GROUND-WATER PROBLEMS IN ARKANSAS

By C. T. Bryant, A. H. Ludwig, and E. E. Morris

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CONVERSION FACTORS

For use of readers who prefer to use metric units, conversion factors for inch-pound terms used in this report are listed below:

Multiply	By	To obtain
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallon per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	3,785	cubic meter per day (m^3/d)

GROUND-WATER PROBLEMS IN ARKANSAS

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Abstract

Arkansas has an abundance of ground water, especially in the Gulf Coastal Plain Province. Ground water in the State is increasing in importance as indicated by its increased use. From 1975 to 1980 ground-water use increased from 2,596 to 4,056 million gallons per day, a 56 percent increase.

Ground-water problems in Arkansas are fairly widespread and include contamination, poor natural quality, overdraft, and low yields. Contamination of shallow domestic wells by human and animal wastes is the most prominent problem as indicated by high nitrate concentrations. Some surficial aquifers appear to have been contaminated by industrial wastes such as phenols, ethylenedibromide, arsenic, barium, cadmium, chromium, lead, selenium, and silver. Contamination of fresh ground water by saline water has occurred in several places due to large-scale pumping of the fresh ground water. The most prominent examples are the Sparta aquifer in Union County and the Quaternary aquifers in Lafayette, Miller, Independence, White, Monroe, Lincoln, Desha and Chicot Counties, and in areas adjacent to the Arkansas River. Continued, large-scale pumping has the potential to increase these areas of contamination. In some areas the occurrence of saline water appears to be of natural origin and not the result of human activity.

Ground-water levels are declining in large areas of the State where pumping rates exceed recharge rates. Ground-water levels in the Sparta aquifer have declined as much as 320 feet in Union County, as much as 260 feet in Columbia County, and as much as 240 feet in Jefferson County. Water levels in the Quaternary aquifer have declined 60 feet or more in parts of Craighead, Cross, Poinsett, Prairie, Lonoke, and Arkansas Counties.

Low yields of ground water in the Interior Highlands hinder large-scale ground-water development. Over most of the Highlands, yields to wells are less than 10 gallons per minute. Exceptions to the low yields are the Arkansas River alluvium which yields 300 to 750 gallons per minute and the Roubidoux and Gunter aquifers in northwest Arkansas which yield as much as 450 and 500 gallons per minute, respectively.

The potential for ground-water contamination is found statewide, especially in moderate or high aquifer recharge zones. A large number of waste impoundments, landfills, open dumps, septic tanks and storage tanks are potential sources of contamination. Waste injection wells and brine ponds in west-central and southern Arkansas and coal mining activities in west-central Arkansas are potential sources of ground-water contamination. Accidents involving hazardous materials transported by pipe lines, vehicles, and trains pose threats to ground water in much of the State.

REPORT SUMMARIZES GROUND-WATER PROBLEMS

Occurrence of ground water and existing and potential ground-water problems are described. Information needed as part of Arkansas' 'Water Quality Management Plan'.

Arkansas has an abundance of ground water. It is one of the State's most valuable resources. Use of ground water in Arkansas increased 56 percent from 1975 to 1980 (Holland and Ludwig, 1981). Excluding hydroelectric diversions, 1980 surface-water use was 1,200 million gallons per day, and 1980 ground-water use was 4,056 million gallons per day. Thus, the importance of ground water as a resource is evident. As ground-water use in Arkansas increases so does the awareness of problems with availability and quality. These problems are of concern to regulatory agencies, water-supply developers, and managers as well as to the general public.

This report was prepared in cooperation with the Arkansas Department of Pollution Control and Ecology and the Arkansas Soil and Water Conservation Commission. The report is one of several tasks in the "Water Quality Management Plan" developed by the Arkansas Department of Pollution Control and Ecology. One of the objectives of the plan is to develop and establish a systematic approach to the protection of ground-water quality. The intent of this report is to provide information about the occurrence, problems and potential problems of ground water in Arkansas as a step in meeting that objective.

For the use of water managers, this report divides the State of Arkansas into 16 ground-water study subdivisions (fig. 1.0-1). These subdivisions coincide with boundaries shown on the Hydrologic Unit Map-1974, State of Arkansas (U.S. Geological Survey, 1977). The subdivision numbers are the same as the first six digits of the Hydrologic Unit numbers. The map does not include Hydrologic Units 080101, 080201 and 080301. These three units define areas within the Mississippi River levee for which no data are available.

Geohydrologic studies by the U.S. Geological Survey in cooperation with the Arkansas Geological Commission provided much of the data used in this report. Additional data were provided by other State and Federal agencies and universities. Especially helpful in providing information were Messrs. Richard Garrett and Ralph Desmarais of the Arkansas Department of Pollution Control and Ecology and Mr. Danny Goodwin of the Arkansas Soil and Water Conservation Commission. Many county and city officials were helpful in locating waste sites and providing information about water resources. District Conservationists of the Soil Conservation Service, U.S. Department of Agriculture, were helpful in providing information about problems with irrigation water.

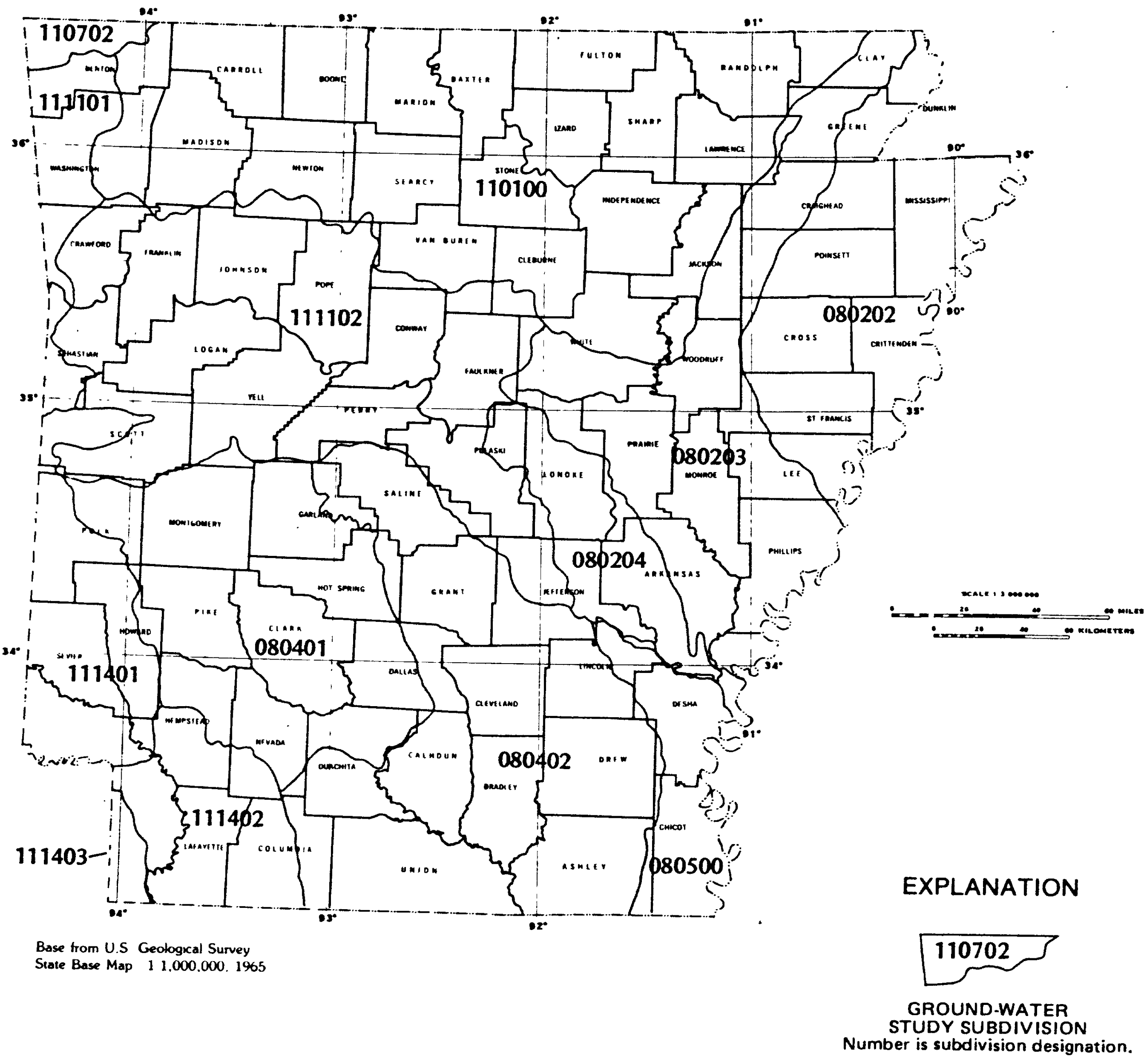

Figure 1.0-1 Ground-water study subdivisions.

GROUND-WATER MOVEMENT

Ground water is one phase of the hydrologic cycle.

Ground water, as it moves from areas of recharge to areas of discharge, is one phase of the hydrologic cycle. The hydrologic cycle is a term applied to the constant movement of water in the atmosphere, and on and beneath the earth's surface (fig. 2.0-1). An understanding of the hydrologic cycle is necessary for understanding and managing ground-water resources.

Figure 2.0-1 is a generalized representation of the hydrologic cycle for Arkansas. Although the cycle is continuous, it is convenient, for discussion purposes, to assume that it begins with the evaporation phase. Moisture evaporates from oceans, lakes, streams, and soils and transpires through plants. The moisture that evaporates forms clouds, which, in time, return water to the land surface as precipitation. In Arkansas most of the precipitation is in the form of rainfall. Part of the precipitation infiltrates directly into the ground, part runs off into streams and lakes and part of it evaporates back into the atmosphere.

Some of the precipitation that infiltrates into the ground passes through the unsaturated zone and into the saturated zone (fig. 2.0-1). The unsaturated zone begins at the land surface and may extend from a few inches to several feet beneath the surface. This zone contains both air and water. The top few inches or feet of the unsaturated zone, known as the soil zone, supports plant life, burrowing insects and animals, and soil bacteria.

Moisture in excess of plant, animal, or evaporation needs is available to percolate downward to the intermediate zone. The intermediate zone ranges in thickness from a few feet to several tens of feet depending on the depth to the water table. The porosity and permeability of the intermediate zone and hence the percolation rate of water through it is dependent on the type of material present. Dense clays retard the percolation of water whereas sands or fractured rocks allow for rapid movement of water through the zone.

Beneath the unsaturated zone all interconnected openings are full of water and the underlying material is saturated. Water in the saturated zone is correctly referred to as ground water. If the material in the saturated zone is capable of transmitting and yielding usable quantities of water to wells or springs, the saturated zone is referred to as an aquifer.

Where the upper surface of the saturated zone is free to rise and fall, water is unconfined and the aquifer is referred to as an unconfined aquifer. The upper surface of the saturated zone in an unconfined aquifer is the water table. Static water levels in wells tapping unconfined aquifers are at the same level as the water table. However, a pumping well in an unconfined aquifer causes a lowering of the water level in the vicinity of the well and a cone of depression is formed (fig. 2.0-1).

Where an aquifer is overlain and underlain by confining beds, it is referred to as a confined (artesian) aquifer. Water levels in tightly cased wells will rise above the top of a confined aquifer (fig. 2.0-1). The level to which water will rise is called the potentiometric surface. The water may even flow at the land surface. Excessive withdrawals of water may reduce the artesian pressure in the aquifer and, in some severe cases, may even cause water levels to drop below the top of the aquifer. Where this occurs, the hydraulic characteristics of the aquifer change and well yields may decline substantially.

Recharge is the net infiltration of precipitation or water from streams or lakes to the ground-water system. The principal factor controlling recharge is the permeability of the surficial material which governs the amount of water moving into the ground-water system.

Discharge from aquifers occurs naturally through seepage to streams or lakes, flow to springs, leakage to other aquifers, and evaporation, and artificially by pumping from wells. Natural discharge usually takes place when the ground-water system is at capacity and cannot accept additional water.

Natural rates of ground-water movement range from a few inches to a few tens of feet per year. These small rates of movement determine the occurrence of fresh ground water. Generally, ground water becomes more mineralized with depth. Mineralization occurs either as the result of the solution of minerals from the aquifer material itself or because the aquifer was deposited in a marine environment and has retained some of the original brines.

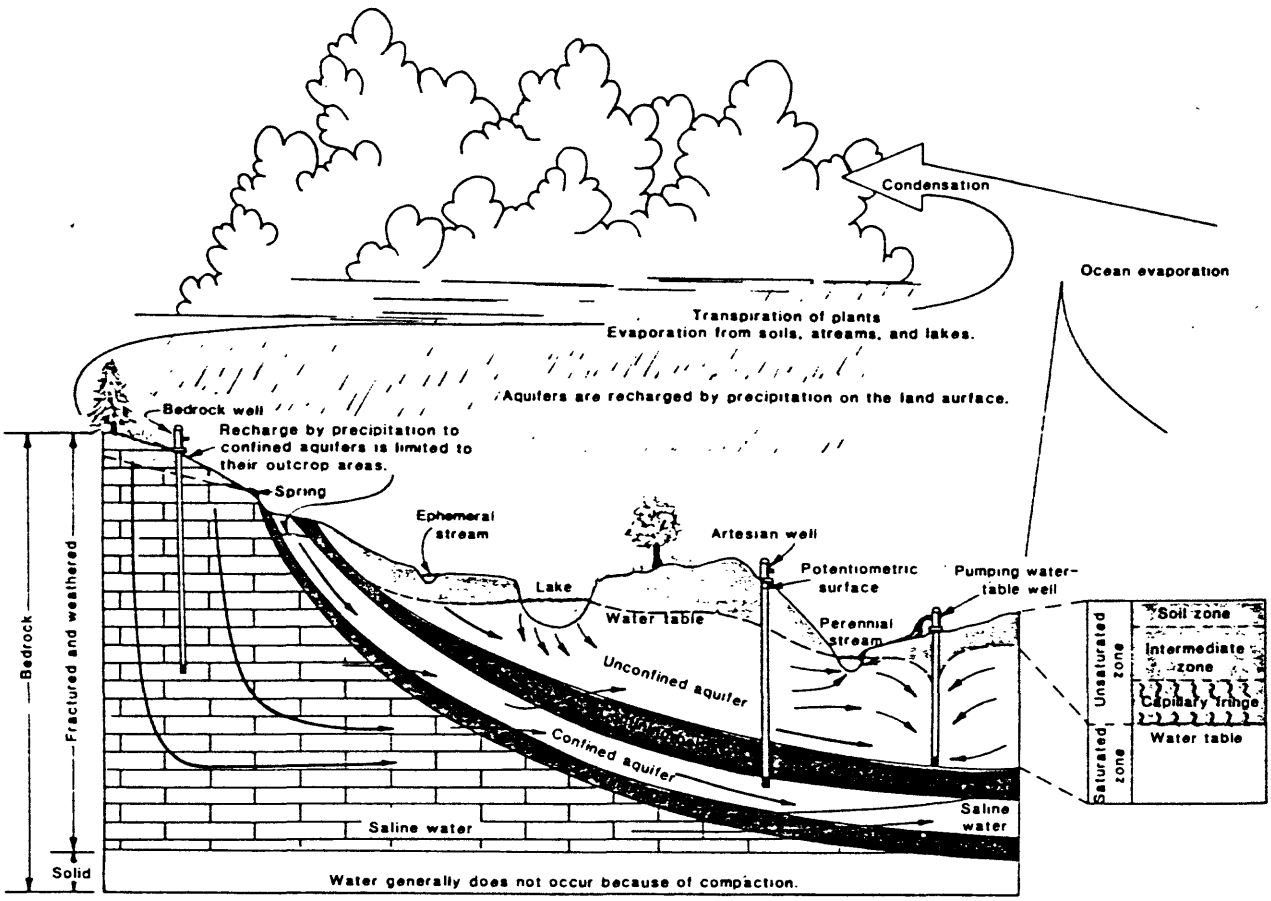

Figure 2.0-1 Generalized hydrologic cycle of Arkansas showing direction of ground-water flow.

GROUND WATER OCCURS IN TWO GEOLOGIC SETTINGS

Ground water is abundant in the Gulf Coastal Plain but is relatively scarce in the Interior Highlands.

Arkansas is divided physiographically into two parts - the Gulf Coastal Plain and the Interior Highlands (front cover) (Fenneman, 1938). The occurrence of ground water is closely associated with the types of rocks which occur in each physiographic area.

The Gulf Coastal Plain encompasses approximately 27,000 square miles in the southeastern half of Arkansas and is underlain in part by thick alluvial deposits and by gently dipping unconsolidated and semiconsolidated sediments (fig. 3.0-1). The sediments that make up the Coastal Plain are of marine and continental origin and consist of alternating sequences of gravel, sand, silt and clay, with local occurrences of limestones and lignite. These sediments form both confining layers and aquifers. In general, the marine deposits consisting of the Jackson Group, Cook Mountain Formation, and Midway Group are composed of clay and form confining layers.

Most of the ground-water supplies in the Coastal Plain are obtained from six aquifers or aquifer systems. These are in the Quaternary deposits, Cockfield Formation, Sparta Sand, Wilcox Group, Nacatoch Sand, and the Tokio Formation. Although other ground-water sources may be important locally for rural domestic supplies, these aquifers constitute the source of nearly all ground-water withdrawals in the southeastern half of the State.

The Quaternary alluvium is the principal source of water for irrigation. Alluvial deposits blanket much of eastern Arkansas, the Ouachita and Red River Valleys in southwestern Arkansas, and isolated areas along the Arkansas River in the Interior Highlands. The alluvium is as much as 250 feet thick in parts of eastern Arkansas and is composed of a coarse sand and gravel aquifer at the base, grading upward to silt and clay at the surface. Wells in the alluvial aquifer generally yield from 1,000 to 2,000 gallons per minute.

The Cockfield Formation, Sparta Sand, Wilcox Group, Nacatoch Sand, and Tokio Formation are part of a thick sequence of semiconsolidated Coastal Plain sediments containing water-bearing units that crop out in bands of varying widths roughly parallel to the Fall Line (the dividing line separating the Gulf Coastal Plain and the Interior Highlands) and dip gently to the south and southeast. All or part of each of these formations are composed of thick sequences of sand which are important freshwater aquifers. These formations range in thickness from 200 to 900 feet. Well yields range from 300 to 2000 gallons per minute. Figure 3.0-1 shows the outcrop areas for these formations.

The Interior Highlands encompass about 31,000 square miles in the northwest half of the State and are underlain by thick sequences of consolidated rocks of Paleozoic age consisting mostly of limestones, dolomites, sandstones and shale. The rocks are extensively folded and faulted, and the primary porosity of the rocks has been greatly reduced by compaction and cementation (Cordova, 1963). Ground water occurs primarily in fractures and joints in the sandstones and shales and solution openings in the limestones and dolomites. These rocks are locally important as the source of water for thousands of rural homes in the region. Wells average about 150 feet in depth and generally yield less than 10 gallons per minute. Yields greater than 25 gallons per minute are rare.

The Roubidoux Formation and the Gunter Sandstone member of the Van Buren Formation constitute the only significant aquifer system, except for the Arkansas River alluvium, in the Interior Highlands. They occur only in the subsurface in Arkansas. The Roubidoux is 100 to 250 feet thick and occurs at depths ranging from 600 feet at the Arkansas-Missouri State line to about 2,300 feet below land surface at the southern limits of the area of use. The Gunter Sandstone member is about 50 feet thick and lies 300 to 600 feet below the Roubidoux Formation. Together, these units may yield up to 500 gallons per minute to wells. The Roubidoux Formation and Gunter Sandstone member are recharged in their outcrop areas in southern Missouri.

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GROUND-WATER AVAILABILITY GOVERNED BY NATURAL CONSTRAINTS

Consolidated rocks in west-central Arkansas yield only small amounts of water to wells. Most units contain saline water at depth.

Ground water is available practically everywhere in the State. At some locations, large quantities of freshwater can be obtained from several aquifers at different depths while at other places, potential ground-water sources are limited or even nonexistent. Thus, the occurrence of ground water in the State is highly variable and is governed by the hydrologic conditions that exist at any given location. The quantity and quality limitations discussed herein represent natural constraints which are determined by the character of the geologic framework which contains the water. Conditions limiting the availability of fresh ground water include: (1) low permeability of sediments or consolidated rocks in a given area, and (2) depth to the base of freshwater. A delineation of areas depicting these two conditions is shown in figure 4.0-1.

Yields to wells of less than 10 gallons per minute occur in a large part of the Interior Highlands in west-central Arkansas and in isolated areas in the Coastal Plain. In the Highlands the surficial rocks yield only limited amounts of water. No freshwater-bearing aquifers exist at depth in the Highlands south of latitude 36°.

Ground-water supplies are also limited in small areas of the Coastal Plain. These consist of areas where the surficial units are comprised of fine-grained sediments that do not readily yield water and, where only saline water is available at depth. Low-yielding areas in the Coastal Plain include the outcrop and subcrop areas of the Carrizo Sand, Wilcox Group, and Midway Group in central and southwestern Arkansas where no freshwater-bearing aquifers exist either beneath or above these units.

In addition to constraints related to low yield, poor water quality may also restrict the use of water. Freshwater occurs in the outcrop areas and for a distance downdip in most of the principal water-bearing units in the State. Freshwater occurs at depths ranging from less than 100 to more than 3,500 feet below land surface. The greatest depth to the base of freshwater occurs in the Gunter Sandstone member of the Van Buren Formation in northern Arkansas. Freshwater is defined herein as water containing less than 1,000 milligrams per liter of total dissolved solid. Concentrations greater than 1,000 milligrams per liter are indicative of high salinity. The salinity is a natural phenomenon resulting from the invasion of formations by brine during or following deposition or by minerals dissolved by reaction as the water percolates through the rocks. The extent to which a given unit contains freshwater represents the limit of flushing of natural brines.

Figure 4.0-1 shows the deepest geologic units which contain freshwater and the elevation of the base of freshwater within each unit. The heavy dashed lines on the map are boundaries indicating the areal extent that a given unit constitutes the lowermost freshwater-bearing source. Beyond the boundary for a given unit the unit either does not contain freshwater or the base of freshwater is in an older (lower) geologic unit. In some areas, as shown on figure 4.0-1, all units contain only saline water. To determine the depth to which freshwater may be found at any given location, subtract, algebraically, the elevation of the base of freshwater at the desired location from the land surface elevation at the site.

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GROUND-WATER PROBLEMS WIDESPREAD

Principal ground-water problems include poor natural quality, contamination, and declining water levels.

Ground-water problems in Arkansas are receiving increased attention from both Federal and State regulatory agencies and from water users. Although Arkansas is blessed with an abundance of good quality ground water, problems are fairly widespread in the State (fig. 5.0-1). Principal problems are poor natural quality, contamination, and declining water levels.

Saline water occurs in several places in the alluvial aquifer (fig. 5.0-1). Most of these occurrences involve the migration of saline water from a source or sources at depth. Saline water occurrences at shallow depth in Miller and Lafayette Counties are the result of brines from deep beneath the surface invading the alluvial aquifer through unplugged wells. In some cases, particularly those in Chicot and Monroe Counties, the avenue by which the saline water migrates to the surface is not fully understood. The water may have moved upwsrd through confining beds that are thinned or absent, through naturally occurring faults, or by artificial means through unplugged casings of abandoned oil test wells. Saline water in the alluvial aquifer in Independence and White Counties are natural occurrences resulting from the upwelling of water from brine-containing rocks beneath the alluvium. The saline water in the Arkansas River alluvium may have resulted as recharge from the Arkansas River, which at times contains saltwater derived from saltbeds in Kansas and Oklahoma. Thus the method by which saline water enters the alluvial aquifer differs in various places. More importantly, the number and areal extent of saline water occurrences has increased in recent years primarily as the result of the decline in water levels caused by large withdrawals for irrigation.

In Union County, large-scale ground-water withdrawals from the Sparta aquifer have changed the natural flow direction and are allowing saline water to migrate toward the center of pumping in the vicinity of El Dorado (Broom and others, 1984).

Some contaminants from industrial wastes appear to have entered shallow aquifers. Ground-water quality monitoring data furnished by industries to the Arkansas Department of Pollution Control and Ecology have shown concentrations of arsenic, barium, cadmium, chromium, lead, mercury, nitrate, selenium and silver exceeding safe drinking water limits (table 7.0-3). In addition, the organic chemicals, ethylenedibromide and phenols, for which no limits have been established, have been reported from a few industrial monitoring wells.

As a result of large-scale withdrawals, ground-water levels are declining in some areas of the Gulf Coastal Plain. Water levels in the Ouaternary aquifer have declined as much as 60 feet in Poinsett, Cross, Craighead, Prairie, Lonoke, and Arkansas Counties where pumping for irrigation has exceeded recharge (fig. 5.0-1). Water levels in these areas have declined as much as 8 feet in a dry year. For most of the area affected, declines are about 0.75 foot per year.

Water levels are declining in the Sparta aquifer in southeastern and south-central Arkansas where pumping for irrigation, municipal and industrial uses has exceeded the recharge capacity for the aquifer. Water levels in the Sparta aquifer in Arkansas County have declined about 100 feet since pumping for irrigation began in 1905. Large scale industrial and municipal pumping from the Sparta Sand in Union County since the 1920's has lowered the water level in the aquifer about 320 feet (fig. 5.0-1). Other counties affected include Columbia with declines approaching 260 feet and Jefferson County with declines of almost 240 feet. Water levels have declined as much as 12 feet during a dry year and are declining about 1 to 3 feet per year in the areas of decline.

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GROUND-WATER PROBLEMS MAY OCCUR ANYWHERE ANYTIME

Potential exists almost everywhere in Arkansas for contamination of ground water from several sources. Greatest potential is in areas of highest recharge.

The potential exists for ground-water problems to occur almost anywhere in the State. Permeable materials that allow water to recharge aquifers will also allow contaminants to enter the ground-water system. Therefore, the potential for contamination is closely related to the recharge rate.

Recharge occurs in varying degrees over the entire State depending on the availability of precipitation, the position of the water table with respect to land surface, and the permeability of the surficial soil or rock material. Previous studies (Sniegocki and Bedinger, 1969) indicate that, on the average, about 2 inches of water enters the ground-water system in the State annually. Model studies of the Quaternary aquifer (Broom and Lyford, 1981) indicate recharge rates of less than 0.4 inch per year, whereas, in a study by Bedinger and others, (1963) a rate of 10 inches per year was determined. Insufficient data preclude a quantitative statewide evaluation of recharge rates. However, in this report, a generalized evaluation is presented, based on precipitation, position of the water table, and permeability of surficial materials.

Zones for various estimated rates of recharge are delineated on figure 6.0-1, and explained in table 7.0-4. Zones delineated on the map are designated as having either high, moderate, or low recharge potential depending on the general nature of the surficial materials within a given area. Areas of high potential include those in which the surficial materials readily allow percolation of water. These include the outcrop areas of confined aquifers, and upland terrace deposits lacking a clay cap, and areas in the Interior Highlands where extensive fracture systems or solution channels have developed. Areas designated as having moderate recharge potential include those in which the surficial materials retard the percolation of water or the ground-water system is capable of storing only limited amounts of water. Aress of low recharge potential include those in which thick, relatively impermeable clays lie directly beneath the land surface. The potential for ground-water contamination by hazardous materials disposed of on the land surface coincide generally with the rates of recharge to aquifers.

Sources of high-potential ground water contamination in Arkansas are waste impoundments, landfills (including open dumps) and hazardous waste operations (fig. 6.0-1). Additional sources of potential ground-water contamination include storage tanks, septic tanks, waste-injection wells, mining activities, pipelines, and wastes spilled during transport.

The State of Arkansas conducted a Surface Impoundment Assessment in 1978-79 to locate all liquid waste holding surface impoundments in the State and, as far as possible, to assess the potential hazards to ground water from these impoundments. In the initial phase 7,640 impoundments were located at 872 sites (Chesney, 1979). The type of impoundments were related to agricultural, oil and gas, industrial, municipal and mining activities. Over 6,000 impoundments were associated with oil and gas operations in west-central and southern Arkansas The oil and gas impoundments were too numerous to show individually and are shown on figure 6.0-1 as generalized areas only.

Of the 7,640 impoundments in the State, 518 were selected for assessment of contamination potential. The assessment conducted by Chesney included descriptions of the characteristics of the impoundments such as size in acres, age, amount and type of wastes present and type of liner, and the presence of monitoring wells. In addition the geologic formations underlying the impoundments were rated according to the ease with which contaminants could penetrate surface layers. With this information numeric ratings were given to the impoundments based on the toxicity and mobility of the waste product and on the local environment. For this report only surface impoundments having a hazard rating of 16 (on a scale of 1 to 29) or above are shown in figure 6.0-1.

There are more than 340 landfills, including sanitary landfills, open dumps, legally closed dumps, and abandoned dumps in Arkansas (fig. 6.0-1). Complete information as to the amount or kinds of wastes that have been disposed of in landfills is not available. Further, little documentation is available to determine if contamination of underlying aquifers has occurred. Included among the impoundments and landfills are several sites known to contain hazardous wastes. Among these sites are several which are covered by Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). RCRA sites are those where hazardous wastes are treated under authorization of regulatory agencies. These sites require permits to operate and in some cases, ground-water monitoring is required. There are 16 of these sites in Arkansas (fig. 6.0-1). CERCLA (Superfund) sites are hazardous waste sites considered to be potential sources of significant harm to human health or the environment. Seven such sites exist in Arkansas.

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7.0 SUPPLEMENTARY DATA

Table 7.0-1.--Primary drinking water standards

[From U.S. Environmental Protection Agency, 1977]

Selected constituent	Maximum contaminant level (milligrams per liter unless otherwise noted)
Arsenic	0.05
Barium	1.00
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Selenium	0.01
Silver	0.05
Fluoride	1.4 - 2.4 depending on average temperature
Nitrate as N[1]	10.00
Coliform bacteria	
a) For standard samples the arithmetic mean of all samples examined in a compliance period shall not exceed	1 colony per 100 milliliter
b) When less than 20 samples per month are examined, not more than one sample shall exceed	4 colonies per 100 millilit
Turbidity	1 turbidity unit
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.10
Toxaphene	0.005
2,4 - D	0.10
2,4,5-TP (Silvex)	0.01
TTHM (total trihalomethanes)	0.10
Combined Radium - 226 and radium - 228	5 pCi/L*
Gross Alpha Particle Activity (including radium-226, excluding radon and uranium)	15 pCi/L
Beta Particle and Photon Radioactivity from manmade radionuclides	Average annual conc. shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/yea
Tritium (total body)	20,000 pCi/L
Strontium-90 (bone marrow)	8 pCi/L

*pCi/L = piocuries/liter

[1]The maximum contaminant level for nitrate applies to community and noncommunity water systems. Other inorganic chemicals apply only to community water systems.

Table 7.0-2.—Public supply and household wells where water-quality constituents exceeded primary drinking water standards (water was untreated at time of collection)

[Map number refers to number on figure 5.0-1. μg/L = micrograms per liter; mg/L = milligrams per liter; five digit numbers in parentheses are STORET parameter codes used for computer storage of data]

MAP NUMBER	STATION NUMBER	DATE OF SAMPLE	GEOLOGIC UNIT[1]	BARIUM, DISSOLVED (μg/L AS BA) (01005)	LEAD, DISSOLVED (μg/L AS PB) (01049)	NITROGEN, NITRATE DISSOLVED (mg/L AS N) (00618)	FLUORIDE, DISSOLVED (mg/L AS F) (00950)	TURBIDITY (NTU) (00076)
			GROUND-WATER STUDY SUBDIVISION 080202					
1	354545090295001	8-09-67	Q	--	--	26.0	10	--
2	360845090310401	4-12-68	Q	--	--	49.0	--	--
3	355920090083001	5-08-57	Q	--	--	18.0	--	--
			GROUND-WATER STUDY SUBDIVISION 080203					
4	350015091594701	7-20-55	Tw	--	--	15.0	--	--
5	350022091175101	7-14-61	Q	--	--	12.0	--	--
6	341830090511301	6-21-50	Ts	--	--	--	2.0	--
			GROUND-WATER STUDY SUBDIVISION 080401					
7	341413092553101	9-22-64	Q	--	--	11.0	--	--
8	334710092384401	8-19-59	Q	--	--	18.0	--	--
9	341247092463401	8-18-64	Ts	--	--	12.0	--	--
10	341045093040001	5-28-63	Ku	--	--	--	2.0	--
11	334756093231804	6-23-83	Kna	--	--	--	3.0	--
12	335152093204901	4-18-51	Kna	--	--	--	3.0	--
13	335455093093201	7-26-46	Kna	--	--	--	3.0	--
		2-23-53	Kna	--	--	--	4.0	--
14	334010093352801	3-27-51	Kto	--	--	--	2.0	--
		2-25-53	Kto	--	--	--	2.0	--
15	334756093231801	8-25-52	Kto	--	--	--	3.0	--

7.0 SUPPLEMENTARY DATA--Continued

Table 7.0-2.--Public supply and household wells where water-quality constituents exceeded primary drinking water standards (water was untreated at time of collection)--Continued

MAP NUMBER	STATION NUMBER	DATE OF SAMPLE	GEOLOGIC UNIT[1]	BARIUM, DISSOLVED (µg/L AS BA) (01005)	LEAD, DISSOLVED (µg/L AS PB) (01049)	NITROGEN, NITRATE DISSOLVED (mg/L AS N) (00618)	FLUORIDE, DISSOLVED (mg/L AS F) (00950)	TURBIDITY (NTU) (00076)
				GROUND-WATER STUDY SUBDIVISION 080402				
16	334644092235301	8-04-59	Q	--	--	13.0	--	--
17	332805092211601	8-06-59	Q	--	--	12.0	--	--
18	332811092333301	8-05-59	Q	--	--	23.0	--	--
19	332925092211401	7-17-79	Q	--	--	14.0	--	--
20	333009092281801	8-06-59	Q	--	--	20.0	--	--
21	333051092231001	8-04-59	Q	--	--	21.0	--	--
22	333159092254901	8-06-59	Q	--	--	12.0	--	--
23	333648092325601	8-04-59	Q	--	--	24.0	--	--
24	334209092250901	8-04-59	Q	--	--	34.0	--	--
25	332521093042201	8-11-59	Tcm	--	--	16.0	--	--
26	332732092492901	8-11-59	Tcm	--	--	18.0	--	--
27	332653092591101	8-11-59	Ts	--	--	33.0	--	--
28	333043092594101	8-10-59	Ts	--	--	13.0	--	--
29	333638092590901	8-10-59	Ts	--	--	12.0	--	--
30	331226092415301	1-10-82	Kna	9,000	--	--	--	--
31	331253092444001	6-14-82	Pzu	--	--	--	5.0	--
32	331128092414102	11-09-82	Tw	1,800	--	--	--	--
		11-09-82	Tw	1,700	--	--	--	--
33	343401092291801	6-25-63	Tm	--	--	--	5.0	--
34	333405091533701	2-09-54	Q	--	--	17.0	--	--
35	333531091552601	3-29-54	Q	--	--	17.0	--	--
36	334106091561401	2-04-54	Q	--	--	26.0	--	--
37	334608091571701	2-04-54	Q	--	--	27.0	--	--
38	332610092144701	7-31-59	Q	--	--	23.0	--	--
39	332907092053101	7-31-59	Q	--	--	11.0	--	--
40	335208091573503	10-04-56	Q	--	--	22.0	--	--
41	335417091523701	4-26-56	Q	--	--	15.0	--	--
42	333623092113901	8-19-59	Tcf	--	--	--	7.0	--
43	333801091501002	12-16-54	Tj	--	--	29.0	--	--
44	334200091495701	10-20-53	Tj	--	--	29.0	--	--
45	335038091511701	8-24-56	Tj	--	--	38.0	--	--
46	334925091412601	4-27-56	Q	--	--	26.0	--	--
47	340502091504301	4-27-56	Q	--	--	23.0	--	--
48	335820091520601	9-13-56	Tj	--	--	21.0	--	--
49	341122092042201	3-28-49	Tj	--	--	13.0	--	--

Table 7.0-2.--Public supply and household wells where water-quality constituents exceeded primary drinking water standards (water was untreated at time of collection)--Continued

MAP NUMBER	STATION NUMBER	DATE OF SAMPLE	GEOLOGIC UNIT[1]	BARIUM, DISSOLVED (µg/L AS BA) (01005)	LEAD, DISSOLVED (µg/L AS PB) (01049)	NITROGEN, NITRATE DISSOLVED (mg/L AS N) (00618)	FLUORIDE, DISSOLVED (mg/L AS F) (00950)	TURBIDITY (NTU) (00076)
GROUND-WATER STUDY SUBDIVISION 110100								
50	360454093431901	9-09-81	Pzu	--	--	--	3.0	--
51	362013093260301	3-01-65	Pzu	--	--	--	--	4.0
52	361150093025601	5-15-67	Pzu	--	--	--	--	5.0
53	361630092351801	7-05-78	Pzu	--	--	--	2.0	--
54	362636092374201	5-03-77	Pzu	--	--	29.0	--	--
55	360007092242601	8-01-75	Pzu	--	--	--	2.0	--
56	355722093093401	1-01-77	Pzu	--	--	--	3.0	--
		7-17-78	Pzu	--	--	--	3.0	--
		6-02-80	Pzu	--	--	--	3.0	2.0
57	361437092163201	4-20-76	Pzu	--	--	--	--	5.0
58	361517091212001	3-25-77	Pzu	--	--	--	2.0	--
59	361003091462201	9-21-77	Pzu	--	200	--	--	--
GROUND-WATER STUDY SUBDIVISION 110702								
60	362503094272001	12-05-69	Pzu	--	--	28.0	--	--
GROUND-WATER STUDY SUBDIVISION 111102								
61	350635093035001	9-06-50	Q	--	--	26.0	--	--
62	350715093022501	9-07-50	Q	--	--	20.0	--	--
63	350819092380301	3-25-58	Q	--	--	12.0	--	--
64	351130093062501	11-27-50	Q	--	--	30.0	--	--
65	351143092494901	11-30-50	Q	--	--	64.0	--	--
66	351144092545801	11-30-50	Q	--	--	20.0	--	--
67	351207092532501	11-30-50	Q	--	--	21.0	--	--
68	351225093072001	11-27-50	Q	--	--	12.0	--	--
69	351226092532601	11-30-50	Q	--	--	33.0	--	--
70	351234092553001	11-29-50	Q	--	--	19.0	--	--
71	350615093061501	8-04-50	Q	--	--	13.0	--	--

7.0 SUPPLEMENTARY DATA--Continued

Table 7.0-2.--Public supply and household wells where water-quality constituents exceeded primary drinking water standards (water was untreated at time of collection)--Continued

MAP NUMBER	STATION NUMBER	DATE OF SAMPLE	GEOLOGIC UNIT[1]	BARIUM, DISSOLVED (μg/L AS BA) (01005)	LEAD, DISSOLVED (μg/L AS PB) (01049)	NITROGEN, NITRATE DISSOLVED (mg/L AS N) (00618)	FLUORIDE, DISSOLVED (mg/L AS F) (00950)	TURBIDITY (NTU) (00076)
GROUND-WATER STUDY SUBDIVISION 111102 (continued)								
72	350635093031502	9-06-50	Q	--	--	34.0	--	--
73	350655093071501	8-03-50	Q	--	--	13.0	--	--
74	350710093070501	8-03-50	Q	--	--	14.0	--	--
75	350750093072001	8-03-50	Q	--	--	12.0	--	--
76	350820093082501	8-03-50	Q	--	--	18.0	--	--
77	350825093054001	7-25-50	Q	--	--	22.0	--	--
78	350850093005501	10-17-50	Q	--	--	21.0	--	--
79	350850093012001	10-17-50	Q	--	--	14.0	--	--
80	350930093074501	7-20-50	Q	--	--	16.0	--	--
81	351050093082801	7-19-50	Q	--	--	11.0	--	--
82	351050093090001	7-19-50	Q	--	--	14.0	--	--
83	351125093083001	7-19-50	Q	--	--	24.0	--	--
84	350645093031501	9-07-50	Q	--	--	14.0	--	--
85	350645093040501	9-06-50	Q	--	--	25.0	--	--
86	350645093050601	8-24-50	Q	--	--	61.0	--	--
87	350650093035001	9-07-50	Q	--	--	19.0	--	--
88	350650093050001	8-22-50	Q	--	--	18.0	--	--
89	350635093031001	9-06-50	Q	--	--	67.0	--	--
90	350820093002501	10-19-50	Q	--	--	13.0	--	--
91	350855093000501	10-18-50	Q	--	--	13.0	--	--
92	350855093004501	10-17-50	Q	--	--	15.0	--	--
93	343949092182701	4-18-63	Ku	--	--	--	7.0	--
GROUND-WATER STUDY SUBDIVISION 111401								
94	334202093513401	2-28-68	Kto	--	--	--	7.0	--
95	334621094154601	7-23-51	Ku	--	--	--	3.0	--
		2-27-68	Ku	--	--	--	3.0	--

Table 7.0-2.--Public supply and household wells where water-quality constituents exceeded primary drinking water standards (water was untreated at time of collection)--Continued

MAP NUMBER	STATION NUMBER	DATE OF SAMPLE	GEOLOGIC UNIT[1]	BARIUM, DISSOLVED (μg/L AS BA) (01005)	LEAD, DISSOLVED (μg/L AS PB) (01049)	NITROGEN, NITRATE DISSOLVED (mg/L AS N) (00618)	FLUORIDE, DISSOLVED (mg/L AS F) (00950)	TURBIDITY (NTU) (00076)
GROUND-WATER STUDY SUBDIVISION UNIT 111402								
96	331902093505401	10-24-68	Tcr	--	--	--	2.0	--
97	334345093373701	6-07-72	Kto	--	--	--	3.0	--
GROUND-WATER STUDY SUBDIVISION 111403								
98	330301093553401	10-25-68	Tw	--	--	--	2.0	--
99	330411093564901	10-23-68	Tw	--	--	--	2.0	--

[1]See figure 3.0-1 for geologic name.

Table 7.0-3--Water-quality data from Resource Conservation and Recovery Act (RCRA) monitoring wells where water-quality constituents exceeded primary drinking water standards

[Map number refers to number on figure 5.0-1. Data furnished by the Arkansas Department of Pollution Control and Ecology. µg/L = micrograms per liter; mg/L = milligrams per liter]

MAP NO.	STATION NUMBER	GEO-LOGIC UNIT[1]	ARSENIC TOTAL (µg/L AS AS) (01002)	BARIUM, TOTAL RECOV-ERABLE (µg/L AS BA) (01007)	CADMIUM TOTAL RECOV-ERABLE (µg/L AS CD) (01027)	CHRO-MIUM, TOTAL RECOV-ERABLE (µg/L AS CR) (01034)	LEAD, TOTAL RECOV-ERABLE (µg/L AS PB) (01051)	MERCURY TOTAL RECOV-ERABLE (µg/L AS HG) (71900)	NITRO-GEN, NITRATE TOTAL (mg/L AS N) (00620)	SELE-NIUM, TOTAL (µg/L AS SE) (01147)	SILVER, TOTAL RECOV-ERABLE (µg/L AS AG) (01077)
					GROUND-WATER STUDY SUBDIVISION 080203						
100	355000090430000	Q	--	1,900	60	--	200	--	29	--	--
101	354956090430000	Q	--	2,200	60	--	200	--	44	--	--
102	354958090430100	Q	--	3,800	60	--	200	--	16	--	--
103	354958090425910	Q	--	2,400	60	--	200	--	42	--	--
104	343300090410001	Q	--	--	--	--	60	--	--	--	--
105	343300090410002	Q	--	--	--	--	60	--	--	50	--
106	343300090410003	Q	--	--	--	--	50	--	--	50	--
107	343300090410004	Q	--	--	--	--	--	--	--	60	--
					GROUND-WATER STUDY SUBDIVISION 080204						
108	344802092001000	Q	--	--	57	--	--	--	--	--	--
109	344729092000800	Q	--	--	135	--	--	--	--	--	--
110	344756092001200	Q	--	--	16	--	--	--	--	--	--
111	344756092000900	Q	--	--	200	--	--	--	--	--	--
112	344756092000600	Q	--	--	62	--	--	--	--	--	--
113	344757092000400	Q	--	--	140	--	--	--	--	--	--
114	344723092000500	Q	--	--	19	--	--	--	--	--	--
115	344723092000900	Q	--	--	47	--	--	--	--	--	--
116	344723092001800	Q	--	--	20	--	--	--	--	--	--
					GROUND-WATER STUDY SUBDIVISION 111102						
117	344600092130000	Q	--	--	--	135	--	--	--	--	--
118	344558092125600	Q	--	--	--	79	--	--	--	--	--
119	344600092125600	Q	--	--	--	128	--	--	--	--	--
120	344601092125600	Q	--	--	--	280	--	--	--	--	--
					GROUND-WATER STUDY SUBDIVISION 080402						
121	332148092424401	Tcf	--	1,900	--	120	260	--	--	940	--
122	332148092424402	Tcf	--	1,200	--	--	--	--	--	--	--
123	332148092424403	Tcf	--	--	--	80	--	--	--	--	--
124	332148092424404	Tcf	--	4,400	--	--	--	--	--	--	--
125	332148092424405	Tcf	--	--	--	100	--	--	--	--	--
126	331100092380001	Tcf	--	--	--	--	--	--	10	--	--
127	331100092380002	Tcf	--	--	--	--	190	--	--	--	--
128	331100092380003	Tcf	--	--	--	120	240	--	--	--	110
129	331100092380004	Tcf	--	--	--	750	270	--	--	--	--
130	331100092380005	Tcf	--	--	--	100	540	--	--	--	--
131	331100092380006	Tcf	--	--	--	--	180	--	--	--	--
132	331100092380007	Tcf	--	--	--	--	130	--	--	--	--
133	331100092380008	Tcf	--	--	--	--	70	--	--	--	--
134	331215092404500	Tcf	80	--	--	--	--	--	--	44	--
135	331212092404400	Tcf	--	1,800	--	--	130	--	--	50	--
136	331210092404700	Tcf	60	1,400	--	--	70	--	--	48	--
137	331212092410200	Tcf	--	--	--	--	--	--	--	50	--
138	331207092412400	Tcf	80	--	--	--	--	--	--	22	--
139	331203092400500	Tcf	150	--	--	--	--	--	--	--	--
140	331201092412100	Tcf	--	--	--	--	--	--	--	37	--
141	331210092413000	Tcf	60	--	--	--	--	--	--	30	--
142	331105092425300	Tcf	--	--	--	--	--	--	30	58	--
143	331105092425301	Tcf	82	--	--	--	53	100	--	84	--
144	331105092425302	Tcf	--	--	--	--	60	3.	--	440	--
145	331105092425303	Tcf	--	--	--	--	--	2.	--	71	--
					GROUND-WATER STUDY SUBDIVISION 111401						
146	340037094215100	Ku	--	2,200	--	--	--	--	--	--	--
147	340040094213801	Ku	--	2,200	--	--	--	--	--	--	--
148	340040094213100	Ku	--	2,200	--	--	--	--	--	--	--
149	340040094213802	Ku	--	2,100	--	--	--	--	--	--	--
150	340052094214000	Ku	--	2,500	--	--	--	--	--	--	--

[1]See figure 3.0-1 for geologic name.

Table 7.0-4--Generalized recharge zones

1. High potential

   A. Flood-plain deposits along major stream channels (not shown on map)
   B. Crowleys Ridge
   C. Upland terraces
   D. Outcrop of Cockfield Formation
   E. Outcrop of Sparta Sand
   F. Outcrop of Wilcox Group (Sand Hills area)
   G. Outcrop of Nacatoch Sand
   H. Outcrop of Tokio Formation
   I. Outcrop of Trinity Group (Cretaceous)
   J. Outcrop of Arkansas Novaculite and Bigfork Chert (Paleozoic)
   K. Paleozoic limestone (north Arkansas)

2. Moderate potential

   A. Low interstream terraces
   B. Outcrop of Cane River Formation, Carrizo Sand, and Wilcox Group (southwest Arkansas)
   C. Paleozoic sandstone and shale

3. Low potential

   A. Interstream terraces
   B. Outcrop of Jackson Group
   C. Outcrop of Cook Mountain Formation
   D. Outcrop of Cane River Formation, Carrizo Sand and Wilcox Group (central Arkansas)
   E. Outcrop of Midway Group
   F. Cretaceous limestone and marl

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