 acre-feet of which 617,000 acre-feet are for control of downstream floods, 1,286,000 acre-feet are for generation of power, and 865,000 acre-feet are in the minimum permanent pool. The dam controls the runoff from 1,105 square miles of drainage area. At full power pool, the lake covers an area of 40,000 acres and has a 690-mile shore line in Garland and Montgomery Counties.* * *"

"Power generation began in August 1955. Gross power produced through June 1964 was 1,315,550,000-kilowatt hours. Power from this project is marketed by the Southwestern Power Administration, Department of the Interior.* * *"

"Operations for flood control began in the spring of 1953. Flood damages prevented by the operation of this project are estimated at $3,192,000.* * *"

"The reservoir provides excellent recreation. Public-use development and land management for the reservoir area are proceeding in accordance with a comprehensive master plan prepared in cooperation with agencies of the Department of the Interior and the Department of Agriculture, as well as state agencies. Fish and wildlife resources are being conserved and developed under the management of the Arkansas State Game and Fish Commission. During 1963 there were 1,418,000 visitors to the reservoir.

"Federal costs through June 1964 were $33,865,147 of which $31,248,927 was for construction and $2,616,220 was for operation and maintenance.* * *"

NORFORK DAM AND RESERVOIR PROJECT, NORTH FORK RIVER, WHITE RIVER WATERSHED, War Department, Corps of Engineers, U.S. Army, Little Rock Engineer District, December 1940.

This report provides a detailed description of Norfork Dam and Reservoir. The concrete structure is 2,624 feet long along the crest and the top of the dam is 220 feet above the stream bed. Total storage in the reservoir is 1,983,000 acre-feet. The reservoir will be operated for flood control and hydroelectric power generation.

BLUE MOUNTAIN DAM AND RESERVOIR PROJECT PETIT JEAN RIVER, ARKANSAS RIVER WATERSHED, War Department, Corps of Engineers, U.S. Army, Little Rock District, April 1940.

This report provides a detailed description of Blue Mountain Dam and Reservoir. The earth embankment structure is 600 feet long at the base and the top is 115 feet above the stream bed. Total storage in the reservoir is 258,000 acre-feet. Blue Mountain Reservoir is operated for flood-control purposes.

NIMROD DAM AND RESERVOIR PROJECT, FOURCHE LA FAVE RIVER, ARKANSAS RIVER WATERSHED, War Department, Corps of Engineers, U.S. Army Little Rock Engineer District, February 1940.

This report provides a detailed description of Nimrod Dam and Reservoir. The length of the concrete dam is given as 986 feet along the axis and the top is 97 feet above the streambed. Total storage is 335,000 acre-feet. The purpose of the dam is for flood control and it will provide immediate protection to the lowlands downstream from the site.

PRELIMINARY ENGINEERING REPORT, WATER SUPPLY, TREATMENT, AND DISTRIBUTION, WYNNE, ARKANSAS, Marion L. Crist and Associates, Incorporated, Little Rock, Arkansas, February 1962.

Detailed studies of the best plan for increasing the available supply of soft, iron-free water indicate that a new well water supply, not to exceed 2 miles south of the southern limits of Wynne is considerably cheaper than the plan of expanding existing treatment facilities and the present well supply. The two present city wells are 800 and 400 feet deep, the deep well yielding 912 gpm and the other 290 gpm.

Field 9--MANPOWER, GRANTS, AND FACILITIES

Group 9A--Education--extramural

No entries.

Group 9B--Education--in-house

No entries.

Group 9C--Research facilities

ANNUAL REPORT OF THE ARKANSAS WATER RESOURCES RESEARCH CENTER FOR FY 1969.

For primary bibliographic entry see 10.

ANNUAL REPORT OF THE ARKANSAS WATER RESOURCES RESEARCH CENTER FOR FY 1970.

For primary bibliographic entry see 10.

ANNUAL REPORT OF THE ARKANSAS WATER RESOURCES RESEARCH CENTER FOR FY 1972.

For primary bibliographic entry see 10.

Group 9D--Grants, contracts, and research act allotments

No entries.

Field 10--SCIENTIFIC AND TECHNICAL INFORMATION

PAPERS ON THE CONSERVATION OF WATER RESOURCES, U.S. Geological Survey Water-supply Paper 234, 1909.

This volume is a reprint of selected papers on the conservation of water resources written by members of the U.S. Geological Survey. The papers constitute a summation of work that had been in progress for more than 20 years. The titles and authors of the papers are as follows.

"Distribution of Rainfall," by Henry Garnett
"Floods," by M. O. Leighton
"Developed Water Powers," compiled under the direction of W. M. Steuart *with discussion by* M. O. Leighton
"Undeveloped Water Powers," by M. O. Leighton
"Irrigation," by F. H. Newell
"Underground Waters," by W. C. Mendenhall
"Denudation," by R. B. Dole and H. Stabler
"Control of Catchment Areas," by H. N. Parker

Most of the papers deal with water resources nationwide, with reference to particular parts of the United States to establish or demonstrate a point. For example M. O. Leighton, in the paper "Floods," utilizes flood data from several rivers in the United States to conclude that the increase in flood tendency in the United States is unmistakable due in by far the largest measure to the denudation of forest areas. (See page 21 of WSP 234.)

Arkansas is shown to have 255 "wheels" developing 5,868 horsepower in table 1 (p. 32) in the paper on "Developed Water Powers." Estimates of streamflow and potential maximum development of horsepower from hydroelectric plants in Arkansas are included in a table on page 54 of the report for western tributaries of the lower Mississippi River.

The paper titled "Denudation" deals with the subject of the rate at which the Earth's crust is being moved as solid particles carried by streams and as matter carried in aqueous solution. Methods of computation and probable accuracy are covered. The estimates for removal reveal that the surface of the United States is being removed at the rate of thirteen ten-thousandths of an inch per year, or 1 inch in 760 years. The amount seems trivial until this total is resolved into units such as 783 million tons per year. As the report states, "if this erosive action had been concentrated upon the Isthmus of Panama* * * it would have excavated the prism for an 85-foot level canal in about 73 days."

A table on page 89 shows estimates of denudation for the Arkansas River basin to be 1 inch every 740 years and for the Arkansas River at Little Rock, the denudation is estimated to be 267 tons per square mile per year.

ANNUAL ADMINISTRATIVE REPORT OF THE STATE GEOLOGIST, FROM DECEMBER 1, 1927 TO DECEMBER 1, 1928, Arkansas Geological Survey, January 1929, by G. C. Branner.

As a result of a request made in April 1927, by Senator T. C. Caraway, for a study of ground-water conditions in the rice-growing district of eastern Arkansas, the U.S. Geological Survey and the Arkansas Geological Survey agreed to cooperate in such a study. The fieldwork is being done by D. G. Thompson and D. W. Weber of the U.S. Geological Survey. Thompson spent 4 months in the summer of 1928 collecting data in the rice fields and will continue the work in 1929.

A detailed geological map of the State of Arkansas on a scale of 1:200,000 or about 8 miles to the inch is in publication. The final editing of the proof of the map has been supervised by Mr. Hugh D. Miser and Mr. George W. Stose, both of the U.S. Geological Survey. The map is the result of about 3 years of work in compiling published and unpublished geological information. This map was drawn by Pearle L. Blackman of the Arkansas Geological Survey. No other detailed large-scale geological map of Arkansas has ever been published.

The cooperative Federal-State stream-gaging work, which was begun in July 1927, will be continued through the fiscal year 1928-29. The work was under Henry C. Beckman and W. S. Frame, both of the U.S. Geological Survey. A total of 15 stations were in operation.

Other work undertaken by the Arkansas Geological Survey also is covered in the report.

ANNUAL ADMINISTRATIVE REPORT OF THE STATE GEOLOGIST, FROM DECEMBER 1, 1937, TO NOVEMBER 30, 1938, Arkansas Geological Survey, 1938, by G. C. Branner.

According to this report the collection and classification of data on springs in Arkansas were completed by W. P. A. personnel. The manuscript, ready for publication, contains data on 305 springs and the publication will contain 100 pages and 20 plates.

A manuscript on lakes also has been compiled. The report contains descriptive data on 487 lakes in Arkansas.

Approximately 2,178 wells are indexed and logs for 400 wells and analyses for 100 water samples are on file by counties. At the close of the fiscal year ending June 30, 1937, 17 stream-gaging stations were being operated under the supervision of the U.S. Geological Survey. Of these 17 stations, 7 were financed by Federal funds, 5 were operated by the Federal Power Commission, and the remaining 5 were maintained in cooperation with the State of Arkansas. At the close of the fiscal year ending June 30, 1938, 32 stations were being operated by the Fort Smith office of the U.S. Geological Survey. An additional 18 stations were recommended for installation. Progress on other activities of the Arkansas Geological Commission also are covered in the report.

ANNUAL ADMINISTRATIVE REPORT OF THE STATE GEOLOGIST, FROM DECEMBER 1, 1931, TO NOVEMBER 30, 1932, Arkansas Geological Survey, 1932, by G. C. Branner.

Included in this report is a brief description of work and progress on a study of the ground water in the rice-growing area of eastern Arkansas. The fieldwork was begun in 1928 by David G. Thompson. The purpose of the study is to determine whether the natural recharge of the ground water is sufficient to offset the amount of water removed for rice irrigation.

Porosities of sandstones in western and northern Arkansas were determined for 194 samples. The object of this study was to determine in what part of the area sandstones may be expected to serve as reservoirs for natural gas.

Arkansas is organized as part of District 7 of the Water Resources Branch of the U.S. Geological Survey. Under the supervision of John H. Gardner, 15 gaging stations were operated, 12 of which are in Arkansas.

The report also covers other activities of the Arkansas Geological Survey.

ARKANSAS MOVES FORWARD, ANNUAL REPORT FOR 1947, Arkansas Resources and Development Commission, March 2, 1948.

Activities of the Division of Geology are described on pages 25 through 36 for 1947. In these activities, the report on "Ground Water Possibilities of Pulaski and Jefferson County" is mentioned. The stream-gaging program in Arkansas, maintained by the U.S. Geological Survey in cooperation with the Arkansas Division of Flood Control, Water, and Soil Conservation is covered on page 69 of the report and shows that 64 stations were in operation.

DEFINITIONS OF SELECTED GROUND-WATER TERMS--REVISIONS AND CONCEPTUAL REFINEMENTS, U.S. Geological Survey Water-Supply Paper 1988, 1972, by S. W. Lohman and others.

For many years there has been a need for more precise definition of ground-water terms used in publications by members of the U.S. Geological Survey. Another problem has been the expression of the coefficient of permeability (defined in this report as hydraulic conductivity) and the coefficient of transmissibility (defined in this report as transmissivity) in inconsistent units that included the U.S. gallon, the foot, and in some expressions, the mile. To meet the need for redefinition of terms an ad hoc committee comprised of U.S. Geological Survey members was formed. This report contains the definitions and recommendations of this committee and the terms are now standard for reports of the Geological Survey.

GLOSSARY OF SELECTED TERMS USEFUL IN STUDIES OF THE MECHANICS OF AQUIFER SYSTEMS AND LAND SUBSIDENCE DUE TO FLUID WITHDRAWAL U.S. Geological Survey Water-Supply Paper 2025, 1972, by J. F. Poland, B. E. Lofgren, and F. S. Riley.

"The geologic and engineering literature contains a variety of terms that have been used to describe the processes and environmental conditions involved in the mechanics of stressed aquifer systems and of land subsidence due to withdrawal of subsurface fluids. The usage of certain of these terms in reports by the U.S. Geological Survey research staff investigating mechanics of aquifer systems and land subsidence is defined and explained in this glossary. Several terms that have developed as a result of the Survey's investigations are also defined."

OUTLINE OF GROUND-WATER HYDROLOGY, WITH DEFINITIONS, U.S. Geological Survey Water-Supply Paper 494, 1923, by O. E. Meinzer.

GENERAL INTRODUCTION AND HYDROLOGIC DEFINITIONS, U.S. Geological Survey Water-Supply Paper 1541-A, 1960, by W. B. Langbein and K. T. Iseri.

WHAT ABOUT WATER? A Staff Survey of Current Research on Water Resources and Utilization, Committee on Science and Astronautics, U.S. House of Representatives, 92d Congress, 2d Session, 1972, 59 pages.

THE DEVELOPMENT OF THE SCIENCE OF HYDROLOGY, Texas Water Commission, Circular Number 63-03, April 1963, Reprinted 1963, by P. B. Jones, G. D. Walker, R. W. Herden, and L. L. McDaniels.

THE DATA OF GEOCHEMISTRY, U.S. Geological Survey Bulletin 770, 1924, by F. W. Clarke.

THE MISSISSIPPI EMBAYMENT STUDY, Southwest Water Works Journal, Volume 42, Number 7, October 1960, pages 58-61, by E. M. Cushing.

SYMPOSIUM OF THE RED RIVER COMPACT COMMISSION--FOUR PARTS, Southwest Water Works Journal, Volume 42, Number 11, February 1961, pages 19-26, Section on pollution control by Leonard White.

GUIDEBOOK TO HYDROLOGY AND GEOLOGY OF THE ARKANSAS RIVER VALLEY AND ADJACENT AREAS, ARKANSAS, mimeographed report, U.S. Geological Survey and Arkansas Geological Commission, January 1966, by M. S. Bedinger, C. G. Stone, D. R. Albin, M. S. Hines, and J. H. Hubble.

The road log of a field trip starting at the Federal Building in Little Rock covers a round-trip distance of 225 miles. The trip proceeds west on State Highway 10 past Lake Maumelle to State Highway 113, along 113 to State Highway 154, along 154 to the Winthrop Rockefeller Farm and back to 154, going west to State Highway 155.

Stops along State Highway 155 include Holla Bend National Wildlife Refuge, where a cutoff meander of the Arkansas River can be seen along with excellent examples of point-bar deposits.

A lunch stop was made near Dardanelle, Ark. A tour was then made through Dardanelle Dam on the Arkansas River followed by a side trip to Mount Nebo State Park.

From Mount Nebo the field trip proceeds southward along State Highway 7 through Centerville, Ark., to State Highway 60 and thence to the Perryville-Fourche La Fave syncline near Nimrod, Ark. Additional stops along State Highway 10 on the return trip include an exposure of the Brazil Branch Breccia and the Stanley Shale.

The guidebook also contains a synopsis of the geology of the eastern frontal Ouachita Mountains. The water resources of the area covered by the field trip are discussed in sections on the alluvial geology, the consolidated rocks of the Ouachita Province, streamflow, and water quality.

ANNUAL REPORT OF THE ARKANSAS WATER RESOURCES RESEARCH CENTER FOR FY 1969, University of Arkansas, July 1969, by A. E. Harvey.

ANNUAL REPORT OF THE ARKANSAS WATER RESOURCES RESEARCH CENTER FOR FY 1970, University of Arkansas, July 1970, by A. E. Harvey.

ANNUAL REPORT OF THE ARKANSAS WATER RESOURCES RESEARCH CENTER FOR FY 1972, University of Arkansas, July 1972, by R. E. Babcock.

The proceedings of the annual Arkansas Water and Sewage Conferences generally contain a wide range of papers, many of which are related to water treatment, distribution, metering, sewage treatment, and subjects pertaining to public water supplies, distribution and sewage facilities. Only those papers dealing more with the occurrence, nature, and management of water resources are listed in the following.

FOURTEENTH ANNUAL ARKANSAS WATER AND SEWAGE CONFERENCE PROCEEDINGS, State Board of Health, April 17, 18, 1944.

"How to Reduce Power Bills for Water Pumping," by M. L. Crist.
"Interpretation of Water Analysis," by W. A. Mahon.
"Development of Wells and Other Ground Water Problems," by C. M. McCord.
"Discussion of Corrosion in Hot Water Systems," by W. A. Mayhan.

FIFTEENTH ANNUAL ARKANSAS WATER AND SEWAGE CONFERENCE PROCEEDINGS, State Board of Health, April 15-17, 1946.

"The Work of the United States Geological Survey in Regard to Quality of Water Work in Arkansas," by I. W. Walling.
"Discussion of the Work of the United States Geological Survey in Regard to Quality of Water Work in Arkansas," by W. W. Hastings
"Arkansas' Water Resources," by Harrison Hale.
"Ground Water of South-Central Arkansas," by E. A. Hewitt.
"Discussion of Ground Water of South-Central Arkansas," by R. C. Baker.

SIXTEENTH ANNUAL ARKANSAS WATER AND SEWAGE CONFERENCE PROCEEDINGS, State Board of Health, April 14-16, 1947.

"pH, Total Alkalinity, Soap-Hardness, Chlorine Residual,--What Are They and How Can They Be Useful in Operating a Water Plant?", by G. F. Bell.

SEVENTEENTH ANNUAL ARKANSAS WATER AND SEWAGE CONFERENCE PROCEEDINGS, State Board of Health, April 12-14, 1948.

"Sewage Disposal in Arkansas," by M. L. Crist.

TWENTIETH ANNUAL ARKANSAS WATER AND SEWAGE CONFERENCE AND SHORT COURSE, State Board of Health, April 9-11, 1951.

"Ground-Water Conditions in Arkansas," by H. B. Counts.

TWENTY-THIRD ANNUAL ARKANSAS WATER AND SEWAGE CONFERENCE AND SHORT COURSE, State Board of Health, April 22-24, 1954.

"Artificial Underground Recharge With Vertical Wells Utilizing Excess Water," by R. M. King.

TWENTY-FIFTH ANNUAL ARKANSAS WATER AND SEWAGE CONFERENCE AND SHORT COURSE, State Board of Health, March 19-21, 1956.

"Artificial-Recharge Experiments in the Grand Prairie Region of Arkansas," by R. T. Sniegocki and J. W. Geurin.

TWENTY-SIXTH ANNUAL ARKANSAS WATER AND SEWAGE CONFERENCE AND SHORT COURSE, State Board of Health, March 18-20, 1957.

"Preliminary Well Surveys (General)," by K. E. Moehrl
"Preliminary Well Surveys (in Arkansas)," by R. M. King
"Chemical Character and Use of Ground Water in Arkansas," by M. E. Schroeder and R. T. Sniegocki.

THIRTIETH ANNUAL ARKANSAS WATER AND SEWAGE CONFERENCE AND 13TH SHORT SCHOOL PROCEEDINGS, State Board of Health, March 20-22, 1961.

"Water-Bearing Formations in the Coastal Plain of Arkansas," by R. L. Hosman.

THIRTY-FOURTH ARKANSAS WATER WORKS AND POLLUTION CONTROL CONFERENCE AND 17TH SHORT SCHOOL PROCEEDINGS, State Board of Health, March 15-17, 1965.

"Clean Water--Its Our Business," by A. J. Steffey.

ARKANSAS WESTERN GAS COMPANY, ANNUAL REPORT, 1968.

This summary of operations includes a discussion of gas storage near Harrison, Ark. An aquifer had been in use for gas storage for a number of years. In 1968 an extensive exploratory program was begun to try to locate the gas. No indication of gas leakage from the ground was observed. The gas was valued at $330,000.

SUBSURFACE GEOLOGY AND RELATED OIL AND GAS POSSIBILITIES OF NORTHEASTERN ARKANSAS, Arkansas Resources and Development Commission Bulletin 20, 1954, by W. M. Caplan.

This detailed treatise on the structure and stratigraphy of northeastern Arkansas deals largely with Paleozoic and Cretaceous rocks and oil and gas possiblilties.

The Paleozoic rocks are of interest as far as ground water is concerned because they lie at a progressively shallower depth as the Fall Line is approached from east to west and the overlying aquifers thin and pinch out. Cretaceous rocks are not extensively developed for ground water in northeast Arkansas but have potential for yielding good-quality water. A series of maps such as one showing contour lines on top of the Paleozoic rocks and thicknesses of Cretaceous rocks are particularly useful in determining possibilities for obtaining ground water and drilling depths.

LOWER CRETACEOUS AND JURASSIC FORMATIONS OF SOUTHERN ARKANSAS AND THEIR OIL AND GAS POSSIBILITIES, Arkansas Geological Survey Information Circular 12, 1940, Reprinted 1949, by R. W. Imlay.

"Deep drilling in southern Arkansas and adjacent States since 1935 has shown that the Upper Cretaceous system is underlain by thousands of feet of Lower Cretaceous and older Mesozoic rocks that are sources of petroleum.* * *"

"The Lower Cretaceous rocks of southern Arkansas range in thickness from about 600 feet at the outcrop in Sevier, Howard, and Pike Counties to over 5,500 feet subsurface in the southwestern corner of the State. These Lower Cretaceous rocks are underlain by Mesozoic (Jurassic) rocks which do not outcrop anywhere in the Gulf region.* * *"

"Extensive revision of current ideas concerning the geological history of the Gulf Coastal region during the Mesozoic era has been made herein."

OIL AND GAS GEOLOGY OF THE GULF COASTAL PLAIN IN ARKANSAS, Arkansas Geological Survey Bulletin 2, 1935, by W. C. Spooner.

This treatise covers 27,370 square miles in the southwestern and eastern parts of Arkansas and is made up of three parts. Part one provides a detailed description of stratigraphy and structure of the area. Part two describes the stratigraphy, structure, and general characteristics of each oil and gas field in Arkansas. Part three is a county-by-county description of casement rocks, stratigraphy, and structure, and includes a list of wells drilled in each county.

Water conditions in each of the well fields are described and generally include an analysis of the water that is withdrawn as the oil is withdrawn.

GENERAL BEDROCK FOUNDATION MAP OF GREATER LITTLE ROCK AREA, Arkansas Geological Commission, April 1972, by C. G. Stone.

This interpretive map, based on current (1972) knowledge of the bedrock geology of the area, shows the areal extent of the various geologic formations and describes their character with respect to suitability for foundation use. The Midway Formation, present in central and southwest Little Rock, is subject to excessive expansion and contraction, resulting from extreme variations in its moisture content and should receive special study and treatment for foundation use.

Most of the area is underlain by Paleozoic sandstones and shales. These may create slide problems on steep slopes.

MINERAL RESOURCES OF ARKANSAS, Arkansas Geological Conservation Commission Bulletin 6, revised 1959.

Bulletin 6 is designed primarily for the layman and contains only generalized geologic descriptions of the various mineral deposits.

The State's mineral fuels consist of coal, lignite, natural gas, natural gasoline, and petroleum. Among the metals to be found in Arkansas are antimony, aluminum, columbium, copper, gold, iron, lead, manganese, mercury, molybdenum, nickel, rare earths, silver, titanium, uranium, and zinc.

Nonmetallic minerals found in the State include asphalt, barite, bromine, chalk and marl, clay, diamonds, fuller's earth and bentonite, greensand, gypsum, limestone, and dolomite, marble, nepheline syenite, novaculite, ocher, phosphate rock, Portland cement materials, quartz crystals, salt, sand and gravel, sandstone and quartzite, silica sand, slate, soapstone, sulfur, tripoli, and water.

A GEOMAGNETIC SURVEY OF THE BAUXITE REGION IN CENTRAL ARKANSAS, Arkansas Geological Survey Bulletin 5, 1930, by N. H. Stearn.

The known deposits of bauxite in central Arkansas are genetically and geographically related to the known masses of igneous rock. It follows that the discovery of hitherto unknown igneous masses in this area may mean the discovery of associated deposits of bauxite.

Waterwise, the report is useful in locating drilling sites where ground water can most likely be developed. By avoiding igneous highs and drilling on the flanks of the highs or in between highs, generally more material that is known to be water producing can be penetrated.

GEOLOGY OF THE ARKANSAS BAUXITE REGION, U.S. Geological Survey Professional Paper 299, 1958, by Mackenzie Gordon, Jr., J. I. Tracey, Jr., and M. W. Ellis.

The Arkansas bauxite region lies near the center of the State in Pulaski and Saline Counties, covering an area of about 275 square miles. The surface rocks in this area are early Tertiary sand and clay. The Tertiary sediments rest on rocks of Paleozoic age and on intrusive masses of nepheline syenite.

The Midway Group (lowermost of the Tertiary sediments) is divided into two formations. In ascending order, these are the Kincaid Formation, a gray marly clay and sandy limestone containing local conglomerate, and the Wills Point Formation, a blue-black or dark-gray clay. Overlying the Midway Group is the Wilcox Group consisting of clays, silts, and sands. Uppermost Tertiary deposits are represented by sands and clays of the Claiborne and Jackson Groups.

The report is well illustrated, containing 39 plates, and 63 figures, principally consisting of maps, sections, isometric projections, photographs, and sketches.

THRUST FAULTING NEAR THE HOT SPRINGS, HOT SPRINGS, NATIONAL PARK, ARKANSAS, University of Arkansas, Institute of Science and Technology, February 1953, by R. H. Arndt and R. B. Stroud.

"Zigzag ridges at Hot Springs are held up by sharply folded, resistant Arkansas novaculite of Devonian-Mississippian age and the Mississippian Hot Springs sandstone. Fold axes plunge southwestward and axial traces strike northeastward. Southeast limbs of folds are overturned.

"Faults are recognized from truncated ridges, convergent fold axes, truncated and missing beds, localized excessive jointing and fracturing, and systematically displaced joint directions. Hot springs emerge from fractured Hot Springs sandstone on the northwest flank of Hot Springs Mountain anticline. Outcrop of Hot Springs sandstone is interrupted for 1,100 feet northeast of the springs where part of the adjacent syncline on the northwest is thrust southeastward against Hot Springs Mountain anticline. Alpha fault extends at least 9,200 feet in a northeast direction on North Mountain. The northwest limb of Hot Springs Mountain anticline is thrust over the southeast limb along Beta fault, which extends for 9,000 feet parallel to Alpha fault. Folds override folds where Alpah and Beta faults have maximum displacements of about 2,000 feet and 1,300 feet, respectively.

"A syncline of shattered novaculite which plunges into the hot springs area may be an aquifer that supplies the pressure head and part of the water of the hot springs."

MANGANESE CARBONATE IN THE BATESVILLE DISTRICT ARKANSAS, U.S. Geological Survey Bulletin 921-A, 1941, by H. D. Miser.

HICKORY VALLEY PHOSPHATE DEPOSIT IN INDEPENDENCE COUNTY, ARKANSAS, Arkansas Resources and Development Commission Bulletin 15, 1949, by C. J. Wells.

THE JACKSON STAGE IN SOUTHEASTERN ARKANSAS, Arkansas Resources and Development Commission Bulletin 19, 1953, by L. J. Wilbert, Jr.

TITANIUM ORE DEPOSITS OF HOT SPRING COUNTY, ARKANSAS, Arkansas Resources and Development Commission Bulletin 16, 1950, by V. C. Fryklund, Jr., and D. F. Holbrook.

TITANIUM IN SOUTHERN HOWARD COUNTY, ARKANSAS, Arkansas Resources and Development Commission Bulletin 13, 1948, by D. F. Holbrook.

UPPER CRETACEOUS OSTRACODA OF ARKANSAS, Arkansas Geological Survey, 1929, by M. C. Israelsky, reprint from "Stratigraphy and Structure of the Gulf Coastal Plain of Arkansas," Arkansas Geological Survey Bulletin 2, by W. C. Spooner and others.

DISCUSSION OF PETROLEUM DEVELOPMENT IN ARKANSAS, 1937-1938, Arkansas Board of Conservation, El Dorado, Arkansas, January 1, 1939.

ARKANSAS VALLEY STRUCTURE, University of Arkansas, Geology Department, duplicated report, by K. C. Jackson.

ZINC AND LEAD DEPOSITS OF NORTHERN ARKANSAS, U.S. Geological Survey Professional Paper 24, 1904, by G. I. Adams, assisted by A. H. Purdue and E. F. Burchard, *with a section on the* Determination and Correlation of Formations, by E. O. Ulrich.

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OIL AND GAS DEVELOPMENT IN ARKANSAS IN 1945, Statistics of Oil and Gas Development, 1945, reprint, American Institute of Mining and Metallurgical Engineers, 1946, by D. K. Mackay and J. W. Sanders.

GUIDE BOOK TO THE PALEOZOIC ROCKS OF NORTHWEST ARKANSAS, Arkansas Geological and Conservation Commission, 1951, reprinted 1955, by E. B. Brewster and N. F. Williams.

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DISCOVERY OF ROCK SALT IN DEEP WELL IN UNION COUNTY, Arkansas Geological Survey Information Circular 5, 1933, by H. W. Bell.

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PITKIN LIMESTONE OF NORTHERN ARKANSAS, Arkansas Geological Survey Bulletin 8, 1942, by W. H. Easton.

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A STRUCTURAL AND PETROLOGICAL NOTE ON THE MAZARN SYNCLINORIUM, Arkansas Academy of Science Proceedings, Volume 19, 1965, by L. J. Lee.

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