HYDROGEOLOGY AND QUALITY OF GROUND WATER IN THE BOONE FORMATION AND COTTER DOLOMITE IN KARST TERRAIN OF NORTHWESTERN BOONE COUNTY, ARKANSAS

By Valarie A. Leidy and E.E. Morris

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CONVERSION FACTORS

For use of readers who prefer to use metric (International System) units, rather than the inch-pound units used in this report, the following conversion factors may be used:

Multiply inch-pound unit	By	To obtain metric unit
foot (ft)	0.3048	meter (m)
gallon (gal)	3.785	liter (L)
gallon per minute (gal/min)	0.0630	liter per second (L/s)
inch (in.)	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
pound (lb)	0.4536	kilogram (kg)
ton	0.9072	megagram (Mg)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = 1.8 \times °C + 32$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

Shallow ground-water flow systems in karst terrain of northwestern Boone County, Arkansas, are particularly susceptible to contamination. Common sources of contamination include cattle manure, chicken manure, which is applied to pasture land as fertilizer, commercial fertilizers, and septic tank effluent. The potential for ground-water contamination of the karst area probably is greater in the northern one-half of the study area where there are more photolineaments and, presumably, subsurface fractures.

Ground-water samples from 17 springs discharging from the Boone Formation, and 17 wells completed in the Cotter Dolomite, were analyzed to determine ambient ground-water quality and to study water-quality variations in a karst area. The chemical constituents in ground water in northwestern Boone County generally did not exceed U.S. Environmental Protection Agency primary or secondary maximum contaminant levels. However, fecal coliform and fecal streptococcus bacteria were detected in most springs and three wells. One spring, located near an abandoned wood-treatment plant (a designated Superfund site), had maximum iron, manganese, lead, and pentachlorophenol concentrations that exceeded the U.S. Environmental Protection Agency's primary or secondary maximum contamination levels for drinking water.

Based on the Wilcoxon statistical test, water in the Boone Formation and Cotter Dolomite are significantly different. Water in the shallower Boone Formation is substantially higher in nitrate, chloride, and orthophosphate concentrations, and higher in fecal coliform and fecal streptococcus bacteria concentrations, than water in the Cotter Dolomite.

Analyses of water samples collected from selected springs emerging from the Boone Formation revealed significant changes in water quality during and immediately after a rainstorm. Springs sampled during a storm which produced 2 to 3 inches of rain exhibited an overall decrease (dilution effects) in specific conductance and concentrations of total alkalinity, calcium, magnesium, sodium, and chloride, and an overall increase (flushing effects) in concentrations of nitrate, fecal coliform, and fecal streptococcus bacteria within 3 to 8 hours after the rain began. The rapid increase in spring flow as well as rapid changes in chemical and bacteriological concentrations after a rainstorm indicates that ground-water flow may be through large solution channels. Fecal coliform and fecal streptococcus bacterial counts increased from 27 to 25,000 colonies per 100 milliliters and 190 to 43,000 colonies per 100 milliliters, respectively, in one spring after a rainstorm. The changes in ion concentrations associated with the rainstorm were as much as 56 times those associated with seasonal variation.

INTRODUCTION

In 1985 the Arkansas Department of Pollution Control and Ecology, in cooperation with the U.S. Geological Survey, initiated a plan to assess ground-water quality on a statewide basis. Five prototype ground-water study areas were developed, each area in a different hydrogeologic and land-use setting. In 1987 the U.S. Geological Survey, in cooperation with the Arkansas Department of Pollution Control and Ecology, began the first of the five studies. This study was located in northwestern Boone County, an area of karst terrain and is the subject of this report.

Northwestern Boone County was chosen for this study because: (1) the area is underlain by carbonate rocks that generally are susceptible to contamination because of secondary fractures, solution channels, and thin soils, (2) the area contains a Superfund site (U.S. Environmental Protection Agency, 1987) that is contaminated with wood preservatives, and (3) chicken and turkey broiler production is expected to increase dramatically and could have a significant effect on ground-water quality.

Purpose and Scope

The purposes of this report are (1) to describe the hydrogeology of northwestern Boone County, Arkansas, an area containing an extensive well-developed karst terrain, (2) to describe and compare the ambient quality of ground water in the Boone Formation and Cotter Dolomite, and (3) to quantify changes in water quality related to seasonal variations and rainfall. The hydrogeology is described in general terms as it relates to the potential for ground-water contamination. The ambient quality of ground water in the Boone Formation and Cotter Dolomite was described by collecting and analyzing water samples from 17 springs and 17 wells during the period from March to October 1987. Analyses included physical properties, major constituents, nutrients, heavy metals, and bacteria. Water samples from a few selected springs and wells were analyzed for dissolved organic carbon and acid extractable organic compounds used as wood preservatives.

Description of the Study Area

The study area includes approximately 160 mi^2 (square miles) surrounding the town of Omaha in northwestern Boone County, Arkansas (fig. 1). Most of the study area is on the Springfield Plateau; however, the northern and eastern sections are partly on the Salem Plateau (fig. 1). Land-surface altitudes range from 700 feet above sea level in the northeastern corner of the area to more than 1,600 feet near the center of the study area.

The study area is primarily drained by Bear Creek and Long Creek. Bear Creek drains northward into Bull Shoals reservoir, and Long Creek drains northward into Table Rock reservoir (fig. 2).

Approximately 70 percent of the study area is pasture land used to graze cattle (fig. 2). The forested ridgetops in the more mountainous northern half of the study area are being cleared to create more pasture land. Thus, pasture land is becoming more evenly distributed in the study area.

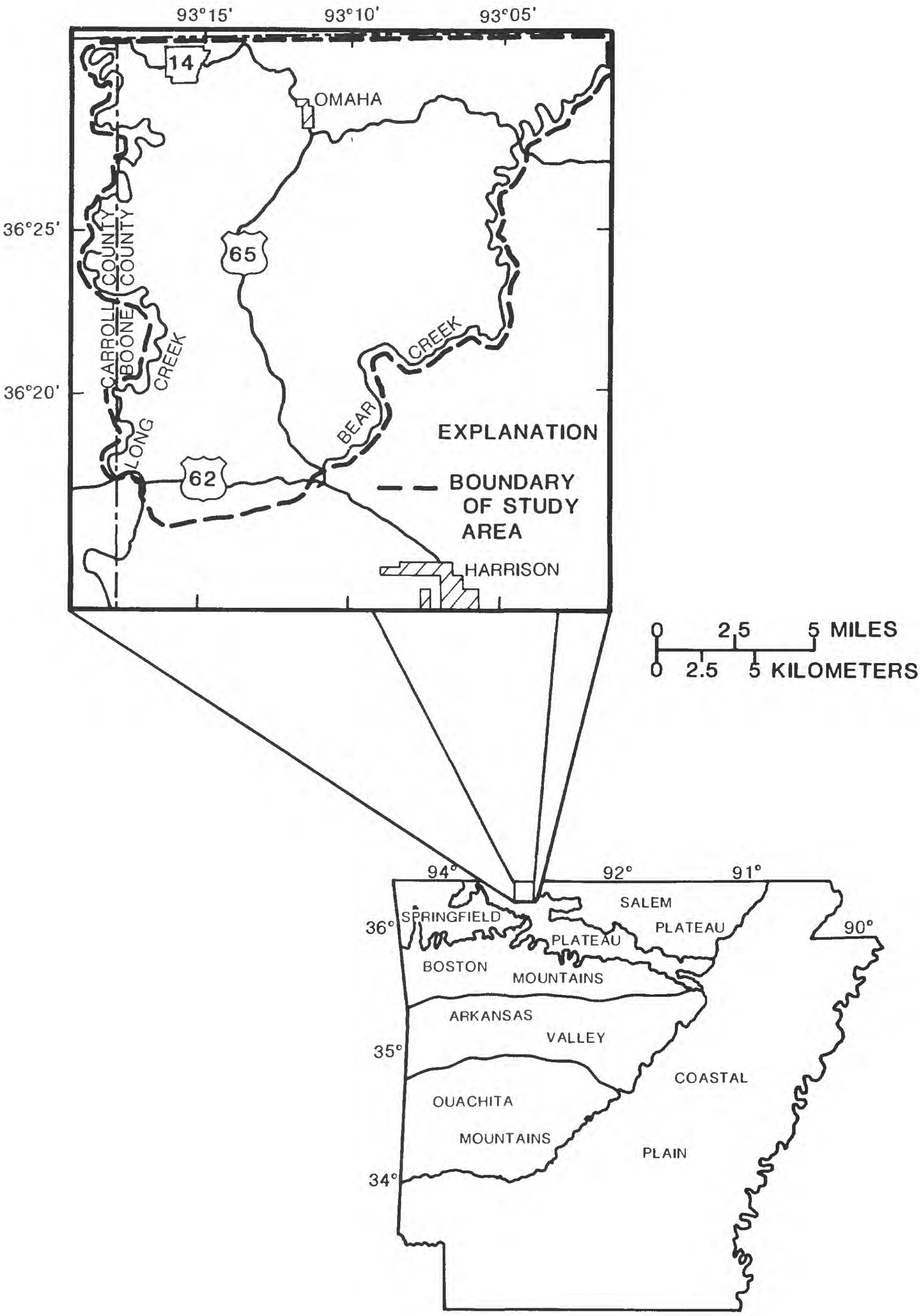
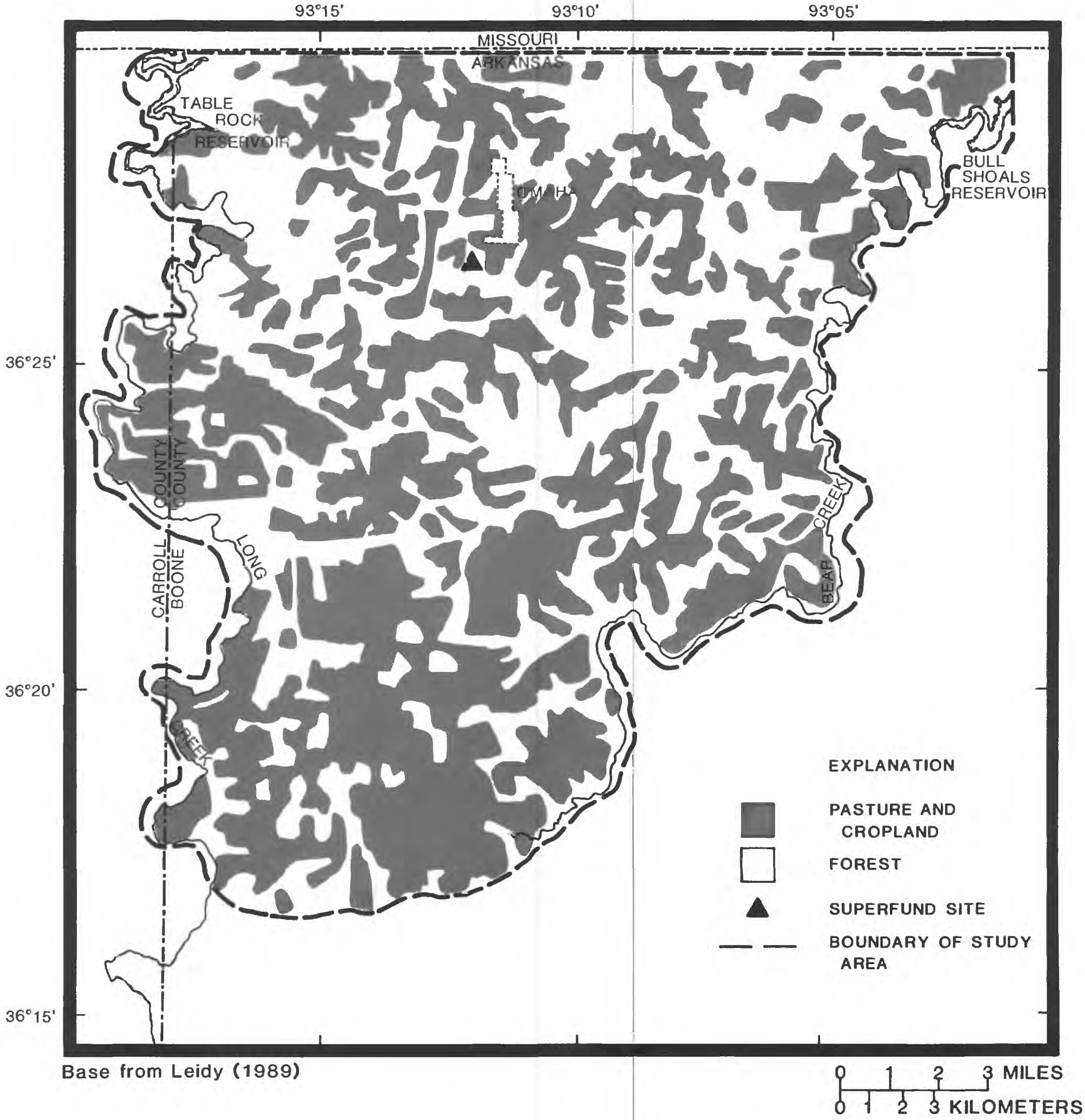


Figure 1.--Location of study area.



Base from Leidy (1989)

Figure 2.--Generalized land use in the study area.

Acknowledgments

The authors wish to thank Dr. Kenneth Steele, professor at the University of Arkansas, for technical guidance and for allowing U.S. Geological Survey personnel use of the University of Arkansas laboratory. Thanks are extended to Dr. Harold MacDonald, professor at the University of Arkansas, for providing airphoto index sheets. A special thanks to Ralph Desmarais, from the Arkansas Department of Pollution Control and Ecology, for his dedicated help in the collection of water samples. The authors also would like to thank the many homeowners in the Omaha area who granted permission and provided assistance in sampling of their wells and springs.

HYDROGEOLOGY

Geologic Setting

Within the study area, the sedimentary section that rests on the Precambrian basement rocks is approximately 5,000 feet thick and consists mainly of Cambrian, Ordovician, and Mississippian age limestone and dolostone with thinner intervals of Devonian and Mississippian age sandstone and shale (table 1) (Frezon and Glick, 1959). Formations pertinent to this investigation include the Batesville Sandstone, Boone Formation, Chattanooga Shale, St. Peter Sandstone, Everton Formation, Powell Dolomite, and Cotter Dolomite (table 1). Rocks exposed in the study area range in age from Middle Ordovician to Mississippian (fig. 3). Surface exposures of Middle Ordovician formations generally coincide with the Salem Plateau, whereas surface exposures of Mississippian formations, that dominate the central part of the study area, coincide with the Springfield Plateau. Cambrian rocks are present but are not discussed in this report.

The Cotter Dolomite, exposed in the northeastern and northwestern corners of the study area (fig. 3), is the oldest formation that is exposed in Boone County. Thicknesses of up to 500 feet have been reported by Caplan (1960) in northern Boone County and counties to the east. The Cotter Dolomite consists of two kinds of rock according to Croneis (1930): a massive, medium-grained, gray rock; and a fine-grained earthy, white to buff rock. Although the formation consists largely of dolostone; shale, chert, and sandstone are present in minor amounts (Croneis, 1930).

The Powell Dolomite, Everton Formation, and St. Peter Sandstone, all Ordovician in age, are thin in the study area and comprise only a small part of the stratigraphic section. These units contain different percentages of sandstone, limestone, and shale.

The Chattanooga Shale, of Devonian and Mississippian age, is exposed in the northwestern corner of the study area and thickens to the west. This unit is very thin and discontinuous, and its extent in the study area is unknown. Typically, the Chattanooga Shale is a black, carbonaceous, highly jointed, fissile shale that unconformably overlies Ordovician or Devonian strata.

The Boone Formation, of Mississippian age, is exposed extensively in the central part of the study area (fig. 3). This formation is absent in the

Table 1.--Generalized correlation of Paleozoic age stratigraphic units and regional geohydrologic units in northern Arkansas

(modified from Imes and Emmett, in press)

Erathem	System	Formation	Geohydrologic unit	Geohydrologic system
Paleozoic	Mississippian	Pitkin Limestone[1]		Western Interior Plains confining system[2]
		Fayetteville Shale[1]		
		Batesville Sandstone		
		Moorefield Formation[1]		
		Boone Formation	Springfield Plateau aquifer	Ozark Plateaus aquifer system
		St. Joe Limestone Member		
	Devonian	Chattanooga Shale	Ozark confining unit	
		Clifty Limestone[1]	Ozark aquifer	
		Penters Chert[1]		
	Silurian	Lafferty Limestone[1]		
		St. Clair Limestone[1]		
		Brassfield Limestone[1]		
	Ordovician	Cason Shale[1]		
		Fernvale Limestone[1]		
		Kimmswick Limestone[1]		
		Plattin Limestone[1]		
		Joachim Dolomite[1]		
		St. Peter Sandstone		
		Everton Formation		
		Smithville Formation[1]		
		Powell Dolomite		
		Cotter Dolomite		
		Jefferson City Dolomite		
		Roubidoux Formation		
		Gasconade Dolomite		
		Van Buren Formation		
		Gunter Sandstone Member[3]		

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[1] Geologic units absent in the study area.

[2] The Western Interior Plains confining system also includes younger sediments south and west of the study area.

[3] Geologic formations of the Cambrian System separate the Ordovician system from the Precambrian basement rocks.

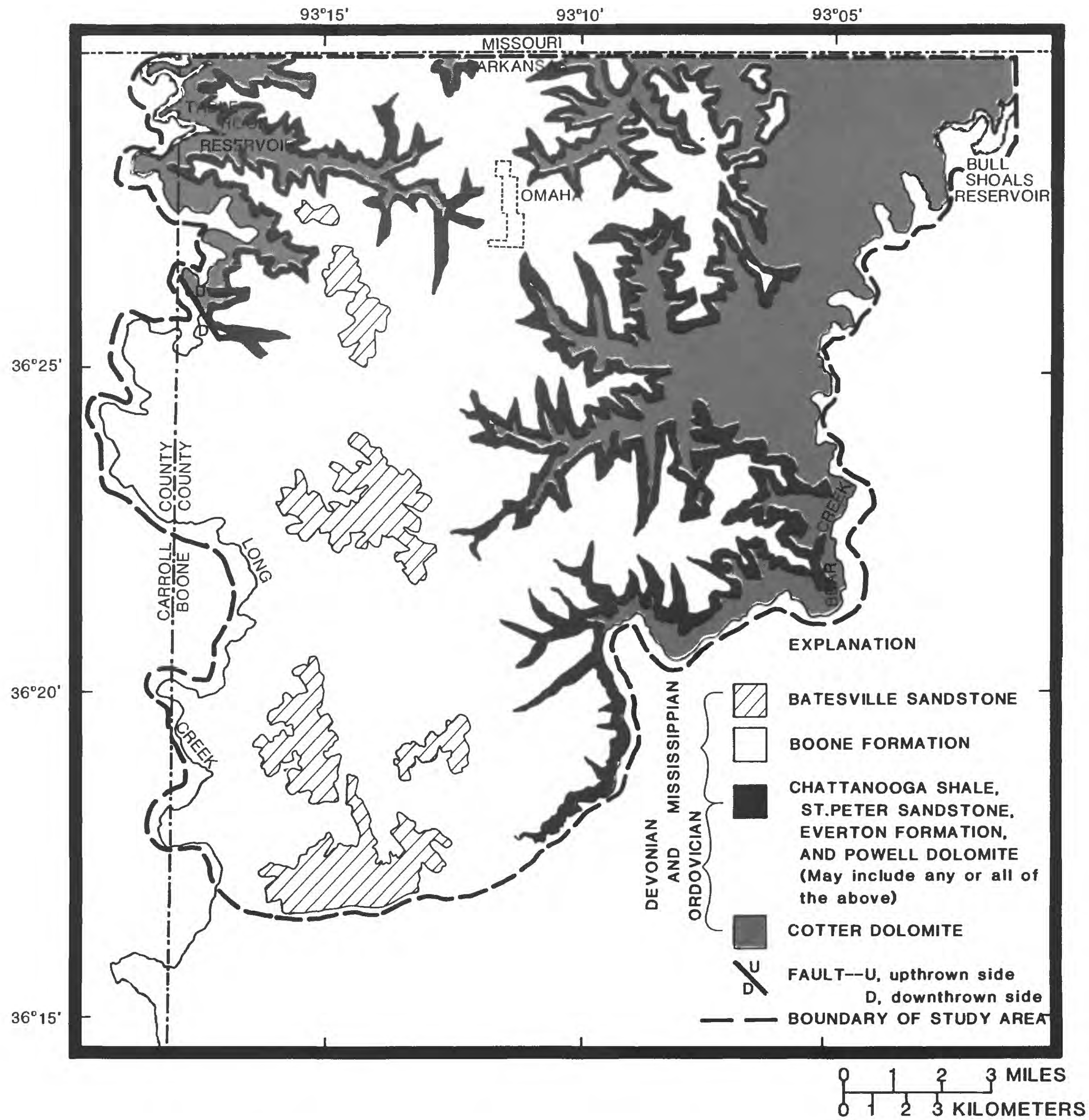


Figure 3.--Generalized bedrock geology of the study area.

northeastern and northwestern corners of the study area where it has been removed by erosion. The Boone Formation reaches a maximum thickness of 375 feet in and around Boone County (Frezon and Glick, 1959). Lithologically, the Boone Formation is composed of gray, crinoidal limestone with up to 70 percent chert, some of which is interbedded (Van den Heuvel, 1979). The St. Joe Limestone member comprises the base of the Boone Formation and lacks the chert nodules that are prevalent in the upper part of the Boone Formation. Thickness of the St. Joe Limestone member ranges from 6 to 84 feet in northern Arkansas (Shanks, 1976).

The Mississippian age Batesville Sandstone overlies the Boone Formation and is exposed sporadically along the western edge of the study area and along isolated hilltops (fig. 3). The Batesville Sandstone is nearly 100 feet thick in the west-central part of the study area and thickens to the southeast. The Batesville is a coarse-to-medium-grained, buff-colored, calcareous sandstone (Croneis, 1930).

Aquifer Systems

Paleozoic rocks in northern Arkansas comprise a part of the Ozark Plateaus aquifer system. According to Imes and Emmett (in press), the upper section of consolidated rocks in the Ozark Plateaus aquifer system is divided into the Springfield Plateau aquifer, Ozark confining unit, and Ozark aquifer (table 1). The major water-bearing units in the area of this investigation, the Boone Formation and Cotter Dolomite, are part of the Springfield Plateau aquifer and Ozark aquifer, respectively. The Western Interior Plains confining system overlies and confines the Ozark Plateaus aquifer system (table 1).

Water in the Boone Formation generally is unconfined in the study area. Recharge is from infiltration of precipitation on the outcrop. Dissolution along the fractures and bedding planes in the limestone of the Boone Formation are the main processes which produce abundant caves, solution channels, and sink holes. Local ground-water movement in the Boone Formation largely is controlled by fracture orientation, small streams, topography, and geology. A small fraction of water in the Boone Formation discharges downward through the Chattanooga Shale (Ozark confining unit) into the deeper flow system; however, the majority of discharge is from springs that issue from solution-enlarged fractures in the Boone Formation. A few residents utilize springs in the Boone Formation as a source of domestic drinking water.

Wells in the study area primarily are open to the Cotter Dolomite, which is part of the Ozark aquifer (table 1). Wells penetrating the Cotter Dolomite range in depth from 350 to 700 feet and commonly yield 5 to 10 gal/min (gallons per minute) (Lamonds, 1972) with depth to water ranging from 100 to 500 feet below land surface. Recharge is by infiltration of precipitation where the Cotter Dolomite is exposed at land surface and by leakage through the overlying units elsewhere. In upland areas, water in the Cotter Dolomite discharges into deeper units. Where the Cotter Dolomite is exposed in deeply incised valleys, discharge may occur as springs and seeps along valley walls.

A 1987 potentiometric surface map of water in the Cotter Dolomite (fig. 4) was constructed based on 43 water-level measurements, topography, and

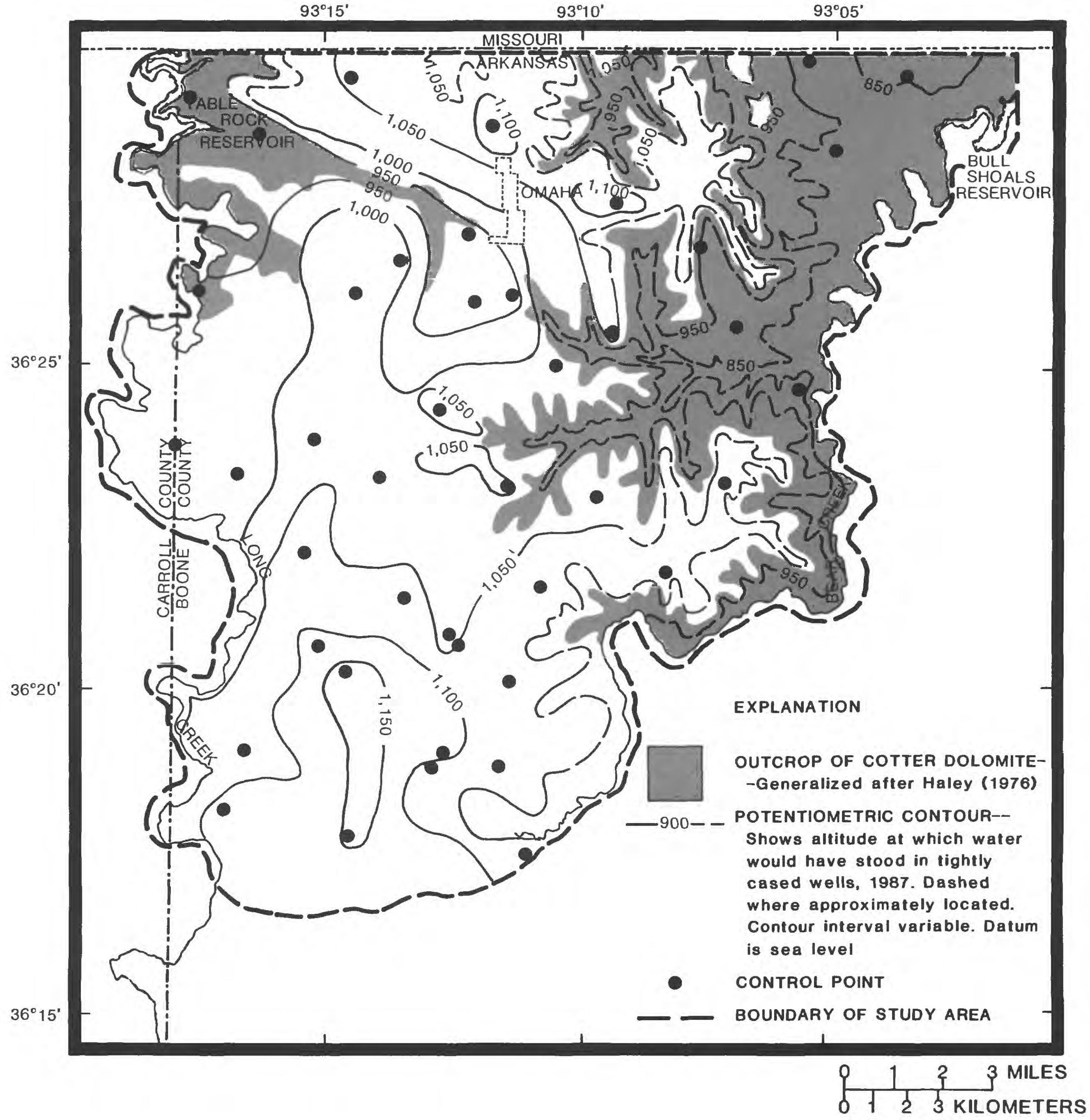


Figure 4.--Potentiometric surface in the Cotter Dolomite, 1987.

geology. The contours form a subdued reflection of the land surface where the Cotter Dolomite is exposed (fig. 4). Where control points were inadequate and where water in the Cotter Dolomite is unconfined, topography and surface drainage were used to determine placement of contour lines. Regional ground-water flow in the Cotter Dolomite appears to be from ground-water highs (west of Ridgeway and north and east of Omaha) toward the major streams bordering the study area (fig. 4). Departures from the regional pattern of ground-water movement may occur in local areas in response to topography and where solution-enlarged fractures and joints are present.

Photolineaments

Photolineaments can provide information for understanding the structural and hydrologic characteristics of an area. Lattman (1958) defined a lineament as a natural linear feature manifested in such forms as topographic, soil tonal, and vegetation alignments, which is expressed continuously for at least 1 mile. Lineaments commonly are visible on aerial photographs and satellite images and are considered to be surface expressions of major subsurface fracture zones. Lineaments are thought to be the result of tensional and compressional stresses that produce fractures and joints. These fractures and joints can provide pathways or conduits for increased movement of ground water and, therefore, are important for recharging major karst springs. The purpose of mapping lineaments in this study was to locate probable areas of increased ground-water flow, and therefore areas with increased potential for contaminant transport.

An airphoto index sheet of Boone County (scale 1:63360) prepared by the U.S. Agriculture Stabilization and Conservation Service (1965) was used to make a photolineament map for northwestern Boone County (fig. 5). Seventy-three lineaments were recognized on the basis of straight stream segments and tonal anomalies. Numerous linear fracture traces less than 1 mile in length also were noted but are not shown in figure 5. Gaines (1978) points out that short straight stream segments in rugged topography may not be due to fracture control but to the force of gravity inducing streamflow to travel straight downhill.

Rose diagrams show the major orientation of photolineaments in the study area (fig. 6). On the basis of their number and length, the photolineaments have bimodal orientations with dominant northwest bearings.

Potential for Ground-Water Contamination

Factors that influence the potential for ground-water contamination in the study area include rock type, the presence or absence of solution-enlarged fractures and joints, ground-water flow directions, soil type and thickness, and land use. Near surface fractures, solution channels and losing streams can provide recharge water and possible surface contaminants with direct passageways to the aquifers. The rate at which recharge waters move into the ground-water system is accelerated if a storm occurs. Runoff can carry potential contaminants directly downslope into fractures in the rocks. Because photolineaments, which may indicate subsurface fractures, are more prevalent in the northern one-half of the study area, the potential for

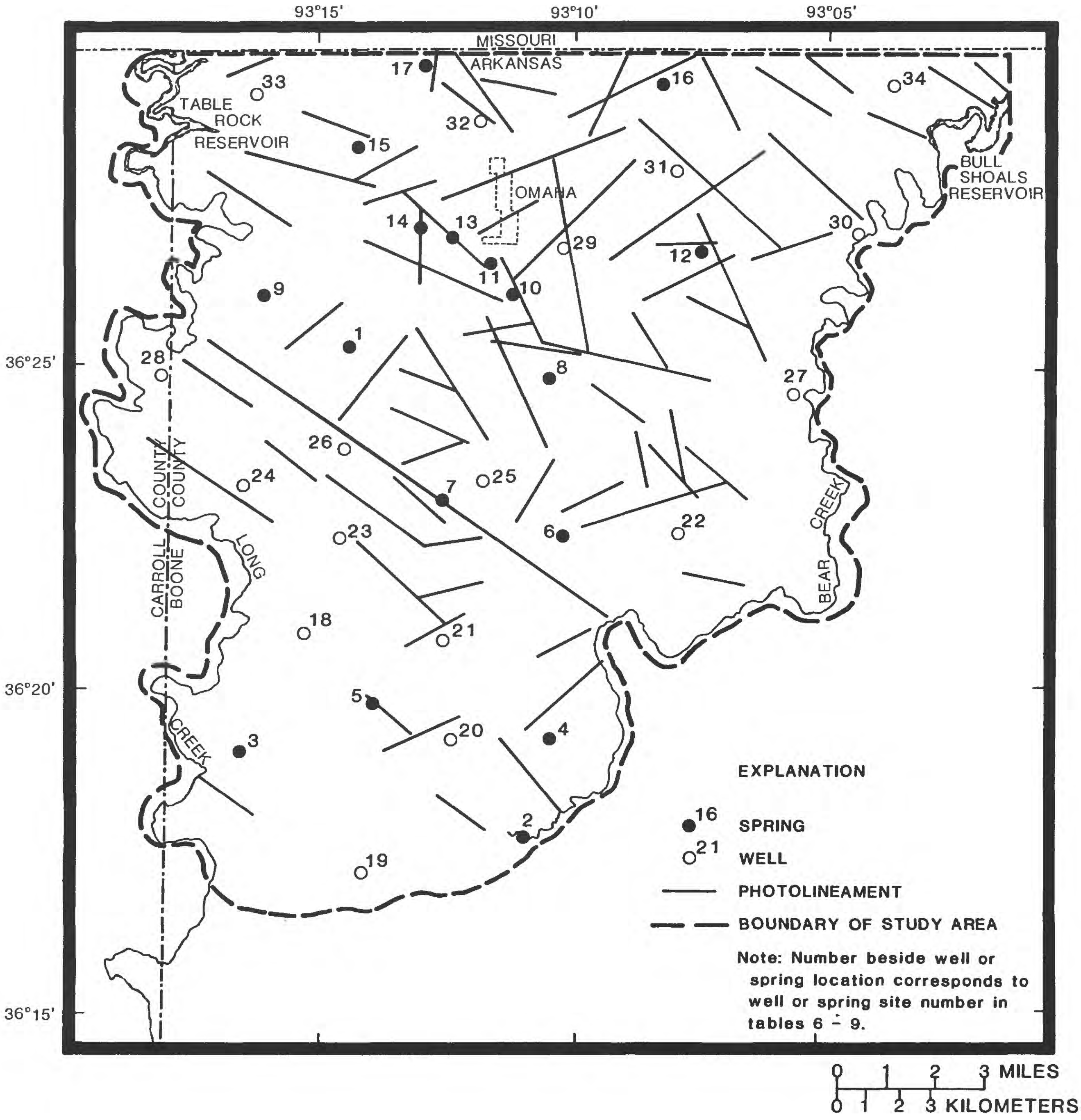


Figure 5.--Photolineaments in the study area.

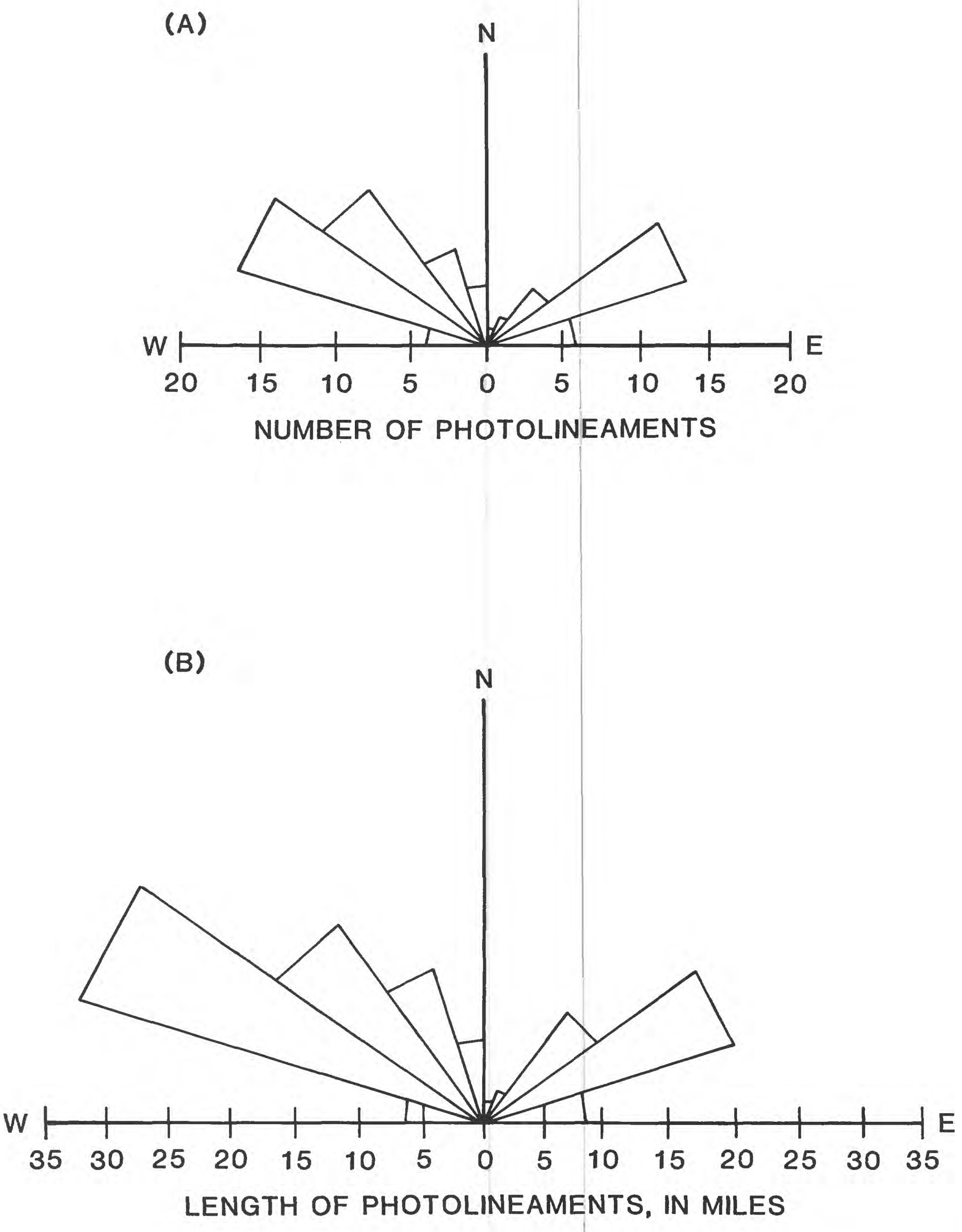


Figure 6.--Photolineament orientation rosettes for study area (A) number of photolineaments and (B) sum of photolineament lengths in miles.

contaminants to enter the aquifers probably is greater there than in other parts of the area. The potential for contaminants to enter the aquifer also is greater on slopes where soils are thin. These thin soils are usually well drained and contain little clay; thus surface contaminants are less likely to be adsorbed on clay surfaces and more likely to be flushed into the fractured bedrock.

Animal manure probably is the principal source of potential contaminants in the study area. Cattle manure may be the largest contributor to bacterial and nutrient contamination, with approximately 70 percent of the study area being used to graze cattle (fig. 2). Chicken litter is also a major source of contamination. In 1987, 89 poultry houses within the study area produced approximately 7,800 tons of chicken litter (Steele and Adamski, 1987). Most of the litter is sold to farmers who apply it to pastures in the spring. Potential contaminants from the animal wastes include: nitrate, potassium, orthophosphate, sodium, chloride, fecal coliform, and fecal streptococci.

Another possible source of contamination is effluent from private septic tanks used at virtually every home and business in the study area. The Nixa soils that predominate in the area around Omaha have been given a "severe hazard rating" by the U.S. Soil Conservation Service for septic tank absorption fields because percolation rates through the very thin soils are slow (Harper and others, 1981). Potential contaminants include nitrate, potassium, orthophosphate, sodium, chloride, fecal coliform, and fecal streptococci.

A U.S. Environmental Protection Agency Superfund site (U.S. Environmental Protection Agency, 1986c) (fig. 2) located just south of Omaha is a known source of contamination. This site is a point source of pentachlorophenol and possibly other contaminants, and has contaminated the water in the shallow Boone Formation in the immediate area. Contaminants could spread by seepage through the soil at the plant site into the underlying limestone or lateral seepage into the nearby creek. However, wastes deposited in a cave on the site constitute the principal threat for contamination of ground water in the area. Wastes from the wood treatment operation were dumped into the cave from the early 1960's to around 1970, when the increasing cost of the chemical used in the treatment process forced use of a recovery system. The entrance to the cave has been boarded and covered with a layer of soil. The wastes consisted of liquid from the washing of the treatment room floor and treatment equipment. The wastes also were collected in a tank and spread over the storage yard to control dust. The plant has not operated since 1985 (Ralph Desmarais, Arkansas Department of Pollution Control and Ecology, written commun., 1987).

DATA COLLECTION

Water-Quality Sampling

The ambient ground-water quality for northwestern Boone County was determined by sampling selected springs and wells from the study area. Two springs adjacent to the Superfund site also were sampled in order to ascertain the areal extent of contamination from the site. The remainder of the springs were located using topographic maps and through discussions with local residents.

During the period from March 1987 to June 1987, water samples were collected from 16 springs discharging from the Boone Formation, 1 spring discharging from the Batesville Sandstone, 16 wells completed in the Cotter Dolomite, and 1 well completed in the Boone Formation. Fifteen spring sites were resampled within 12 hours of a rainstorm to detect changes in the water quality in response to storms. During the period from late September 1987 to early October 1987, all 34 spring and well sites were resampled to establish differences in water chemistry related to season. In mid-September three springs were sampled five times during and after a rainstorm to further study the effects of rain on water chemistry.

Spring discharge measurements were made when possible. Discharges of smaller springs were measured using a 4-gallon bucket and timer; whereas, discharges of larger springs were measured using stream-gaging techniques described by Carter and Davidian (1968).

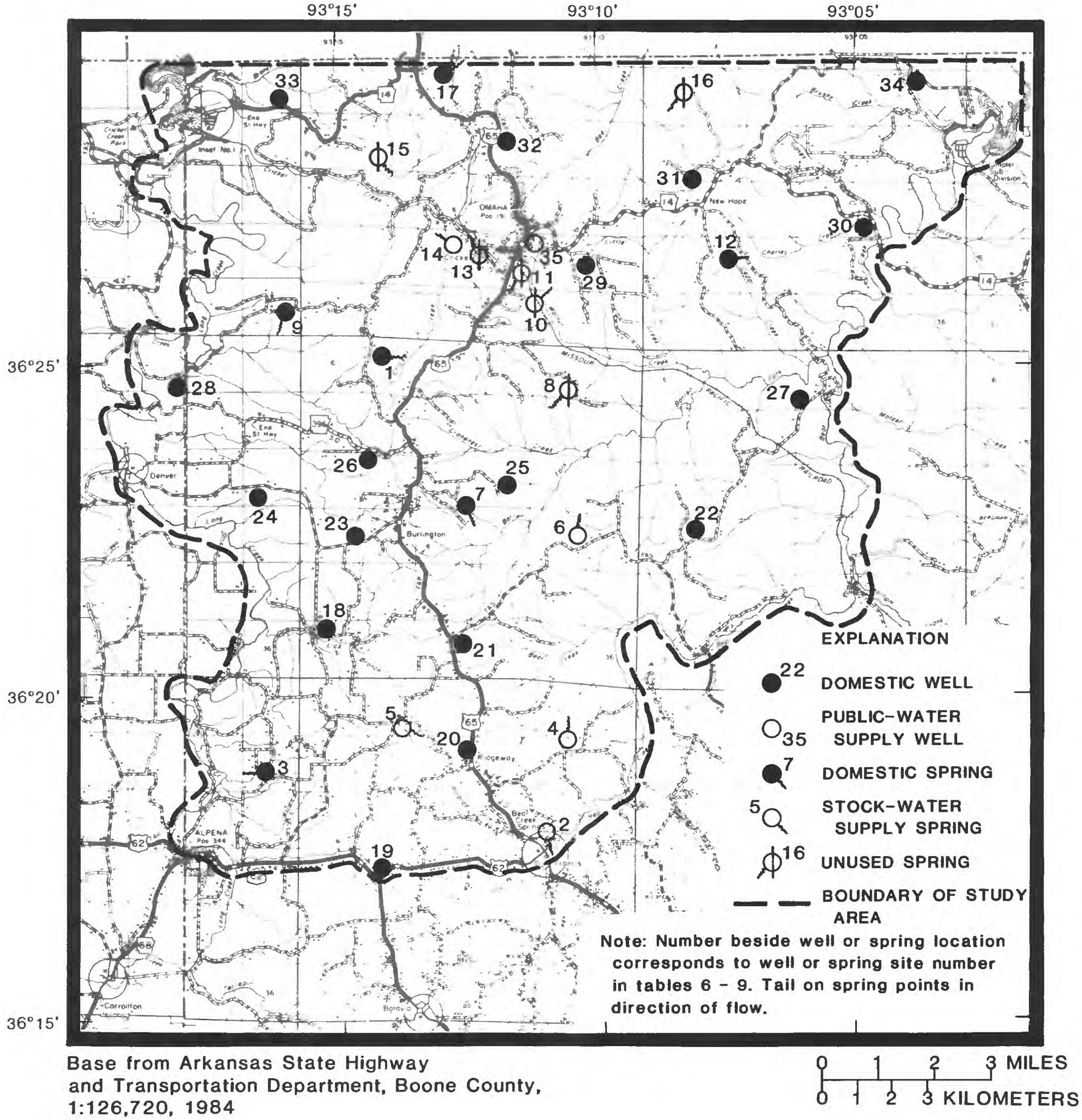
The location and site number of the wells and springs sampled are shown on figure 7. The station number and local identifier corresponding to each site number in tables 6 through 9 (at the end of report) identify the well or spring in the U.S. Geological Survey's National Water Information System (NWIS).

Laboratory Analysis

Water samples were analyzed by the University of Arkansas and the U.S. Geological Survey. Samples analyzed by the University of Arkansas were used in the statistical evaluation of water quality in the study area. Samples analyzed by the U.S. Geological Survey were part of a duplicate sampling effort for quality-control purposes.

Laboratory analyses made by the University of Arkansas included nitrate-nitrogen, phosphate, sulfate, chloride, ammonia-nitrogen, manganese, iron, lead, zinc, cadmium, cobalt, nickel, copper, calcium, magnesium, sodium, and potassium. Nitrate-nitrogen and phosphate concentrations were determined by colorimetric methods (cadmium-reduction and ascorbic acid methods, respectively). Sulfate and chloride determinations were made using the turbidimetric and mercuric nitrate titration methods, respectively. All four of these analyses were carried out following U.S. Environmental Protection Agency methods (U.S. Environmental Protection Agency, 1983; Hach Chemical Co., 1984). The ammonia-nitrogen analysis was performed using the phenate method as outlined by the American Public Health Association (1985). Heavy metals (manganese, iron, lead, zinc, cadmium, cobalt, nickel, and copper) were determined by atomic absorption spectrophotometry. Chelation and extraction techniques were used to concentrate the metals prior to analysis (Nix and Goodwin, 1970). Calcium and magnesium also were analyzed by atomic absorption spectrophotometry; and sodium and potassium were determined by flame emission spectrophotometry (Perkin Elmer Corporation, 1973; American Public Health Association, 1985). Cesium chloride was added to calcium, magnesium, sodium, and potassium analyses to minimize ionization interferences in the flame.

The analysis of samples by the U.S. Geological Survey were completed according to guidelines set forth by Stevens and others (1975), Wood (1976), Skougstad and others (1979), Goerlitz and Brown (1972), Greeson and others



Base from Arkansas State Highway
and Transportation Department, Boone County,
1:126,720, 1984

Figure 7.--Sample site locations and site numbers in study area.

(1977), and Friedman and Erdmann (1982). Additional constituents analyzed by the U.S. Geological Survey but not analyzed by the University of Arkansas laboratory included carbon dioxide, fluoride, silica, dissolved solids, arsenic, boron, chromium, strontium, aluminum, selenium, mercury, dissolved organic carbon, and acid extractable organic compounds used as wood preservatives. All bacteria analyses were made using the membrane filter method (Greeson and others, 1977). A gas-chromatograph flame-ionization detector was used to scan for the presence of organic substances and to provide a semiquantitative estimate of the concentration of the substances found. Tables 7 and 9 show the number of organic substances found in each sample with identifiable peaks greater than 10 percent of an internal standard of 23 µg/L (micrograms per liter) perdeuteronaphthalene.

Duplicate samples were analyzed by both the U.S. Geological Survey and the University of Arkansas for 15 spring sites and 6 well sites, as part of the quality-control program and assessment of analytical accuracy. Results of the duplicate analyses are given in tables 6 and 8. Results of the analyses by the two laboratories generally are in good agreement. Both laboratories performed very well in an interlaboratory testing program conducted by the U.S. Geological Survey and analytical results from both laboratories have been stored in the U.S. Geological Survey water-quality data base.

To further ensure quality control, cation/anion balances were determined for all samples. The percent difference between cation (calcium, magnesium, sodium, potassium, iron, manganese) and anion (chloride, sulfate, alkalinity, nitrate) concentrations in meq/L (milliequivalents per liter) for each sample are listed in tables 6 and 8.

AMBIENT GROUND-WATER QUALITY

Water Quality in the Boone Formation

The water from the majority of springs sampled in this study was from the Boone Formation and the chemical analyses of these samples are indicative of the quality of water in the formation. Water-quality data from springs are listed by site number in tables 6 and 7. Water samples from 14 springs were grouped for statistical summary and comparison by "wet season" and "dry season." Water samples collected in mid-March, early May, and mid-June when recharge is large were grouped as "wet season" samples, and those collected in late September and early October when recharge is small were grouped as "dry season" samples. Summary statistics for each season (table 2) generally indicate that water in the Boone Formation is potable with respect to inorganic and organic constituents with the exception of water from site 13, which contained pentachlorophenol. However, bacteria were detected in samples from all spring sites, except site 13 where wood treatment chemicals may have killed the bacteria (table 6). An average calcium to magnesium ratio of 23.8 for all samples indicates that the waters were from limestone aquifers (Meisler and Becker, 1967).

Table 2.--Descriptive statistics for wet- and dry-season water quality for water in the Boone Formation

[N=number of samples; gal/min=gallons per minute; °C=degrees Celsius; µS/cm=microsiemens per centimeter at 25 degrees Celsius; mg/L=milligrams per liter; µg/L=micrograms per liter; mL=milliliter; five digit numbers in parentheses are STORET parameter codes used for computer storage of data. Concentrations less than the detection limit were set to one-half of the detection limit for calculation of these statistics]

		Descriptive statistics				
Property	Season	N	Mean	Standard deviation	Median	Range
Flow rate (gal/min) (00059)	wet	14	137.2	367.8	8.5	1.5-1,400
	dry	14	102.0	345.7	4.5	.9-1,302
Temperature (°C) (00010)	wet	14	14.1	1.5	14.0	12.0-17.0
	dry	14	15.2	.9	15.0	14.0-17.5
Specific conductance (µS/cm) (00095)	wet	14	344.9	82.8	331.5	240-492
	dry	14	417.6	77.9	435.0	288-539
Hardness (mg/L as CaCO$_3$) (00900)	wet	14	158.1	48.8	160.0	83-220
	dry	14	185.7	49.7	190.0	110-270
Carbon dioxide (mg/L) (00405)	wet	14	28.6	39.9	11.5	5.5-158.0
	dry	14	14.9	14.4	9.7	1.7- 48.0
pH (units) (00400)	wet	14	7.2	.4	7.2	6.2-7.6
	dry	14	7.5	.4	7.5	6.9-8.1
Alkalinity (mg/L as CaCO$_3$) (00410)	wet	14	135.1	53.0	132.0	54-200
	dry	14	167.1	56.6	150.0	106-274
Nitrogen, nitrite plus nitrate (mg/L as N) (00631)	wet	14	2.10	2.78	1.07	.80-10.75
	dry	14	2.78	3.53	1.10	.02-11.20
Nitrogen, ammonia dissolved (mg/L as N) (00608)	wet	14	.04	.06	.02	.01-.20
	dry	14	.02	.03	.01	.01-.10
Chloride, dissolved (mg/L as Cl) (00940)	wet	14	7.41	3.96	6.50	2.00-15.00
	dry	14	10.04	6.01	8.30	1.74-20.25
Sulfate, dissolved (mg/L as SO$_4$) (00945)	wet	14	4.6	2.1	3.5	1.5-9.2
	dry	14	4.3	3.0	3.0	1.5-9.8
Phosphorus, ortho, dissolved (mg/L as P) (00671)	wet	14	.03	.03	.02	.01-.12
	dry	14	.04	.05	.03	.01-.16
Calcium, dissolved (mg/L as Ca) (00915)	wet	14	59.5	20.4	58.5	29.0- 85.3
	dry	14	68.3	21.2	69.5	36.0-104.0

Table 2.--Descriptive statistics for wet- and dry-season water quality for water in the Boone Formation--Continued

Property	Season	N	Mean	Standard deviation	Median	Range
		Descriptive statistics				
Magnesium, dissolved (mg/L as Mg) (00925)	wet	14	2.26	0.75	2.30	1.3-4.2
	dry	14	3.22	1.45	2.95	1.5-6.6
Sodium, dissolved (mg/L as Na) (00930)	wet	14	3.86	1.81	3.20	2.1- 8.2
	dry	14	4.90	3.19	3.45	2.6-13.0
Potassium, dissolved (mg/L as K) (00935)	wet	14	1.59	.98	1.35	.5-4.6
	dry	14	2.62	2.06	1.90	1.0-9.3
Manganese, dissolved (µg/L as Mn) (01056)	wet	13	6.2	13.0	2.0	.5- 47.0
	dry	14	40.3	141.3	1.0	1.0-531.0
Iron, dissolved (µg/L as Fe) (01046)	wet	13	14.8	36.8	4.0	1.0-137.0
	dry	14	16.6	40.7	5.0	5.0-158.0
Lead, dissolved (µg/L as Pb) (01049)	wet	13	13.3	21.2	10.0	1.0- 82.0
	dry	14	12.4	35.7	2.0	1.0-136.0
Zinc, dissolved (µg/L as Zn) (01090)	wet	13	8.3	8.7	6.0	.4-33.0
	dry	14	7.5	7.0	5.5	1.0-27.0
Cadmium, dissolved (µg/L as Cd) (01025)	wet	13	.8	1.6	.3	.3- 6.0
	dry	14	2.0	4.1	1.0	.3-16.0
Nickel, dissolved (µg/L as Ni) (01065)	wet	13	4.2	6.3	3.0	1.5-25.0
	dry	14	8.5	18.9	2.5	2.5-74.0
Cobalt, dissolved (µg/L as Co) (01035)	wet	13	2.2	2.5	2.0	.5-10.0
	dry	14	5.6	13.6	2.0	2.0-53.0
Copper, dissolved (µg/L as Cu) (01040)	wet	13	1.4	.3	1.5	1.0-2.0
	dry	14	1.1	.3	1.0	1.0-2.0
Fecal coliform (colonies/ 100 mL) (31625)	wet	13	22.9	31.9	7.0	<1-96
	dry	14	298.9	745.0	27.0	<1-2,800
Fecal streptococci (colonies/ 100 mL (31673)	wet	8	631.1	1,145.2	95.0	14-3,380
	dry	14	905.7	2,295.2	185.0	<1-8,800

Inorganic Constituents

The water in the Boone Formation is a calcium-bicarbonate type that is hard to very hard (Hem, 1985) with median hardness values (as $CaCO_3$) of 160 mg/L (milligrams per liter) and 190 mg/L for wet and dry seasons, respectively (table 2). Specific conductance of samples that were not collected during rainstorms, ranged from 240 µS/cm (microsiemens per centimeter at 25 degrees Celsius) to 539 µS/cm (table 2). Specific conductance is proportional to the dissolved minerals in the water. At all springs, fluoride, chloride, sulfate, and total dissolved solids concentrations (table 6) were well within the standards established in the National Interim Primary and Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1986a; 1986b).

High concentrations of nitrate, nitrite, and orthophosphate in rural ground water is indicative of possible contamination by fertilizer, manure, or septic tank effluent. Nitrate plus nitrite concentrations in water from one spring (site 16) exceeded the U.S. Environmental Protection Agency (USEPA) primary maximum contaminant level of 10 mg/L as N (U.S. Environmental Protection Agency, 1986a) with a mean concentration of 11.1 mg/L as N (table 6). However, nitrate plus nitrite concentrations in water from most springs were less than 3.0 mg/L as N. Median nitrate plus nitrite concentrations for wet- and dry-season samples were 1.07 mg/L and 1.10 mg/L as N, respectively (table 2). Orthophosphate concentrations generally were low and median concentrations were 0.02 mg/L and 0.03 mg/L as P for wet- and dry-season samples, respectively (table 2). The two springs that had the highest concentrations of nitrate plus nitrite and orthophosphate were sites 11 and 16 (table 6).

The trace metal concentrations of water from springs were small with the exception of sites 9 and 13. The zinc concentration at site 9 was anomalously high (690 µg/L) (table 6) relative to the wet and dry season median concentrations of 6.0 µg/L and 5.5 µg/L, respectively (table 2). Because this spring was sampled from a faucet approximately 80 feet from the spring, the high concentration of zinc at this site is most likely due to galvanized pipes in the plumbing (Wagner and others, 1976), although another possible source for the zinc could be minerals in the aquifer (Steele and Dilday, 1984). Water from spring site 13 contained iron, manganese, and lead in concentrations that exceeded the USEPA primary and secondary maximum contaminant levels of 0.3 mg/L, 0.05 mg/L, and 0.05 mg/L for drinking water, respectively (U.S. Environmental Protection Agency, 1986a; 1986b) (table 6). Cobalt, nickel, and cadmium concentrations also were elevated at site 13 relative to the other springs (table 6). Site 13 is located within 1/4 mile of an abandoned wood treatment plant (Superfund site).

Bacteria

Fecal coliform and fecal streptococcus bacteria normally are present in the large intestines of humans and other warm-blooded animals. These bacteria are used as indicators of fecal contamination and the possible presence of pathogenic microorganisms. Generally, a ratio of fecal coliform to fecal streptococcus bacteria of 4.0 or more indicates human sources of contamination and a ratio of 0.7 or less indicates livestock sources of contamination (U.S. Environmental Protection Agency, 1978).

All springs sampled contained fecal coliform and fecal streptococcus bacteria except site 13 near the Superfund site (table 6). Average fecal coliform to fecal streptococcus ratios for the wet season (0.05) and the dry season (0.33) indicate that the source of bacterial contamination in water from the springs was probably livestock wastes.

Organic Constituents

Samples from springs in the area were analyzed for selected organic constituents including dissolved organic carbon and 11 acid extractable compounds (table 7). Dissolved organic carbon concentrations ranged from 0.5 mg/L to 4.6 mg/L as carbon (table 7). A gas chromatograph flame-ionization scan detected 49 organic chemicals in the spring water from site 13, adjacent to the Superfund site. Water from this spring and two other springs adjacent to the Superfund site (sites 10 and 14) were analyzed for acid extractable compounds used as wood preservatives. Measurable concentrations of organic constituents were detected only at site 13. Water from site 13 had a pentachlorophenol concentration of 1,200 µg/L (table 7). The proposed U.S. Environmental Protection Agency maximum contaminant level for pentachlorophenol is 200 µg/L (U.S. Environmental Protection Agency, 1985).

Water Quality in the Cotter Dolomite

The majority of well water samples in this study were obtained from wells completed in the Cotter Dolomite, and the chemical analyses of these samples are indicative of the chemical quality of water in the Cotter Dolomite. Water-quality data for the water from these wells are listed by site number in tables 8 and 9. Water samples from 16 wells were grouped for statistical summary and comparison by "wet season" (large recharge rates) and "dry season" (small recharge rates) in the same manner as the springs. Summary statistics for each season (wet and dry) indicate that water in the Cotter Dolomite is suitable for human consumption (table 3). An average calcium to magnesium ratio of 2.2 for all samples indicated that the waters had been in contact with a dolomite (Meisler and Becker, 1967).

Inorganic Constituents

The water in the Cotter Dolomite is a very hard calcium-magnesium-bicarbonate type with median hardness values of 260 mg/L and 240 mg/L for wet- and dry-season samples, respectively (table 3). Specific conductance of water samples from the Cotter Dolomite ranged from 360 to 700 µS/cm. Fluoride, chloride, sulfate, and total dissolved-solids concentrations (table 8), were well within standards established in the National Interim Primary and Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1986a; 1986b).

Nitrate plus nitrite concentrations generally were less than 1.0 mg/L in all wells with the exception of site 28, which had elevated concentrations of 2.01 mg/L and 3.24 mg/L as N for wet- and dry-season samples, respectively (table 8). Median nitrite plus nitrate concentration for all wells was 0.13 mg/L as N for the wet season and 0.18 mg/L as N for the dry season (table 3).

Table 3.--Descriptive statistics for wet- and dry-season water quality for water in the Cotter Dolomite

[N=number of samples; °C=degrees Celsius; µS/cm=microsiemens per centimeter at 25 degrees Celsius; mg/L=milligrams per liter; µg/L=micrograms per liter; mL=milliliter; five digit numbers in parentheses are STORET parameter codes used for computer storage of data. Concentrations less than the detection limit were set to one-half of the detection limit for calculation of these statistics]

		Descriptive statistics				
Property	Season	N	Mean	Standard deviation	Median	Range
Temperature (°C) (00010)	wet	16	17.3	2.0	16.8	13.5-22.0
	dry	16	17.8	1.4	18.0	16.0-20.0
Specific conductance (µS/cm) (00095)	wet	16	511.6	98.6	540.0	360-680
	dry	16	512.4	109.7	529.0	362-700
Hardness (mg/L as $CaCO_3$) (00900)	wet	16	253.1	61.2	260.0	170-380
	dry	16	253.1	68.0	240.0	180-390
Carbon dioxide (mg/L) (00405)	wet	16	31.8	27.7	22.5	3.2-102.0
	dry	16	34.1	20.9	28.0	12.0- 82.0
pH (units) (00400)	wet	16	7.3	.3	7.3	6.9-7.9
	dry	16	7.2	.2	7.2	6.9-7.6
Alkalinity (mg/L as $CaCO_3$) (00410)	wet	16	244.3	54.7	237.0	133-334
	dry	16	221.0	59.6	227.0	110-338
Nitrogen, nitrite plus nitrate (mg/L as N) (00631)	wet	16	.27	.49	.13	.02-2.01
	dry	16	.44	.82	.18	.02-3.24
Nitrogen, ammonia dissolved (mg/L as N) (00608)	wet	16	.05	.11	.01	.01-.37
	dry	16	.08	.07	.08	.01-.20
Chloride, dissolved (mg/L as Cl) (00940)	wet	16	2.89	2.10	2.25	.50-8.00
	dry	16	3.98	2.54	3.33	1.15-8.90
Sulfate, dissolved (mg/L as SO_4) (00945)	wet	16	26.5	10.3	23.8	14.4-52.0
	dry	16	30.7	18.6	20.8	14.6-72.0
Phosphorus, ortho, dissolved (mg/L as P) (00671)	wet	16	.01	.01	.01	.01-.04
	dry	16	.003	.003	.003	.01-.01
Calcium, dissolved (mg/L as Ca) (00915)	wet	16	59.2	15.5	60.0	37.0-92.0
	dry	16	56.1	13.4	58.5	38.0-75.0
Magnesium, dissolved (mg/L as Mg) (00925)	wet	16	25.84	9.96	21.8	7.8-46.8
	dry	16	27.20	10.79	23.00	11.2-49.6
Sodium, dissolved (mg/L as Na) (00930)	wet	16	5.04	4.52	2.75	1.5-15.5
	dry	16	6.04	6.78	2.70	1.4-24.0

Table 3.--Descriptive statistics for wet- and dry-season water quality for water in the Cotter Dolomite--Continued

Property	Season	Descriptive statistics				
		N	Mean	Standard deviation	Median	Range
Potassium, dissolved (mg/L as K) (00935)	wet	16	2.90	1.64	3.00	1.0-6.2
	dry	16	3.60	1.83	3.70	1.2-6.3
Manganese, dissolved (µg/L as Mn) (01056)	wet	16	2.1	1.3	2.0	.1-4.0
	dry	16	1.4	.5	1.0	1.0-2.0
Iron, dissolved (µg/L as Fe) (01046)	wet	16	9.6	7.2	7.0	4.0-29.0
	dry	16	14.9	21.1	8.0	.5-90.0
Lead, dissolved (µg/L as Pb) (01049)	wet	16	8.1	5.5	7.0	2.0-16.0
	dry	16	1.2	.4	1.0	1.0- 2.0
Zinc, dissolved (µg/L as Zn) (01090)	wet	16	768.1	523.4	628.0	129-1,900
	dry	16	405.2	407.1	263.1	67-1,439
Cadmium, dissolved (µg/L as Cd) (01025)	wet	16	.6	.6	.3	.3-2.0
	dry	16	.5	.5	.3	.3-2.0
Nickel, dissolved (µg/L as Ni) (01065)	wet	16	2.9	.4	3.0	1.5-3.0
	dry	16	2.7	.6	3.0	2.5-5.0
Cobalt, dissolved (µg/L as Co) (01035)	wet	16	2.3	1.0	2.0	.1-4.0
	dry	16	2.0	.0	1.0	1.0-1.0
Copper, dissolved (µg/L as Cu) (01040)	wet	16	2.4	1.5	1.5	1.5-6.0
	dry	16	1.0	.0	1.0	1.0-1.0
Fecal coliform (colonies/ 100 mL) (31625)	wet	16	.1	.5	.0	0-2
	dry	16	.1	.3	.0	0-1
Fecal streptococci (colonies/ 100 mL (31673)	wet	16	31.1	113.2	1.0	0-440
	dry	16	8.3	23.2	2.5	0-95

Concentrations of iron, lead, manganese, and copper generally were low and were less than the USEPA primary and secondary maximum contaminant levels of 300 µg/L, 50 µg/L, 50 µg/L, and 1,000 µg/L, respectively (U.S. Environmental Protection Agency, 1986a; 1986b). Zinc concentrations ranged from 67 µg/L to 1,900 µg/L with median concentrations of 628 µg/L and 263 µg/L, respectively, for wet- and dry-season samples (table 3). Zinc concentrations were elevated in water samples from some wells but were less than the USEPA secondary maximum contaminant level of 5,000 µg/L for zinc (U.S. Environmental Protection Agency, 1986b).

Water from site 24 had a large strontium concentration (860 µg/L) (table 8) relative to the 110 µg/L median concentration of strontium for the United States public water supplies (Hem, 1985). Site 24 also had an elevated boron concentration of 210 µg/L (table 8). The high concentrations of strontium and boron in water from this well may have been due to the fact that the well had been chlorinated several days prior to sampling.

Bacteria

Fecal coliform bacteria were detected in water samples from only two wells in the Cotter Dolomite (sites 19 and 27); however, fecal streptococcus bacteria were detected at all sites. Site 27 was a shallow well (240 feet) with a peak fecal coliform concentration of 4 colonies per 100 mL (milliliter). Concentrations of fecal streptococcus bacteria in this well ranged from 2 colonies per 100 mL in September to 440 colonies per 100 mL in May (table 8). The anomalously high concentration in May could have been the result of sampling technique. Fecal streptococcus concentrations at the remaining wells in the Cotter Dolomite were less than 8 colonies per 100 mL with the exception of sites 29 and 32, which had peak concentrations of 95 and 14 colonies per 100 mL, respectively (table 8). Well depths at sites 29 and 32 were 675 feet and 705 feet, respectively. Leakage from the surface or sampling technique could be a possible explanation for the higher fecal streptococcus concentrations in these wells.

Organic Constituents

Water samples from three wells (sites 24, 27, and 34) were analyzed for dissolved organic carbon (table 9). The mean dissolved organic carbon concentration of these three samples was 0.77 mg/L as carbon. Two of these samples were scanned for organic compounds by the gas-chromatograph flame-ionization detector method (table 9). No organic compounds were detected at either site.

Comparison of Water Quality

The quality of the water in the Boone Formation and Cotter Dolomite was compared statistically to identify significant differences in mean temperature, specific conductance, pH, concentrations of fecal coliform, and fecal streptococcus bacteria and concentrations of chemical constituents. Standard statistical analysis programs were used to determine the means for each parameter and to perform the Wilcoxon rank sum test (also called the Mann-Whitney test) to compare the means. The Wilcoxon test is a nonparametric test with no assumptions, unlike the Student's t-test (a parametric test) in which data are assumed to be normally distributed, independent, and have equal variances. Inspection of the data and quantitative checks (skewness and histograms) for normality lead to serious doubts as to whether or not the distributions were sufficiently normal for application of the traditional t-test. Some statisticians prefer to use the Wilcoxon rank sum test in all situations because normality tests do not always detect nonnormal populations, especially when sample sizes are small (Iman and Conover, 1983). In addition, variances proved to be significantly different between some constituents indicating that the Wilcoxon test was more appropriate for these constituents. The Wilcoxon test is calculated by performing the two-sample t-test on rank transformed data for the combined data set. The null hypotheses for this test is that the two means are equal, $\mu_1 = \mu_2$; the alternative hypothesis is that the two means are not equal, $\mu_1 \neq \mu_2$. Descriptive statistics for constituents in wet-season water samples from the Boone Formation and Cotter Dolomite and probability values for the Wilcoxon rank sum test are given in table 4. A 5-percent significance level was chosen. Therefore, a probability value less than 0.05 would indicate a significant difference between mean concentrations. Chemical analyses used in the statistical comparison are given in tables 6 and 8.

Results of the Wilcoxon test indicated that water in the Cotter Dolomite has significantly higher specific conductance and concentrations of total alkalinity, hardness, magnesium, sulfate, potassium, and zinc and significantly lower concentrations of nitrite plus nitrate, chloride, orthophosphate, fecal coliform, and fecal streptococcus than water from springs discharging from the Boone Formation (table 4). The higher specific conductance and concentrations of total alkalinity, hardness, magnesium, sulfate, potassium and zinc in water from the Cotter Dolomite were expected because this unit is predominantly a dolomite interbedded with shale and sandstone, and is stratigraphically below the Boone Formation, which allows for a longer contact time between the water and aquifer rock. The higher concentrations of nitrate, chloride, orthophosphate, fecal coliform, and fecal streptococcus in water from the Boone Formation, all of which share a common source of human and animal wastes, probably are a result of the transport of contaminants through fractures or solution channels into the shallow ground-water flow system.

WATER QUALITY VARIATIONS

Ground-water quality can have marked seasonal and short-term fluctuations in karst terrain where the shallow aquifer is sensitive to changes in recharge and rainfall. These fluctuations in water quality in the Boone Formation and Cotter Dolomite are discussed in the following sections.

Seasonal Variations

Fourteen springs discharging from the Boone Formation and 16 wells completed in the Cotter Dolomite were sampled during the wet season and during the dry season to determine any significant seasonal variations in temperature, specific conductance, pH, and concentrations of fecal coliform and

Table 4.--Descriptive statistics and resultant probability values for the Wilcoxon rank sum test comparing water quality in the Boone Formation with that of water in the Cotter Dolomite in the wet season

[N=number of samples; °C=degrees Celsius; µS/cm=microsiemens per centimeter at 25 degrees Celsius; mg/L=milligrams per liter; µg/L=micrograms per liter; mL=milliliter; five digit numbers in parentheses are STORET parameter codes used for computer storage of data. Concentrations less than the detection limit were set to one-half of the detection limit for calculation of these statistics]

		Descriptive statistics					Wilcoxon probability value
Property	Geologic unit	N	Mean	Standard deviation	Median	Range	
Temperature (°C) (00010)	Boone Formation	14	14.1	1.5	14.0	12.0-17.0	0.0001
	Cotter Dolomite	16	17.3	2.0	16.8	13.5-22.0	
Specific conductance (µS/cm) (00095)	Boone Formation	14	344.9	82.8	311.5	240-492	.0001
	Cotter Dolomite	16	511.6	98.6	540.0	360-680	
Hardness (mg/L as $CaCO_3$) (00900)	Boone Formation	14	158.1	48.8	160.0	83-220	.0002
	Cotter Dolomite	16	253.1	61.6	260.0	170-380	
Carbon dioxide (mg/L) (00405)	Boone Formation	14	28.6	39.9	11.5	5.5-158.0	.2426
	Cotter Dolomite	16	31.8	27.7	22.5	3.2-102.0	
pH (units) (00400)	Boone Formation	14	7.2	.4	7.2	6.2-7.6	.6092
	Cotter Dolomite	16	7.3	.3	7.3	6.8-7.9	
Alkalinity (mg/L as $CaCO_3$) (00410)	Boone Formation	14	135.1	53.0	132.0	54-200	.0003
	Cotter Dolomite	16	244.3	54.6	232.0	133-334	
Nitrogen, nitrite plus nitrate (mg/L as N) (00631)	Boone Formation	14	2.10	2.78	1.07	.08-10.75	.0001
	Cotter Dolomite	16	.27	.49	.13	.02-2.01	
Nitrogen, ammonia dissolved (mg/L as N) (00608)	Boone Formation	14	.04	.06	.02	.01-.20	.4185
	Cotter Dolomite	16	.05	.11	.01	.01-.37	
Chloride, dissolved (mg/L as Cl) (00940)	Boone Formation	14	7.41	3.96	6.50	2.00-15.00	.0003
	Cotter Dolomite	16	2.89	2.10	2.25	.50-8.00	
Sulfate, dissolved (mg/L as SO_4) (00945)	Boone Formation	14	4.6	2.1	3.5	1.5-9.2	.0001
	Cotter Dolomite	16	26.5	10.3	23.8	14.4-52.0	
Phosphorus, ortho, dissolved (mg/L as P) (00671)	Boone Formation	14	.03	.03	.02	.01-.12	.0024
	Cotter Dolomite	16	.01	.01	.01	.01-.04	
Calcium, dissolved (mg/L as Ca) (00915)	Boone Formation	14	59.5	20.4	58.5	29.0-85.3	.9032
	Cotter Dolomite	16	59.2	15.5	60.0	37.0-92.0	
Magnesium, dissolved (mg/L as Mg) (00925)	Boone Formation	14	2.26	.75	2.30	1.3-4.2	.0001
	Cotter Dolomite	16	25.84	9.96	21.80	7.8-46.8	
Sodium, dissolved (mg/L as Na) (00930)	Boone Formation	14	3.86	1.81	3.20	2.1-8.2	.5406
	Cotter Dolomite	16	5.04	4.52	2.75	1.5-15.5	
Potassium, dissolved (mg/L as K) (00935)	Boone Formation	14	1.59	.98	1.35	.5-4.6	.0127
	Cotter Dolomite	16	2.90	1.64	3.00	1.0-6.2	
Manganese, dissolved (µg/L as Mn) (01056)	Boone Formation	13	6.2	13.0	2.0	.5-47.0	[a].7237
	Cotter Dolomite	16	2.1	1.3	2.0	.1-4.0	
Iron, dissolved (µg/L as Fe) (01046)	Boone Formation	13	14.8	36.8	4.0	1.0-137.0	[a].0768
	Cotter Dolomite	16	9.6	7.2	7.0	4.0-29.0	
Lead, dissolved (µg/L as Pb) (01049)	Boone Formation	13	13.3	21.2	10.0	1.0-82.0	[a].9826
	Cotter Dolomite	16	8.1	5.5	7.0	2.0-16.0	
Zinc, dissolved (µg/L as Zn) (01090)	Boone Formation	13	8.3	8.7	6.0	.4-33.0	.0001
	Cotter Dolomite	16	768.1	523.4	628.0	129.0-1,900.0	
Cadmium, dissolved (µg/L as Cd) (01025)	Boone Formation	13	.8	1.6	.3	.3-6.0	[a].0288
	Cotter Dolomite	16	.6	.6	.3	.3-2.0	
Nickel, dissolved (µg/L as Ni) (01065)	Boone Formation	13	4.2	6.3	3.0	1.5-25.0	[a].3116
	Cotter Dolomite	16	2.9	.4	3.0	1.5-3.0	

Table 4.--Descriptive statistics and resultant probability values for the Wilcoxon rank sum test comparing water quality in the Boone Formation with that of water in the Cotter Dolomite in the wet season--Continued

Property	Geologic unit	Descriptive statistics N	Mean	Standard deviation	Median	Range	Wilcoxon probability value
Cobalt, dissolved (µg/L as Co) (01035)	Boone Formation	13	2.2	2.5	2.0	0.5-10.0	[a]0.1358
	Cotter Dolomite	16	2.3	1.0	2.0	.1-4.0	
Copper, dissolved (µg/L as Cu) (01040)	Boone Formation	13	1.4	.3	1.5	1.0-2.0	[a].0048
	Cotter Dolomite	16	2.4	1.5	1.5	1.5-6.0	
Fecal coliform (colonies/ 100 mL) (31625)	Boone Formation	13	22.9	31.9	7.0	<1-96	.0001
	Cotter Dolomite	16	.1	.5	.0	0-2	
Fecal streptococci (colonies/100 mL) (31673)	Boone Formation	8	631.1	1,145.2	95.0	14-3,380	.0001
	Cotter Dolomite	14	31.1	113.2	1.0	0-440	

[a] Because of more than one detection limit value in the two data sets, the actual probability value may be higher or lower than the probability shown.

fecal streptococcus bacteria and concentrations of chemical constituents. Standard statistical analysis programs were used to determine the mean concentrations of the various properties or constituents and to perform the Wilcoxon rank sum test to compare the means. Descriptive statistics for each variable for the wet and dry seasons and resultant probability values (Wilcoxon test) for water in the Boone Formation are given in table 5. A 5-percent significance level was chosen. Therefore, a probability value less than 0.05 would indicate a significant difference between mean concentrations. Chemical analyses used in the statistical comparisons are given in table 6.

For water in the Boone Formation, specific conductance, temperature, pH, and concentrations of magnesium and potassium were significantly higher in the dry season than in the wet season. The Wilcoxon test showed the median specific conductance of water in the Boone Formation to be significantly higher in the dry season (435 µS/cm) compared to the wet season (332 µS/cm) with a probability value of 0.0184 (table 5). Similar results were obtained in northwestern Arkansas (Ogden, 1980). However, only wells were sampled in his study. The increase in specific conductance of ground water in the dry season is related to increased residence time in the aquifer and lack of dilution by recharge.

The pH of the water in the Boone Formation also is significantly higher in the dry season (7.5) than in the wet season (7.2). This could possibly be the result of low pH rainwater entering the aquifer in the wet season. Another possible explanation for a lower pH in the wet season is a greater concentration of carbon dioxide (29 mg/L) in the soil available to dissolve in the ground water and form carbonic acid during the wet season (table 5). Because the soil is moist during the wet season, microorganisms may be more active and release more carbon dioxide into the soil. Therefore, more carbon dioxide may be available to be washed into the aquifer during the wet season. Also, ground-water temperatures were significantly colder in the wet season (table 5), which allows more carbon dioxide to dissolve in the water. Even though a lower pH in the wet season favors dissolution of carbonate rock, which increases the concentrations of calcium and magnesium in the ground water, calcium and magnesium concentrations are larger in the dry season when dilution by recharge water is minimal (table 5). The magnesium concentration is significantly larger in the dry season with a probability value of 0.0455 (table 5). In the wet season, a greater quantity of recharging water is flushed more rapidly through the fractured rock matrix, thereby diluting the magnesium concentration at a faster rate than magnesium ions are dissolved. Dilution also may explain the significantly smaller average potassium concentration in the wet season (1.59 mg/L) as compared to the dry season (2.62 mg/L) (table 5).

Resultant probability values (Wilcoxon test) comparing wet- and dry-season water quality characteristics for water in the Cotter Dolomite also were calculated for each property or constituent. Only mean zinc and orthophosphate concentrations were found to be significantly different with season. For this reason, the probability values (Wilcoxon test) are not presented in a table. Mean zinc and orthophosphate concentrations were significantly higher in the wet season (768 mg/L zinc) (0.01 mg/L orthophosphate as P) as compared to the dry season (405 mg/L zinc) (0.003 mg/L orthosphosphate as P) at the 5-

Table 5.--Descriptive statistics and resultant probability values for the Wilcoxon rank sum test comparing water quality during wet and dry seasons for water in the Boone Formation

[N=number of samples; gal/min=gallons per minute; °C=degrees Celsius; µS/cm=microsiemens per centimeter at 25 degrees Celsius; mg/L=milligrams per liter; µg/L=micrograms per liter; mL=milliliter; five digit numbers in parentheses are STORET parameter codes used for computer storage of data. Concentrations less than the detection limit were set to one-half of the detection limit for calculation of these statistics]

		Descriptive statistics					
Property	Season	N	Mean	Standard deviation	Median	Range	Wilcoxon probability value
Flow rate (gal/min) (00059)	wet	14	137.2	367.8	8.5	1.5-1,400	0.0800
	dry	14	102.0	345.7	4.5	.9-1,302	
Temperature (°C) (00010)	wet	14	14.1	1.5	14.0	12.0-17.0	.0110
	dry	14	15.2	.9	15.0	14.0-17.5	
Specific conductance (µS/cm) (00095)	wet	14	344.9	82.8	331.5	240-492	.0184
	dry	14	417.6	77.9	435.0	288-539	
Hardness (mg/L as $CaCO_3$) (00900)	wet	14	158.1	48.8	160.0	83-220	.2283
	dry	14	185.7	49.7	190.0	110-270	
Carbon dioxide (mg/L) (00405)	wet	14	28.6	39.9	11.5	5.5-158.0	.1876
	dry	14	14.9	14.4	9.7	1.7-48.0	
pH (units) (00400)	wet	14	7.2	.4	7.2	6.2-7.6	.0154
	dry	14	7.5	.4	7.5	6.9-8.1	
Alkalinity (mg/L as $CaCO_3$) (00410)	wet	14	135.1	53.0	132.0	54-200	.1445
	dry	14	167.1	56.6	150.0	106-274	
Nitrogen, nitrite plus nitrate (mg/L as N) (00631)	wet	14	2.10	2.78	1.07	.80-10.75	.9466
	dry	14	2.78	3.53	1.10	.02-11.20	
Nitrogen, ammonia dissolved (mg/L as N) (00608)	wet	14	.04	.06	.02	.01-.20	.0186
	dry	14	.02	.03	.01	.01-.10	
Chloride, dissolved (mg/L as Cl) (00940)	wet	14	7.41	3.96	6.50	2.00-15.00	.2581
	dry	14	10.04	6.01	8.30	1.74-20.25	
Sulfate, dissolved (mg/L as SO_4) (00945)	wet	14	4.6	2.1	3.5	1.5-9.2	.2963
	dry	14	4.3	3.0	3.0	1.5-9.8	

Table 5.--Descriptive statistics and resultant probability values for the Wilcoxon rank sum test comparing water quality during wet and dry seasons for water in the Boone Formation--Continued

		Descriptive statistics					Wilcoxon probability value
Property	Season	N	Mean	Standard deviation	Median	Range	
Phosphorus, ortho, dissolved (mg/L as P) (00671)	wet	14	.03	.03	.02	.01-.12	0.5561
	dry	14	.04	.05	.03	.01-.16	
Calcium, dissolved (mg/L as Ca) (00915)	wet	14	59.5	20.4	58.5	29.0-85.3	.3926
	dry	14	68.3	21.2	69.5	36.0-104.0	
Magnesium, dissolved (mg/L as Mg) (00925)	wet	14	2.26	.75	2.30	1.3-4.2	.0455
	dry	14	3.22	1.45	2.95	1.5-6.6	
Sodium, dissolved (mg/L as Na) (00930)	wet	14	3.86	1.81	3.20	2.1-8.2	.3653
	dry	14	4.90	3.19	3.45	2.6-13.0	
Potassium, dissolved (mg/L as K) (00935)	wet	14	1.59	.98	1.35	.5-4.6	.0169
	dry	14	2.62	2.06	1.90	1.0-9.3	
Manganese, dissolved (µg/L as Mn) (01056)	wet	13	6.2	13.0	2.0	.5-47.0	[a].9212
	dry	14	40.3	141.3	1.0	1.0-531.0	
Iron, dissolved (µg/L as Fe) (01046)	wet	13	14.8	36.8	4.0	1.0-137.0	[a].2185
	dry	14	16.6	40.7	5.0	5.0-158.0	
Lead, dissolved (µg/L as Pb) (01049)	wet	13	13.3	21.2	10.0	1.0-82.0	[a].0188
	dry	14	12.4	35.7	2.0	1.0-136.0	
Zinc, dissolved (µg/L as Zn) (01090)	wet	13	8.3	8.7	6.0	.4-33.0	[a].8494
	dry	14	7.5	7.0	5.5	1.0-27.0	
Cadmium, dissolved (µg/L as Cd) (01025)	wet	13	.8	1.6	.3	.3-6.0	[a].1651
	dry	14	2.0	4.1	1.0	.3-16.0	
Nickel, dissolved (µg/L as Ni) (01065)	wet	13	4.2	6.3	3.0	1.5-25.0	[a]0.4942
	dry	14	8.5	18.9	2.5	2.5-74.0	
Cobalt, dissolved (µg/L as Co) (01035)	wet	13	2.2	2.5	2.0	0.5-10.0	[a].0960
	dry	14	5.6	13.6	2.0	2.0-53.0	
Copper, dissolved (µg/L as Cu) (01040)	wet	13	1.4	.3	1.5	1.0-2.0	[a].0013
	dry	14	1.1	.3	1.0	1.0-2.0	
Fecal coliform (colonies/ 100 mL) (31625)	wet	13	22.9	31.9	7.0	<1-96	.1411
	dry	14	298.9	745.0	27.0	<1-2,800	
Fecal streptococci (colonies/100 mLO (31673)	wet	8	631.1	1,145.2	95.0	14-3,380	.7666
	dry	14	905.7	2,295.2	185.0	<1-8,800	

[a] Because of more than one detection limit value in the two data sets, the actual probability value may be higher or lower than the probability shown.

percent significance level. This difference in concentration could be the result of water from different sources entering the well as the water table fluctuates with season.

Overall, statistical tests indicate the chemistry of the water in the Cotter Dolomite to be less variable with season than that of water in the Boone Formation. This situation is expected because the water in the Cotter Dolomite is deeper and less responsive to seasonal recharge differences.

Response to Rainfall

Three springs (sites 2, 5, and 7) issuing from the Boone Formation were sampled during and after a rainstorm of approximately 2 to 3 inches that began at 6:30 p.m. on September 14, 1987, and lasted for 1.5 hours. The three springs were chosen on the basis of the following criteria: (1) each site had to be located near a road to allow for easy access during times of high water and to allow quick sampling, (2) the three sites had to be within reasonable distance from each other so each could be sampled at approximately the same time, and (3) each spring had to have sufficient flow for making discharge measurements using standard stream-gaging techniques. Spring site numbers 2, 5, and 7 (fig. 7) are known to local residents as Bear Creek Spring, Lick Branch Spring, and Flag Spring, respectively. These springs were sampled approximately 4, 7, 11, 19, and 28 hours after the rainfall began. Two weeks after the rainstorm, an additional sample was collected at each spring. This sample was assumed to represent background concentrations before the storm. Discharges at each spring were measured approximately 19 hours after the rainstorm began and again 2 weeks after the rainstorm. Gage heights were recorded when discharge measurements were not possible because of high water, darkness, and time constraints. Two measured discharges and associated gage heights for each spring allowed discharges to be estimated at the time of each sample collection. Results of chemical and bacterial analyses and discharge measurements for the rainstorm are included in table 6.

Graphs relating conductance and constituent concentrations to time in hours after the rainstorm began are shown in figures 8 to 12. The graphs show the time for each constituent to reach a minimum or maximum concentration and return to the background concentrations. According to Steele and others (1985), ground-water constituents can be divided into three groups based on their behavior as the storm hydrograph peaks:

Group 1: constituents exhibiting a decrease in concentration (dilution effects),
Group 2: constituents exhibiting an increase in concentration (flushing effects), and
Group 3: constituents exhibiting either a decrease or an increase in concentration depending on conditions within the drainage basin.

All three springs (sites 2, 5, and 7) exhibited similar dilution and flushing trends. For this report, however, only one site, site 5 (Lick Branch Spring), will be discussed.

For Lick Branch Spring (site 5), specific conductance and total alkalinity, calcium, magnesium, sodium, and chloride concentrations decreased initially, indicating dilution effects; whereas, nitrite plus nitrate, potassium, and orthophosphate concentrations and fecal coliform and fecal streptococcus bacteria counts (colonies) increased initially, indicating flushing effects. All of the above mentioned constituents reached minimum or maximum concentrations at peak flow only 3 hours after the rain began. Similar dilution and flushing effects were observed in studies done by Steele and others (1985), Parr (1987), Wickliff (1988), Adamski (1987), and Widmann (1982) for springs in Washington and Benton Counties, Arkansas; however, peak discharges for these studies were obtained 8 to 24 hours after the rain began. The rapid increase in discharge from 0.9 gal/min to 625 gal/min (table 6) in 3 hours for Lick Branch Spring indicates flow through large solution channels.

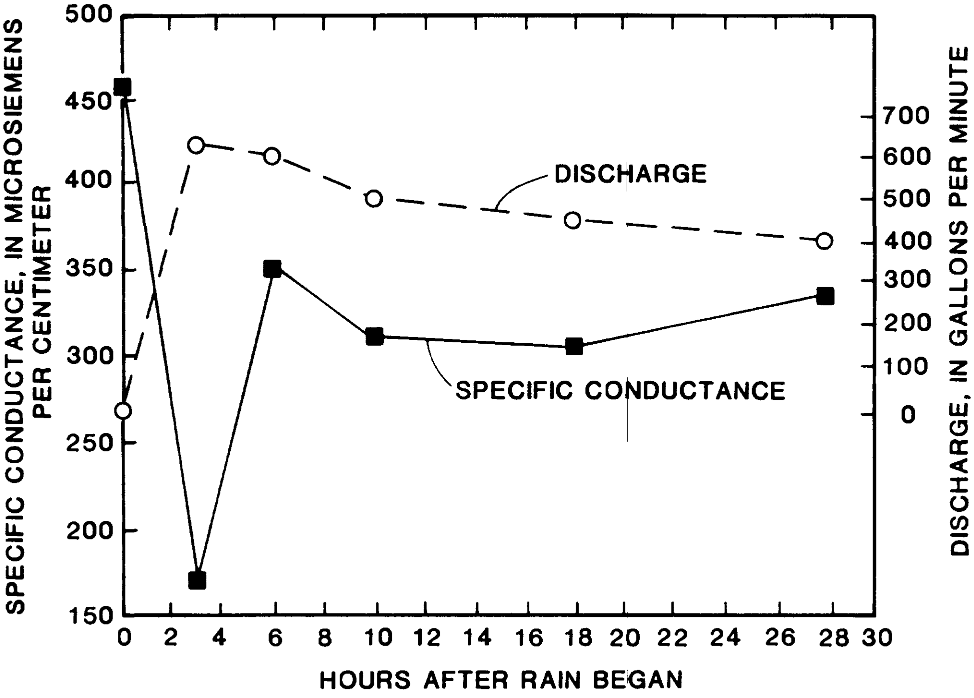


Figure 8.--Relation of specific conductance and discharge of Lick Branch Spring with time after rain began on September 14, 1987.

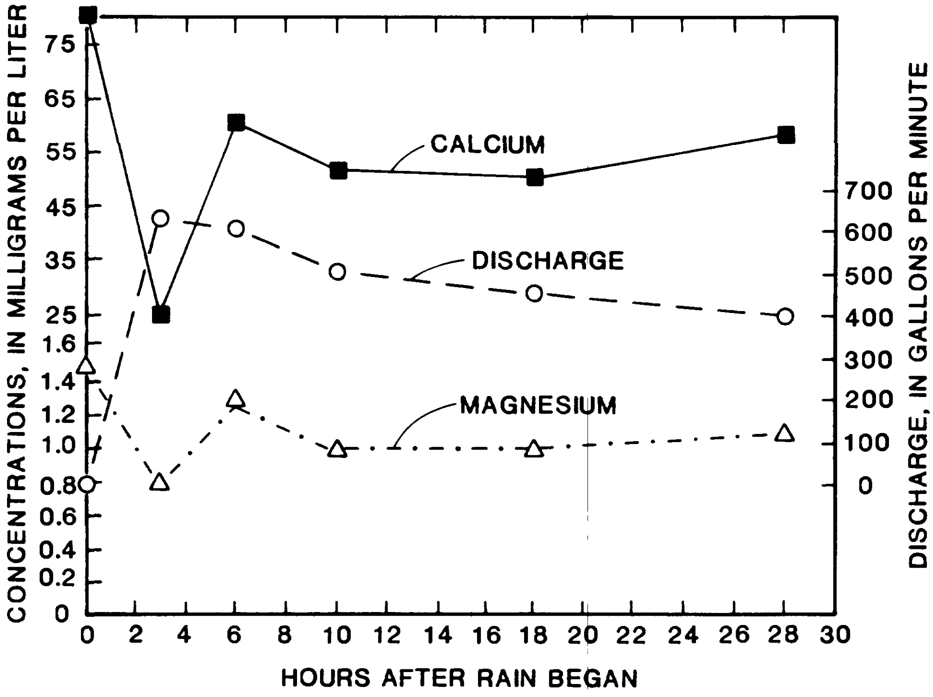


Figure 9.--Relation of calcium and magnesium concentrations and discharge of Lick Branch Spring with time after rain began on September 14, 1987.

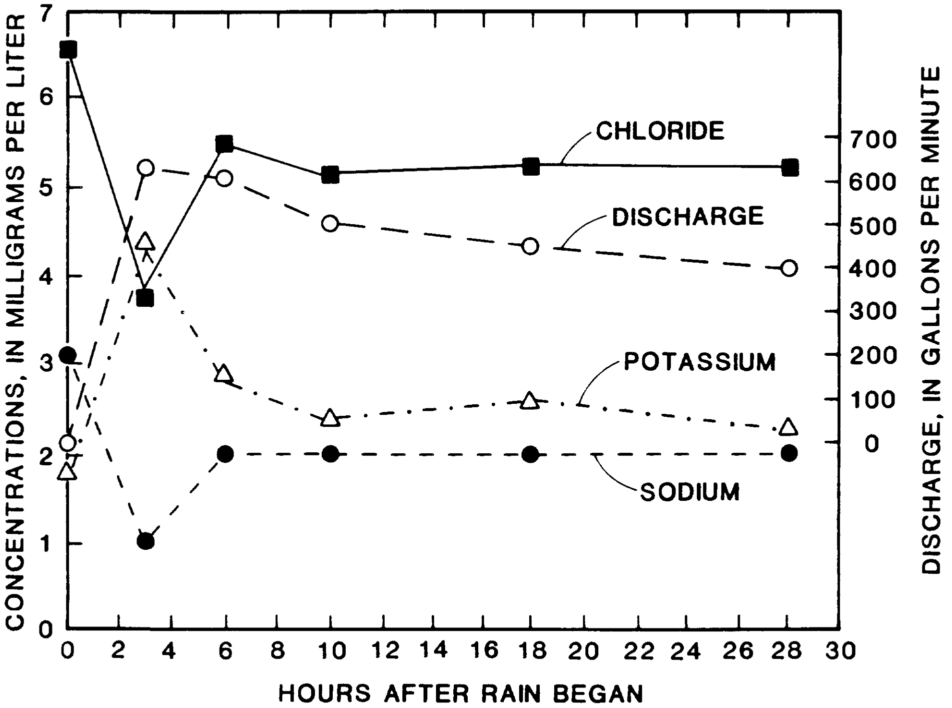


Figure 10.--Relation of sodium, chloride, and potassium concentrations and discharge of Lick Branch Spring with time after rain began on September 14, 1987.

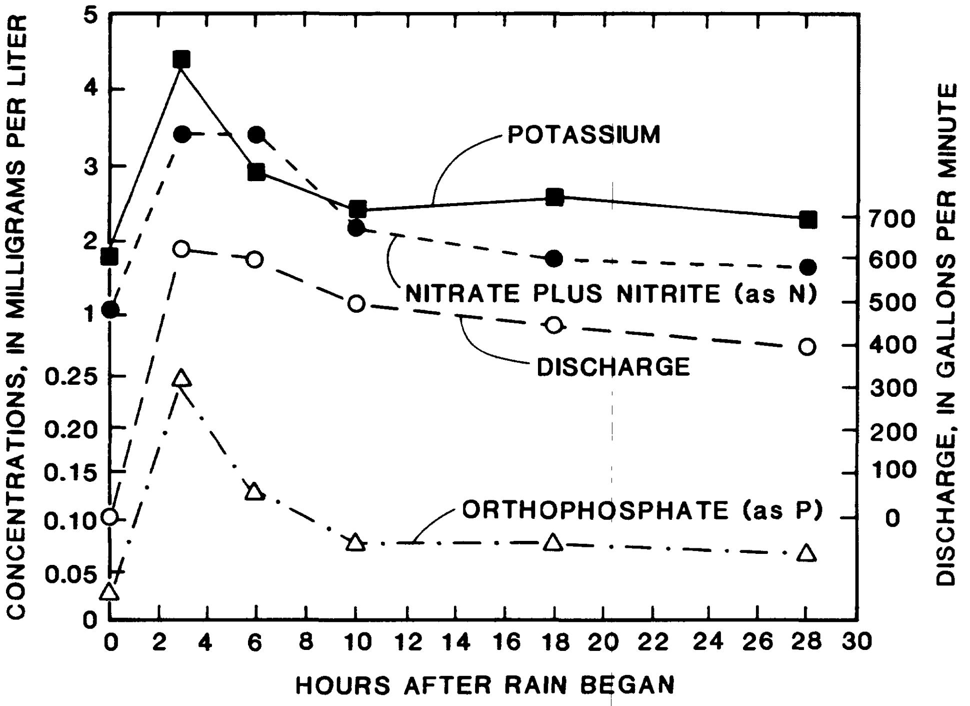


Figure 11.--Relation of potassium, nitrate, and orthophosphate concentrations and discharge of Lick Branch Spring with time after rain began on September 14, 1987.

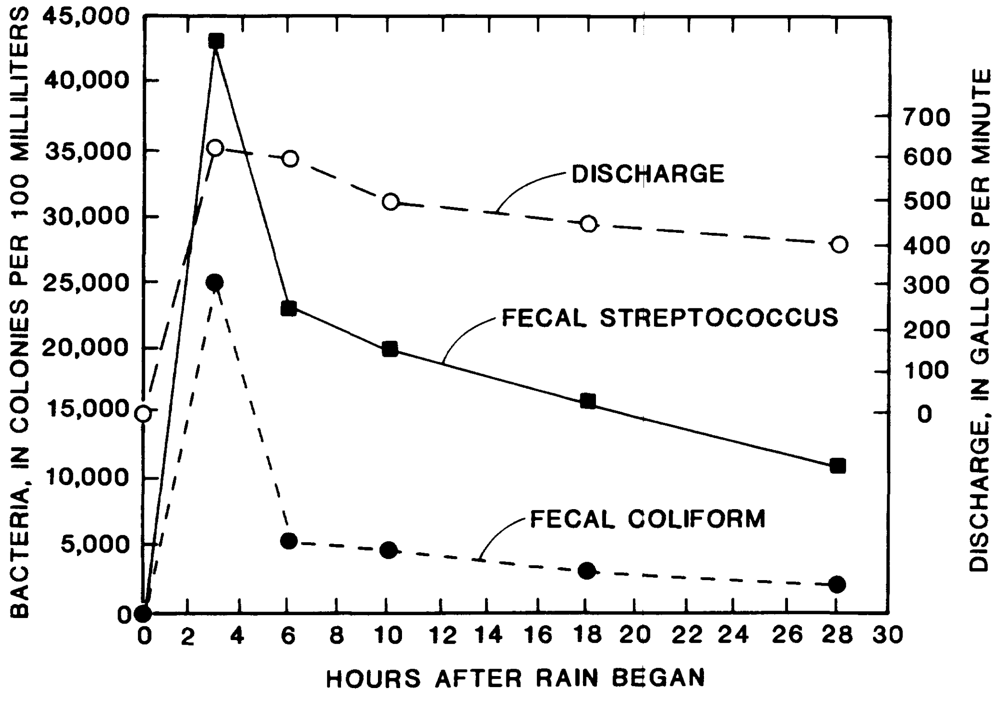


Figure 12.--Relation of fecal coliform and fecal streptococcus colonies and discharge of Lick Branch Spring with time after rain began on September 14, 1987.

Specific conductance and calcium, magnesium, sodium, and chloride concentrations significantly decreased for the first 3 hours after the rain began, then rapidly increased for several hours before stabilizing and gradually returning to background levels (figs. 8-10) as discharge slowly decreased to base flow. Specific conductance (fig. 8) varied in a manner similar to calcium concentrations (fig. 9) and total alkalinity (bicarbonate ions at pH values in this study) as expected because conductance is essentially controlled by the concentrations of these two ions in limestone terrains. With the increase in recharge water, sodium and chloride concentrations were diluted; however, the transport of these ions in grams per hour (g/hr) at peak flow (142 g/hr sodium and 532 g/hr chloride) far exceeded the transport at base flow (0.6 g/hr sodium and 1.3 g/hr chloride) indicating sodium and chloride ions were actually washed into the aquifer system (fig. 10).

Nitrite plus nitrate, potassium, orthophosphate, fecal coliform, and fecal streptococci concentrations increased rapidly until the discharge peaked about 3 hours after the rain began. Concentrations then returned to background concentrations as discharge gradually decreased (figs. 11 and 12). These rapid increases in concentration are the result of the introduction of these ions from surface sources. The overall quick response and large range of chemical changes over a short period of time for Lick Branch Spring indicate a shallow flow system through "cave-like" passages with a capture area located close to the spring orifice (fig. 13). Perhaps interconnected conduits above the water table provide a temporary or alternate path for ground water under high-flow conditions as water travels from the point of recharge to the spring outlet. Lick Branch Spring is located in a 0.5 mi^2 surface drainage basin that is approximately 98 percent pasture land. Animal and human wastes and commercial chemicals used to fertilize pasture land probably are a source for the bacteria and the nitrite plus nitrate, orthophosphate, and potassium ions. Fecal coliform and fecal streptococcus colonies substantially increased from 27 to 25,000 colonies per 100 mL and 190 to 43,000 colonies per 100 mL, respectively, within 3 hours of the onset of rainfall (fig. 12). However, 6 hours after the rain began, fecal coliform and fecal streptococcus bacteria concentrations decreased to 5,400 colonies per 100 mL and 23,000 colonies per 100 mL, respectively, and at 28 hours fecal coliform and fecal streptococcus colonies had decreased to 2,000 colonies per 100 mL and 11,000 colonies per 100 mL, respectively. Fecal coliform to fecal streptococcus ratios at base flow (0.14) and at peak flow (0.58) indicate animal sources.

Fluctuations in the concentrations of dissolved chemical constituents at spring sites 2 and 7 during a rainstorm were as much as 14 times greater than fluctuations associated with seasonal changes and as much as 56 times greater for spring site 5. Fecal coliform concentration changes during the rainstorm for site 5 were approximately 1,400 times that associated with seasonal variations. Changes in the flow of these springs because of a rainstorm appear to be much more important controls on water chemistry of the spring than is season. This conclusion is consistent with findings reported by Jacobson and Langmuir (1974) for springs in Pennsylvania.

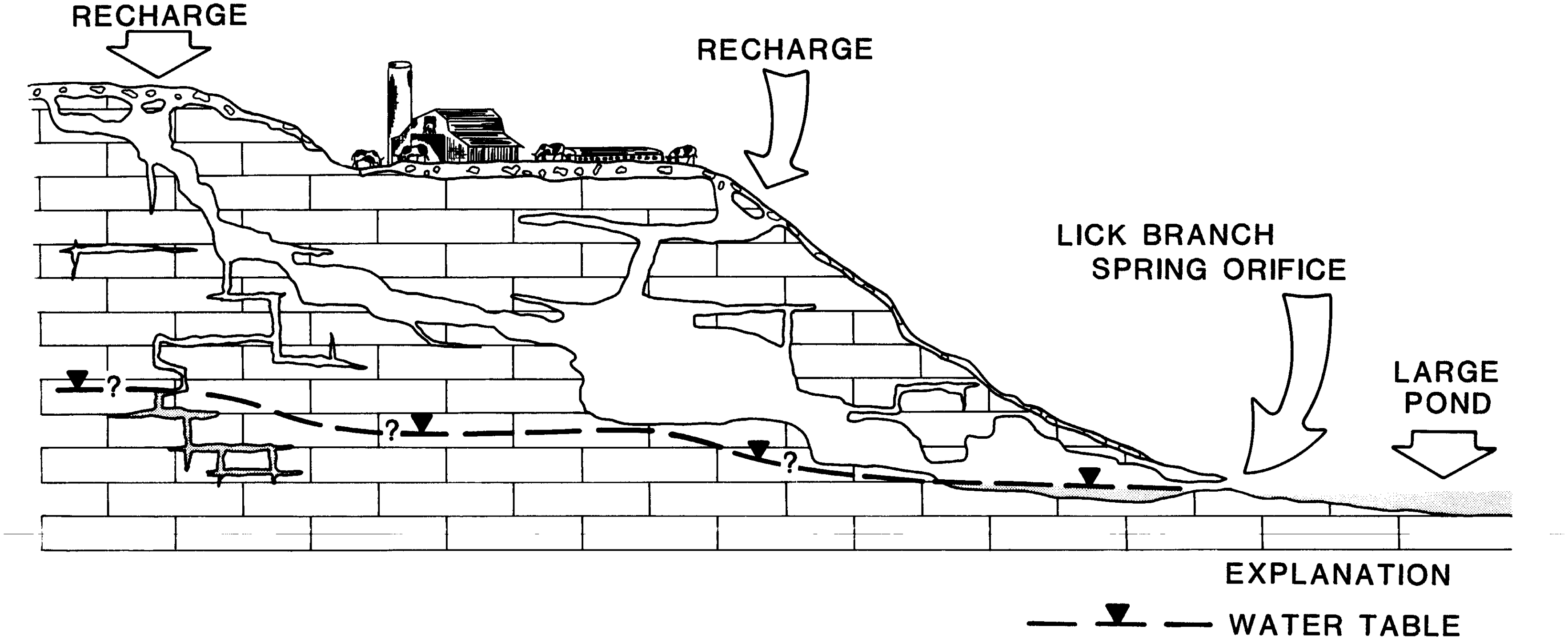


Figure 13.--Conceptualized flow system of Lick Branch Spring.

SUMMARY AND CONCLUSIONS

Northwestern Boone County, Arkansas, is underlain by carbonate rocks. Ground water in the area is susceptible to contamination and relatively large water-quality variations because near surface fractures and solution channels provide recharge water with direct passageways to the aquifers. Sources of ground-water contamination in the area include cattle manure and chicken manure, which commonly is applied as fertilizer to pasture land, commercial fertilizers, and septic tank effluent. The potential for ground-water contamination probably is greater in the northern one-half of the study area where there are more photolineaments, and presumably, more subsurface fractures than in the southern half of the area.

Regional ground-water flow in the Cotter Dolomite is from west of Ridgeway and northeast of Omaha toward the major streams (Bear and Long Creeks) bordering the study area. Departures from the regional pattern of ground-water movement may occur in local areas in response to topography and where solution-enlarged fractures and joints are present.

Concentrations of chemical constituents in ground water in northwestern Boone County generally did not exceed U.S. Environmental Protection Agency (USEPA) primary or secondary maximum contaminant levels. Fecal coliform and fecal streptococcus bacteria were found in all springs and three wells (sites 18, 19, and 27). Fecal coliform to fecal streptococcus ratios for both springs and wells were less than 0.7 and indicated livestock sources of contamination. Only one spring (site 16) exceeded the USEPA primary maximum contaminant level for nitrite plus nitrate (10 mg/L as N) with a mean concentration of 11.1 mg/L as N. One spring, located near an abandoned wood treatment plant (a USEPA designated Superfund site), had maximum iron, manganese, lead, and pentachlorophenol concentrations that exceeded either the USEPA's primary or secondary maximum contaminant levels for drinking water. Wood treatment chemicals originating from the plant site probably are the source of contaminants.

Spring water discharging from the Boone Formation had significantly higher concentrations of nitrite plus nitrate, chloride, orthophosphate, fecal coliform, and fecal streptococci and significantly lower hardness and concentrations of magnesium, bicarbonate (alkalinity), sulfate, potassium, and zinc and specific conductance values than water from wells open to the deeper Cotter Dolomite. Water in the Boone Formation is more susceptible to surface contaminants than water in the deeper Cotter Dolomite because stratigraphically the Boone Formation is above the Cotter Dolomite.

The effects of season on water quality were directly related to seasonal recharge patterns. In springs in the Boone Formation specific conductance, temperature, pH, and concentrations of magnesium and potassium in water were significantly higher during the dry season than during the wet season. In water from wells in the Cotter Dolomite, concentrations of zinc and orthophosphate were significantly higher during the wet season than during the dry season. The chemistry of the water in the Cotter Dolomite was less variable with season than the water in the Boone Formation because the Cotter Dolomite is deeper, and less responsive to variations in seasonal recharge.

Water from the Boone Formation sampled at three springs during a rainstorm, exhibited a decrease in specific conductance, and concentrations of bicarbonate (alkalinity), calcium, magnesium, sodium, and chloride, and an increase in concentrations of nitrate plus nitrite, fecal coliform and fecal streptococcus bacteria within 3 to 8 hours after the rain began. Decreasing concentrations are usually the result of dilution from the recharge water. However, the transport of sodium and chloride ions in grams per hour (g/hr) at peak flow far exceeded the transport at base flow indicating sodium and chloride ions were washed into the aquifer. Increasing concentrations are the result of flushing of chemicals or bacteria in surficial material into the aquifer. Fecal coliform and fecal streptococcus counts increased from 27 to 25,000 colonies per 100 milliliters and from 190 to 43,000 colonies per 100 milliliters, respectively, in spring number 5 after a rainstorm. During a rainstorm, ground water exhibited changes in ion concentrations as much as 56 times those associated with seasonal variation.

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Table 6.--Flow rate, physical properties, and inorganic chemical analyses of ground water from springs in northwestern Boone County, Arkansas

[Condition, indicates wet and dry seasonal samples used in statistical analysis, rainstorm samples, and quality assurance (QA) samples; --, not measured; K, plate count outside ideal range; E, estimated value; deg C, degrees Celsius; wh wat, whole water; tot fld, total field; cols./100 mL, colonies per 100 milliliters; mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; gal/min, gallons per minute; meq/L, milliequivalents per liter; five digit numbers in parentheses are STORET parameter codes used for computer storage of data; USGS, U.S. Geological Survey; UofA, University of Arkansas]

Site number	Station number	Local identifier	Owner	Latitude	Longitude	Geologic unit	Agency analyzing sample	Date sampled	Time	Condition
1	362506093135701	20N21W05CAA1SP	Blevins, I.	36 25 06 N	093 13 57 W	Batesville Sandstone	USGS	03-19-87	1245	QA
							UofA	03-19-87	1246	Rain
							UofA	05-08-87	0845	Other
							UofA	05-08-87	0915	Other
							UofA	10-01-87	1130	Other
							UofA	10-01-87	1200	Other
2	361753093110401	19N21W14CDB1SP	Bear Creek Springs Trout Farm	36 17 53 N	093 11 04 W	Boone Formation	USGS	03-18-87	1300	QA
							UofA	03-18-87	1301	Rain
							UofA	05-07-87	0930	Wet
							UofA	09-15-87	0000	Rain
							UofA	09-15-87	0200	Rain
							UofA	09-15-87	0600	Rain
							UofA	09-15-87	1415	Rain
							UofA	09-15-87	2300	Rain
							UofA	10-02-87	1200	Dry
3	361900093162201	19N22W12CAB1SP	Salvage, H.	36 19 00 N	093 16 22 W	Boone Formation	USGS	03-13-87	0945	QA
							UofA	03-13-87	0946	Wet
							UofA	06-20-87	1230	Rain
							UofA	10-01-87	0730	Dry
4	361923093103801	19N21W11ABD1SP	Thompson, D.	36 19 23 N	093 10 38 W	Boone Formation	USGS	03-18-87	1400	QA
							UofA	03-18-87	1401	Rain
							UofA	05-08-87	1400	Wet
							UofA	10-01-87	0930	Dry
5	361942093134701	19N21W05DDB1SP	Henson, B.	36 19 42 N	093 13 47 W	Boone Formation	USGS	03-13-87	0845	QA
							UofA	03-13-87	0846	Wet
							UofA	06-20-87	1145	Rain
							UofA	09-14-87	2130	Rain
							UofA	09-15-87	0030	Rain
							UofA	09-15-87	0415	Rain
							UofA	09-15-87	1200	Rain
							UofA	09-15-87	2145	Rain
							UofA	10-01-87	0815	Dry
6	362226093102201	20N21W23DAB1SP	Roberts, T.	36 22 26 N	093 10 22 W	Boone Formation	USGS	03-18-87	1515	QA
							UofA	03-18-87	1516	Rain
							UofA	05-08-87	1545	Wet
							UofA	10-01-87	1015	Dry

Table 6.--Flow rate, physical properties, and inorganic chemical analyses of ground water from springs in northwestern Boone County, Arkansas--Continued

Site number	Station number	Local identifier	Owner	Latitude	Longitude	Geologic unit	Agency ana- lyzing sample	Date Sampled	Time	Condi- tion
7	362304093123001	20N21W16DDC1SP	Bowman, T.	36 23 04 N	093 12 30 W	Boone Formation	USGS	03-19-87	1330	QA
							UofA	03-19-87	1331	Rain
							UofA	05-07-87	1030	Wet
							UofA	09-14-87	2315	Rain
							UofA	09-15-87	0115	Rain
							UofA	09-15-87	0500	Rain
							UofA	09-15-87	1315	Rain
							UofA	09-15-87	2230	Rain
							UofA	10-02-87	1400	Dry
8	362455093103201	20N21W02DBA1SP	Huffman, D.	36 24 55 N	093 10 32 W	Boone Formation	USGS	03-19-87	1100	QA
							UofA	03-19-87	1101	Rain
9	362556093155401	21N22W36DBD1SP	Skaggs. J.	36 25 56 N	093 15 54 W	Boone Formation	UofA	06-20-87	1600	Rain
10	362607093111001	21N21W35BBC1SP	Unknown	36 26 07 N	093 11 10 W	Boone Formation	USGS	03-20-87	1030	QA
							UofA	03-20-87	1031	Rain
							UofA	05-08-87	1115	Wet
							UofA	10-02-87	1630	Dry
11	362638093113101	21N21W27DBD1SP	Unknown	36 26 38 N	093 11 31 W	Boone Formation	UofA	03-11-87	1535	Wet
							UofA	06-20-87	0845	Rain
							UofA	10-02-87	1515	Dry
12	362648093072801	21N20W29ACA1SP	Barnes, H.	36 26 48 N	093 07 28 W	Boone Formation	USGS	03-12-87	1630	QA
							UofA	03-12-87	1631	Wet
							UofA	06-20-87	0945	Rain
							UofA	10-02-87	0915	Dry
13	362658093121001	21N21W27BCB1SP	Unknown	36 26 58 N	093 12 10 2	Boone Formation	USGS	03-11-87	1345	QA
							UofA	03-11-87	1346	Wet
							UofA	06-20-87	0745	Rain
							UofA	10-01-87	1300	Dry
14	362714093125101	21N21W28BAA1SP	Tate, W.	36 27 14 N	093 12 51 W	Boone Formation	USGS	03-18-87	1615	QA
							UofA	03-18-87	1616	Rain
							UofA	05-07-87	1745	Wet
							UofA	10-01-87	1400	Dry
15	362823093140401	21N21W17CAC1SP	Williamson, J.	36 28 23 N	093 14 04 W	Boone Formation	USGS	03-19-87	0930	QA
							UofA	03-19-87	0931	Rain
							UofA	05-07-87	1545	Wet
							UofA	10-01-87	1530	Dry
16	362923093081001	21N20W08BCB1SP	Robertson, J.	36 29 23 N	093 08 10 W	Boone Formation	USGS	03-12-87	0900	QA
							UofA	03-12-87	0901	Wet
							UofA	06-20-87	1045	Rain
							UofA	10-02-87	1000	Dry
17	362945093124801	21N21W9BAD1SP	Edson, R.	36 29 45 N	093 12 48 W	Boone Formation	USGS	03-19-87	0830	QA
							UofA	03-19-87	0831	Rain
							UofA	05-07-87	1700	Wet
							UofA	10-01-87	1630	Dry

Table 6.--Flow rate, physical properties, and inorganic chemical analyses of ground water from springs in northwestern Boone County, Arkansas--Continued

Site number	Date	Elevation of land surface datum (feet above sea level) (72000)	Flow rate, instantaneous (gal/min) (00059)	Temperature water (deg C) (00010)	Specific conductance (µS/cm) (00095)	pH (standard units) (00400)	Calcium dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Total hardness (mg/L as $CaCO_3$) (00900)	Hardness noncarb wh wat tot fld (mg/L as $CaCO_3$) (00902)	Sodium, dissolved (mg/L as Na) (00930)	Sodium adsorption ratio (00931)	Potassium, dissolved (mg/L as K) (00935)
1	03-19-87	1,360	--	11.0	530	7.60	85	8.8	250	52	7.2	0.2	2.6
	03-19-87	1,360	--	11.0	530	7.60	79	11	240	45	7.0	.2	2.8
	05-08-87	1,360	2.5	18.5	790	7.40	120	15	370	93	13	.3	2.0
	05-08-87	1,360	2.5	18.5	740	7.40	120	15	360	85	13	.3	2.0
	10-01-87	1,360	1.5	19.0	780	7.60	120	14	360	62	12	.3	2.5
	10-01-87	1,360	--	19.5	790	7.80	120	13	360	65	12	.3	2.1
2	03-18-87	1,100	2500	13.0	259	7.40	49	1.1	130	13	2.0	.1	1.4
	03-18-87	1,100	E2500	13.0	259	7.40	48	1.2	120	27	2.1	.1	1.5
	05-07-87	1,100	E1400	14.5	430	7.50	79	1.6	200	7	2.7	.1	1.0
	09-15-87	1,100	E6000	17.0	440	6.90	76	1.8	200	5	2.6	.1	1.5
	09-15-87	1,100	E7000	16.0	407	6.90	72	1.6	190	0	2.4	.1	1.4
	09-15-87	1,100	E6500	16.0	435	6.90	72	1.6	190	4	2.6	.1	1.3
	09-15-87	1,100	4970	15.0	440	6.90	74	1.5	190	0	2.2	.1	1.2
	09-15-87	1,100	E2500	15.0	440	6.90	74	1.6	190	1	2.4	.1	1.4
	10-02-87	1,100	1300	15.0	440	7.20	77	1.8	200	4	2.9	.1	1.4
3	03-13-87	1,180	70	12.0	492	6.90	89	1.4	230	13	4.1	.1	1.3
	03-13-87	1,180	70	12.0	492	6.90	85	1.5	220	22	4.0	.1	1.4
	06-20-87	1,180	E5.0	15.0	525	7.70	91	1.5	230	0	4.1	.1	1.0
	10-01-87	1,180	6.0	15.0	535	7.40	98	1.8	250	14	3.9	.1	1.4
4	03-18-87	1,240	E5.0	13.0	300	7.50	57	1.4	150	6	1.8	.1	.9
	03-18-87	1,240	2.5	13.0	300	7.50	58	1.5	150	9	2.1	.1	.05
	05-08-87	1,240	2.5	17.0	420	7.00	81	2.2	210	14	2.1	.1	1.0
	10-01-87	1,240	1.0	14.5	458	7.70	100	2.9	270	0	2.8	.1	1.9
5	03-13-87	1,180	E400	12.0	395	6.90	80	1.2	200	11	3.2	.1	1.4
	03-13-87	1,180	E400	12.0	395	6.90	78	1.3	200	21	3.3	.1	1.5
	06-20-87	1,180	E5.0	15.0	460	7.20	86	1.3	220	7	2.3	.1	1.0
	09-14-87	1,180	E625	19.0	170	7.00	25	.8	66	20	1.0	.1	4.4
	09-15-87	1,180	E600	17.0	350	7.10	61	1.3	160	12	2.0	.1	2.9
	09-15-87	1,180	E500	17.0	310	7.00	52	1.0	130	14	2.0	.1	2.4
	09-15-87	1,180	450	17.0	305	6.90	51	1.0	130	11	2.0	.1	2.6
	09-15-87	1,180	E400	17.0	335	6.90	59	1.1	150	11	2.0	.1	2.3
	10-01-87	1,180	0.9	16.0	458	7.00	81	1.5	210	0	3.1	.1	1.8
6	03-18-87	1,200	E10	14.5	390	7.20	68	1.7	180	36	2.7	.1	1.0
	03-18-87	1,200	E10	14.5	390	7.20	62	1.7	160	22	2.8	.1	1.4
	05-08-87	1,200	3.0	16.0	440	7.60	84	2.3	220	30	2.6	.1	1.2
	10-01-87	1,200	4.0	15.5	539	7.50	94	2.6	250	13	2.8	.1	3.1
7	03-19-87	1,180	E220	14.0	275	7.10	49	1.2	130	30	2.1	.1	1.4
	03-19-87	1,180	E220	14.0	275	7.10	46	1.1	120	4	2.4	.1	1.6
	05-07-87	1,180	E55	14.0	390	7.20	74	1.4	190	19	2.6	.1	1.0
	09-14-87	1,180	E525	15.0	340	7.00	56	1.4	150	5	2.8	.1	1.5
	09-15-87	1,180	E500	15.0	340	7.00	54	1.4	140	15	2.4	.1	1.5
	09-15-87	1,180	E425	15.0	350	7.00	59	1.5	150	14	2.2	.1	1.6

Table 6.--Flow rate, physical properties, and inorganic chemical analyses of ground water from springs in northwestern Boone County, Arknasas--Continued

Site number	Date	Elevation of land surface datum (feet above sea level) (72000)	Flow rate, instantaneous (gal/min) (00059)	Temperature water (deg C) (00010)	Specific conductance (µS/cm) (00095)	pH (standard units) (00400)	Calcium dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Total hardness (mg/L as $CaCO_3$) (00900)	Hardness noncarb wh wat tot fld (mg/L as $CaCO_3$) (00902)	Sodium, dissolved (mg/L as Na) (00930)	Sodium adsorption ratio (00931)	Potassium, dissolved (mg/L as K) (00935)
7	09-15-87	1,180	350	15.0	379	7.00	63	1.5	160	4	2.4	0.1	1.4
	09-15-87	1,180	E200	15.0	375	6.90	64	1.5	170	6	2.8	.1	1.5
	10-02-87	1,180	51	15.0	410	7.20	72	1.6	190	22	2.6	.1	1.6
8	03-19-87	1,200	E15	13.0	250	7.30	39	1.9	110	21	3.8	.2	1.4
	03-19-87	1,200	E15	13.0	250	7.30	39	2.1	110	24	4.0	.2	1.8
9	06-20-87	1,325	--	24.0	418	7.70	66	2.6	180	28	5.5	.2	1.5
10	03-20-87	1,190	E25	15.0	140	7.50	--	--	--	--	--	--	--
	03-20-87	1,190	E25	15.0	140	7.50	20	1.4	56	1	3.0	.2	1.5
	05-08-87	1,190	6.0	13.0	250	7.50	38	2.3	100	14	4.8	.2	1.3
	10-02-87	1,190	5.0	14.0	324	7.80	46	3.0	130	21	6.4	.3	2.4
11	03-11-87	1,320	60	14.0	255	6.80	29	2.6	83	19	8.2	.4	2.3
	06-20-87	1,320	60	16.0	320	7.40	43	4.0	120	26	8.6	.4	2.0
	10-02-87	1,320	10	15.0	356	7.80	36	4.2	110	0	13	.6	3.3
12	03-12-87	1,100	5.0	14.0	308	7.20	47	2.1	130	27	2.5	.1	1.9
	03-12-87	1,100	5.0	14.0	308	7.20	43	2.3	120	35	2.6	.1	2.1
	06-20-87	1,100	2.5	17.0	330	7.40	54	3.1	150	33	3.0	.1	2.6
	10-02-87	1,100	1.0	15.5	393	7.70	60	4.3	170	32	3.8	.1	3.1
13	03-11-87	1,140	E5.0	13.5	313	6.20	57	2.6	150	11	2.7	.1	1.5
	03-11-87	1,140	E5.0	13.5	313	6.20	55	2.6	150	17	3.1	.1	1.7
	06-20-87	1,140	E7.0	16.0	420	6.80	72	3.8	200	31	2.6	.1	3.3
	10-01-87	1,140	7.0	15.5	463	6.90	73	4.0	200	3	3.1	.1	1.9
14	03-18-87	1,040	E15	13.0	188	7.80	32	2.7	91	7	1.4	.1	.9
	03-18-87	1,040	E15	13.0	188	7.80	31	2.9	89	7	1.5	.1	1.0
	05-07-87	1,040	9.0	16.0	270	7.40	47	2.4	130	12	2.6	.1	<1.0
	10-01-87	1,040	2.0	17.5	302	7.50	49	3.5	140	13	2.6	.1	1.0
15	03-19-87	1,200	E40	15.0	289	7.80	50	2.0	130	16	2.9	.1	1.3
	03-19-87	1,200	E40	15.0	289	7.80	48	2.2	130	6	3.0	.1	1.7
	05-07-87	1,200	E2.0	14.5	350	7.50	62	3.0	170	36	3.4	.1	1.5
	10-01-87	1,200	1.5	14.5	430	8.00	67	4.8	190	52	7.4	.2	3.0
16	03-12-87	1,240	1.5	13.0	275	7.00	40	4.0	120	61	6.9	.3	4.7
	03-12-87	1,240	1.5	13.0	275	7.00	38	4.2	110	58	7.0	.3	4.6
	06-20-87	1,240	E1.5	15.0	420	7.30	55	5.7	160	54	8.2	.3	6.0
	10-02-87	1,240	1.0	15.0	450	8.10	56	6.6	170	59	10	.4	9.3
17	03-19-87	1,300	E250	14.0	132	7.40	19	1.2	52	8	3.0	.2	1.3
	03-19-87	1,300	E250	14.0	132	7.40	18	1.5	51	3	3.3	.2	1.4
	05-07-87	1,300	E100	14.0	240	7.40	39	1.9	110	15	5.0	.2	1.2
	10-01-87	1,300	35	14.5	288	7.40	43	2.5	120	9	4.2	.2	1.5

Table 6.--Flow rate, physical properties, and inorganic chemical analyses of ground water from springs in northwestern Boone County, Arkansas--Continued

Site number	Date	Alkalinity wh wat tot fld (mg/L as $CaCO_3$) (00410)	Carbon dioxide dissolved (mg/L as CO_2) (00405)	Chloride, dissolved (mg/L as Cl) (00940)	Sulfate dissolved (mg/L as SO_4) (00945)	Fluoride, dissolved (mg/L as F) (00950)	Nitrogen, ammonia dissolved (mg/L as N) (00608)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N) (00631)	Phosphorus, ortho, dissolved (mg/L as P) (00671)	Silica, dissolved (mg/L as SiO_2) (00955)	Solids, residue at 180 deg. C dissolved (mg/L) (70300)
1	03-19-87	197	9.6	13	44	0.1	--	1.90	0.02	9.8	295
	03-19-87	197	9.5	--	43	--	<0.01	.22	.03	--	--
	05-08-87	279	22	20	75	--	.01	2.10	.03	--	--
	05-08-87	279	22	20	72	--	< .01	2.07	.04	--	--
	10-01-87	294	14	21	68	--	.04	3.56	.03	--	--
	10-01-87	292	8.9	21	68	--	< .01	3.56	.03	--	--
2	03-18-87	114	8.8	3.8	9.3	< .1	--	.87	.02	8.7	151
	03-18-87	98	7.7	3.1	5.9	--	< .01	.51	.02	--	--
	05-07-87	197	12	4.3	3.4	--	.06	.92	.01	--	--
	09-15-87	192	47	5.0	<3.0	--	< .01	1.28	.02	--	--
	09-15-87	188	46	5.0	3.0	--	< .01	1.32	.02	--	--
	09-15-87	182	44	5.0	<3.0	--	< .01	1.32	.02	--	--
	09-15-87	198	48	4.5	3.1	--	< .01	1.44	.02	--	--
	09-15-87	190	46	4.8	<3.0	--	< .01	1.28	.02	--	--
	10-02-87	196	24	5.6	3.0	--	< .01	.88	.02	--	--
3	03-13-87	207	52	7.0	12	< .1	--	.70	< .01	10	252
	03-13-87	197	49	6.5	9.2	--	< .01	.42	.02	--	--
	06-20-87	238	9.2	6.0	7.3	--	< .01	.41	.01	--	--
	10-01-87	238	18	6.6	9.0	--	< .01	.50	.02	--	--
4	03-18-87	142	8.7	2.0	5.4	< .1	--	.91	< .01	11	160
	03-18-87	142	8.7	2.0	3.0	--	.04	.88	.01	--	--
	05-08-87	197	38	2.0	3.4	--	.04	.12	< .01	--	--
	10-01-87	274	11	3.9	3.0	--	.10	.10	.02	--	--
5	03-13-87	192	47	7.5	6.9	< .1	--	1.40	.02	10	234
	03-13-87	180	43	6.5	4.3	--	< .01	1.17	.02	--	--
	06-20-87	213	26	4.0	<3.0	--	< .01	1.03	.03	--	--
	09-14-87	46	8.9	3.8	3.2	--	< .01	3.40	.25	--	--
	09-15-98	146	22	5.5	<3.0	--	< .01	3.40	.13	--	--
	09-15-87	120	23	5.1	<3.0	--	< .01	2.20	.08	--	--
	09-15-87	120	29	5.3	<3.0	--	< .01	1.80	.08	--	--
	09-15-87	141	34	5.3	<3.0	--	< .01	1.68	.07	--	--
	10-01-87	210	41	6.6	3.0	--	< .01	1.10	.03	--	--
6	03-18-87	141	17	6.6	4.0	< .1	--	13.0	.01	12	193
	03-18-87	139	17	6.0	1.5	--	< .01	4.68	.02	--	--
	05-08-87	189	9.1	6.0	3.1	--	.20	2.10	.02	--	--
	10-01-87	232	14	8.2	<3.0	--	< .01	2.72	.03	--	--
7	03-19-87	97	15	3.4	7.8	< .1	--	.81	.01	10	147
	03-19-87	115	18	2.7	3.9	--	< .01	.69	.01	--	--
	05-07-87	172	21	2.8	3.5	--	.01	.74	.03	--	--
	09-14-87	141	27	6.5	<3.0	--	< .01	1.40	.03	--	--
	09-15-87	126	24	5.5	<3.0	--	< .01	2.44	.02	--	--
	09-15-87	140	27	4.8	3.1	--	< .01	2.76	.02	--	--

Table 6.--Flow rate, physical properties, and inorganic chemical analyses of ground water from springs in northwestern Boone County, Arkansas--Continued

Site number	Date	Alaklinity wh wat tot fld (mg/L as $CaCO_3$) (00410)	Carbon dioxide dis-solved (mg/L as CO_2) (00405)	Chloride, dis-solved (mg/L as Cl) (00940)	Sulfate dis-solved (mg/L as SO_4) (00945)	Fluoride, dis-solved (mg/L as F) (00950)	Nitrogen, ammonia dis-solved (mg/L as N) (00608)	Nitrogen, NO_2+NO_3 dis-solved (mg/L as N) (00631)	Phosphorus, ortho, dis-solved (mg/L as P) (00671)	Silica, dis-solved (mg/L as SiO_2) (00955)	Solids, residue at 180 deg. C dis-solved (mg/L) (70300)
7	09-15-87	160	31	3.8	3.1	--	<0.01	1.96	0.02	--	--
	09-15-87	160	39	4.3	<3.0	--	< .01	2.12	.02	--	--
	10-02-87	164	20	1.7	<3.0	--	< .01	1.10	.03	--	--
8	03-19-87	84	8.2	10	7.2	<0.1	--	2.40	< .01	11	132
	03-19-87	82	8.0	10	5.3	--	.03	1.88	.01	--	--
9	06-20-87	148	5.6	25	3.5	--	.04	1.31	.01	--	--
10	03-20-87	55	3.4	--	--	--	--	--	--	--	--
	03-20-87	55	3.4	5.0	3.1	--	< .01	1.23	.03	--	--
	05-08-87	90	5.5	12	<3.0	--	.01	1.38	.02	--	--
	10-02-87	106	3.2	17	<3.0	--	< .01	2.08	.06	--	--
11	03-11-87	64	20	12	6.5	--	< .01	3.08	.12	--	--
	06-20-87	98	7.7	15	5.0	--	.04	3.19	.09	--	--
	10-02-87	112	3.4	18	7.8	--	< .01	2.72	.14	--	--
12	03-12-87	9	12	3.3	6.1	< .1	--	4.70	.02	12	157
	03-12-87	82	11	3.5	5.1	--	< .01	3.93	.02	--	--
	06-20-87	115	8.9	3.5	4.5	--	.02	6.80	.04	--	--
	10-02-87	136	5.2	5.8	5.8	--	< .01	7.40	.03	--	--
13	03-11-87	141	173	13	11	< .1	--	.17	.04	10	196
	03-11-87	131	158	6.0	7.1	--	.12	.08	.03	--	--
	06-20-87	164	51	10	11	--	.16	.84	.10	--	--
	10-01-87	196	48	9.7	6.5	--	.10	< .40	< .01	--	--
14	03-18-87	84	2.6	2.1	5.5	< .1	--	.38	< .01	9.1	96
	03-18-87	82	2.6	1.7	3.9	--	.03	.53	.01	--	--
	05-07-87	115	8.8	7.8	3.2	--	.03	.36	.01	--	--
	10-01-87	124	7.6	8.3	<3.0	--	< .01	.12	< .01	--	--
15	03-19-87	117	3.6	6.3	6.4	< .1	--	2.50	< .01	11	163
	03-19-87	123	3.8	5.8	5.2	--	< .01	2.16	.01	--	--
	05-07-87	131	8.2	7.5	3.5	--	.06	3.40	.03	--	--
	10-01-87	135	2.6	20	4.5	--	< .01	8.20	.02	--	--
16	03-12-87	55	11	16	9.3	< .1	--	12.0	.06	11	185
	03-12-87	54	10	15	7.3	--	< .01	10.8	.09	--	--
	06-20-87	107	11	17	7.0	--	.02	10.2	.09	--	--
	10-02-87	108	1.7	20	9.8	--	< .01	11.2	.16	--	--
17	03-19-87	45	3.4	5.4	5.4	< .1	--	1.40	.01	9.1	70
	03-19-87	48	3.7	5.5	3.2	--	< .01	1.27	.02	--	--
	05-07-87	90	6.8	11	3.2	--	.03	.96	.02	--	--
	10-01-87	109	8.4	10	<3.0	--	< .01	.84	.02	--	--

Table 6.--Flow rate, physical properties, and inorganic chemical analyses of ground water from springs in northwestern Boone County, Arkansas--Continued

Site number	Date	Solids, sum of constituents, dissolved (mg/L) (70301)	Arsenic, dissolved (µg/L as As) (01000)	Boron, dissolved (µg/L as B) (01020)	Cadmium dissolved (µg/L as Cd) (01025)	Chromium, hexavalent, dissolved (µg/L as Cr) (01032)	Cobalt, dissolved (µg/L as Co) (01035)	Copper, dissolved (µg/L as Cu) (01040)	Zinc, dissolved (µg/L as Zn) (01090)	Iron, dissolved (µg/L as Fe) (01046)	Lead, dissolved (µg/L as Pb) (01049)	Manganese, dissolved (µg/L as Mn) (01056)
1	03-19-87	289	<1	10	<1	<1	<1	10	46	14	<5	--
	03-19-87	--	--	--	<1	--	<1	6	110	7	5	1
	05-08-87	--	--	--	<1	--	<4	6	16	4	21	4
	05-08-87	--	--	--	<1	--	<4	<3	2	4	16	<2
	10-01-87	--	--	--	2	--	<4	<2	6	5	2	<2
	10-01-87	--	--	--	<1	--	<4	<2	21	8	2	<2
2	03-18-87	144	<1	10	<1	<1	<1	2	4	96	<5	--
	03-18-87	--	--	--	<1	--	<1	<2	1	43	5	9
	05-07-87	--	--	--	1	--	<4	<3	5	7	10	2
	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	10-02-87	--	--	--	<1	--	<4	<2	5	5	<2	<2
3	03-13-87	254	<1	<10	<1	<1	<1	1	3	5	<5	--
	03-13-87	--	--	--	<1	--	<1	<2	3	<2	5	<1
	06-20-87	--	--	--	<1	--	<4	<3	<1	4	<4	2
	10-01-87	--	--	--	1	--	<4	<2	13	5	2	<2
4	03-18-87	165	<1	<10	<1	<1	<1	1	<3	9	<5	--
	03-18-87	--	--	--	<1	--	<1	<2	1	2	<2	<1
	05-08-87	--	--	--	<1	--	<4	<3	6	<4	<4	16
	10-01-87	--	--	--	1	--	<4	<2	4	8	2	11
5	03-13-87	227	<1	10	<1	<1	<1	1	7	7	<5	--
	03-13-87	--	--	--	--	--	--	--	--	--	--	--
	06-20-87	--	--	--	<1	--	<4	<3	<1	4	4	2
	09-14-87	--	--	--	--	--	--	--	--	--	--	--
	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	10-01-87	--	--	--	1	--	<4	<2	13	5	<2	4
6	03-18-87	181	<1	<10	<1	<1	<1	<1	6	20	<5	--
	03-18-87	--	--	--	<1	--	<1	<2	1	<2	<2	<1
	05-08-87	--	--	--	<1	--	<4	<3	4	7	10	47
	10-01-87	--	--	--	1	--	<4	<2	7	8	2	<2
7	03-19-87	133	<1	<10	<1	<1	<1	2	8	21	<5	--
	03-19-87	--	--	--	<1	--	<1	<2	11	9	5	1
	05-07-87	--	--	--	<1	--	<4	<3	<1	4	10	2
	09-14-87	--	--	--	--	--	--	--	--	--	--	--
	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	09-15-87	--	--	--	--	--	--	--	--	--	--	--

Table 6.--Flow rate, physical properties, and inorganic chemical analyses of ground water from springs in northwestern Boone County, Arkansas--Continued

Site number	Date	Solids, sum of constituents, dissolved (mg/L) (70301)	Arsenic dissolved (µg/L as As) (01000)	Boron, dissolved (µg/L as B) (01020)	Cadmium dissolved (µg/L as Cd) (01025)	Chromium, hexavalent, dis-, solved (µg/L as Cr) (01032)	Cobalt, dissolved (µg/L as Co) (01035)	Copper, dissolved (µg/L as Cu) (01040)	Zinc, dissolved (µg/L as Zn) (01090)	Iron, dissolved (µg/L as Fe) (01046)	Lead, dissolved (µg/L as Pb) (01049)	Manganese, dissolved (µg/L as Mn) (01056)
7	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	09-15-87	--	--	--	--	--	--	--	--	--	--	--
	10-02-87	--	--	--	<1	--	<4	<2	6	5	<2	<2
8	03-19-87	125	<1	<10	<1	<1	<1	1	6	5	<5	--
	03-19-87	--	--	--	<1	--	<1	<2	8	6	5	1
9	06-20-87	--	--	--	<1	--	<4	<3	690	4	16	2
10	03-20-87	--	--	--	--	--	--	--	--	--	--	--
	03-20-87	--	--	--	<1	--	<1	<2	10	6	<2	1
	05-08-87	--	--	--	<1	--	<4	<3	17	<4	<4	<2
	10-02-87	--	--	--	<1	--	<4	<2	2	5	2	<2
11	03-11-87	--	--	--	<1	--	<1	<2	--	6	2	4
	06-20-87	--	--	--	1	--	<4	<3	5	4	<4	11
	10-02-87	--	--	--	2	--	<4	<2	13	8	7	2
12	03-12-87	135	<1	<10	<1	<1	<1	1	5	14	<5	--
	03-12-87	--	--	--	<1	--	<1	2	10	9	<2	<1
	06-20-87	--	--	--	3	--	<4	<3	<1	4	<4	2
	10-02-87	--	--	--	2	--	<4	<2	6	5	7	<2
13	03-11-87	184	<1	20	<1	<1	<1	1	51	440	<5	--
	03-11-87	--	--	--	6	--	10	<2	11	140	82	4
	06-20-87	--	--	--	4	--	20	<3	32	440	27	1,300
	10-01-87	--	--	--	16	--	50	2	27	160	140	530
14	03-18-87	104	<1	<10	<1	<1	<1	<1	5	15	<5	--
	03-18-87	--	--	--	<1	--	<1	<2	1	7	13	1
	05-07-87	--	--	--	<1	--	<4	<3	6	7	16	2
	10-01-87	--	--	--	<1	--	<4	<2	<2	5	<2	7
15	03-19-87	150	<1	<10	<1	<1	<1	<1	6	9	<5	--
	03-19-87	--	--	--	<1	--	<1	<2	5	2	5	<1
	05-07-87	--	--	--	<1	--	<4	<3	33	4	10	<2
	10-01-87	--	--	--	1	--	<4	<2	3	5	2	<2
16	03-12-87	125	<1	<10	<1	<1	<1	1	4	5	<5	--
	03-12-87	--	--	--	<5	--	<1	<2	1	2	13	<1
	06-20-87	--	--	--	<1	--	<4	<3	1	7	<4	2
	10-02-87	--	--	--	2	--	<4	<2	2	5	7	<2
17	03-19-87	71	<1	<10	<1	<1	<1	1	7	22	<5	--
	03-19-87	--	--	--	<1	--	<1	<2	1	7	5	<1
	05-07-87	--	--	--	<1	--	<4	<3	6	4	10	<2
	10-01-87	--	--	--	<1	--	<4	<2	3	5	2	<2

Table 6.--Flow rate, physical properties, and inorganic chemical analyses of ground water from springs in northwestern Boone County, Arkansas--Continued

Site number	Date	Nickel, dis- solved (µg/L as Ni) (01065)	Stron- tium, dis- solved (µg/L as Sr) (01080)	Alum- inum, dis- solved (µg/L as Al) (01106)	Sele- nium, dis- solved (µg/L as Se) (01145)	Mercury dis- solved (µg/L as Hg) (71890)	Coli- form, fecal, mf agar (cols./ 100 mL) (31625)	Strep- tococci fecal, kf agar (cols./ 100 mL) (31673)	Total cations (meq/L)	Total anions (meq/L)	Percent differ- ence cations/ anions
1	03-19-87	<1	170	20	<1	0.2	39	K1,100	5.347	5.360	- 0.12
	03-19-87	<3	--	--	--	--	33	K1,100	5.220	7.085	-15.16
	05-08-87	<6	--	--	--	--	<1	150	8.078	7.863	1.36
	05-08-87	<6	--	--	--	--	1	11	7.911	7.798	.72
	10-01-87	5	--	--	--	--	K3	77	7.716	8.143	- 2.69
	10-01-87	<5	--	--	--	--	K10	1,400	7.718	8.103	- 2.43
2	03-18-87	<1	32	110	<1	<0.1	K400	K1,100	2.664	2.646	.34
	03-18-87	<3	--	--	--	--	K400	K1,100	2.628	2.205	8.76
	05-07-87	<6	--	--	--	--	7	65	4.218	4.107	1.34
	09-15-87	--	--	--	--	--	K1,200	K1,700	4.092	4.132	- .47
	09-15-87	--	--	--	--	--	K940	K4,200	3.865	4.054	- 2.39
	09-15-87	--	--	--	--	--	490	K2,800	3.871	3.935	- .81
	09-15-87	--	--	--	--	--	600	K2,700	3.943	4.251	- 3.75
	09-15-87	--	--	--	--	--	420	K1,300	3.965	4.085	- 1.48
	10-02-87	<5	--	--	--	--	70	K370	4.153	4.198	- .54
3	03-13-87	<1	66	20	<1	<0.1	4	--	4.769	4.799	- .31
	03-13-87	<3	--	--	--	--	4	--	4.590	4.403	2.09
	06-20-87	<6	--	--	--	--	27	K730	4.869	5.102	- 2.33
	10-01-87	<5	--	--	--	--	K30	400	5.245	5.165	.77
4	03-18-87	<1	34	20	<1	<0.1	K200	320	3.062	3.077	- .24
	03-18-87	<3	--	--	--	--	K200	320	3.111	3.017	1.54
	05-08-87	<6	--	--	--	--	1	90	4.341	4.072	3.20
	10-01-87	5	--	--	--	--	K2,800	K8,800	5.600	5.655	- .48
5	03-13-87	<1	47	20	<1	<0.1	9	--	4.267	4.337	- .81
	03-13-87	--	--	--	--	--	9	--	4.202	3.912	3.57
	06-20-87	<6	--	--	--	--	K470	K3,400	4.525	4.525	.00
	09-14-87	--	--	--	--	--	K25,000	K43,000	1.470	1.335	4.82
	09-15-87	--	--	--	--	--	K5,400	K23,000	3.313	3.378	- .97
	09-15-87	--	--	--	--	--	K4,700	K20,000	2.826	2.763	1.13
	09-15-87	--	--	--	--	--	K3,100	K16,000	2.781	2.737	.80
	09-15-87	--	--	--	--	--	K2,000	K11,000	3.181	3.148	.52
	10-01-87	<5	--	--	--	--	K27	190	4.347	4.522	- 1.97
6	03-18-87	<1	39	30	<1	<0.1	K400	K560	3.678	4.021	- 4.45
	03-18-87	<3	--	--	--	--	K400	K570	3.377	3.312	.97
	05-08-87	<6	--	--	--	--	34	100	4.527	4.136	4.52
	10-01-87	<5	--	--	--	--	160	820	5.107	5.125	- .18
7	03-19-87	<1	35	30	<1	<0.1	K220	K720	2.673	2.260	8.37
	03-19-87	<3	--	--	--	--	K220	K720	2.532	2.503	.58
	05-07-87	<6	--	--	--	--	2	14	3.947	3.640	4.05
	09-14-87	--	--	--	--	--	K880	K6,200	3.070	3.163	- 1.49
	09-15-87	--	--	--	--	--	K1,300	K7,000	2.953	2.910	.74
	09-15-87	--	--	--	--	--	300	K5,000	3.205	3.193	.18

Table 6.--Flow rate, physical properties, and inorganic chemical analyses of ground water from springs in northwestern Boone County, Arkansas--Continued

Site number	Date	Nickel, dis-solved (µg/L as Ni) (01065)	Stron-tium, dis-solved (µg/L as Sr) (01080)	Alum-inum, dis-solved (µg/L as Al) (01106)	Sele-nium, dis-solved (µg/L as Se) (01145)	Mercury dis-solved (µg/L as Hg) (71890)	Coli-form, fecal, mf agar (cols./100 mL) (31625)	Strep-tococci fecal, kf agar (cols./100 mL) (31673)	Total cations (meq/L)	Total anions (meq/L)	Percent differ-ence cations/anions
7	09-15-87	--	--	--	--	--	200	K2,700	3.408	3.508	-1.44
	09-15-87	--	--	--	--	--	K1,100	K4,000	3.478	3.531	-.76
	10-02-87	5	--	--	--	--	K23	100	3.879	3.467	5.61
8	03-19-87	<1	37	<10	<1	<0.1	K550	K1,100	2.304	2.287	.37
	03-19-87	<3	--	--	--	--	K550	K1,100	2.341	2.164	3.93
9	06-20-87	<6	--	--	--	--	77	K1,300	3.786	3.772	.19
10	03-20-87	--	--	--	--	--	--	--	--	--	--
	03-20-87	<3	--	--	--	--	--	--	1.283	1.392	-4.06
	05-08-87	<6	--	--	--	--	<1	45	2.328	2.312	.35
	10-02-87	<5	--	--	--	--	K7	90	2.883	2.795	1.56
11	03-11-87	<3	--	--	--	--	--	--	2.076	1.986	2.22
	06-20-87	<6	--	--	--	--	55	K800	2.901	2.699	3.61
	10-02-87	5	--	--	--	--	<1	K7	2.793	3.091	-5.07
12	03-12-87	1	52	50	<1	<.1	73	--	2.677	2.539	2.64
	03-12-87	<3	--	--	--	--	73	--	2.502	2.124	8.16
	06-20-87	<6	--	--	--	--	13	K820	3.147	2.976	2.80
	10-02-87	<5	--	--	--	--	K27	500	3.593	3.529	.91
13	03-11-87	5	56	10	<1	<.1	<1	--	3.238	3.451	-3.17
	03-11-87	25	--	--	--	--	<1	--	3.145	2.912	3.85
	06-20-87	17	--	--	--	--	80	150	4.173	3.854	3.98
	10-01-87	74	--	--	--	--	<1	<1	4.184	4.330	-1.71
14	03-18-87	<1	23	50	<1	<.1	94	480	1.904	1.885	.51
	03-18-87	<3	--	--	--	--	94	480	1.877	1.807	1.91
	05-07-87	<6	--	--	--	--	2	K680	2.682	2.589	1.78
	10-01-87	<5	--	--	--	--	K17	100	2.873	2.785	1.56
15	03-19-87	<1	44	<10	<1	<.1	K440	K1,200	2.820	2.833	-.22
	03-19-87	<3	--	--	--	--	K440	K1,200	2.750	2.866	-2.07
	05-07-87	<6	--	--	--	--	16	680	3.528	3.145	5.74
	10-01-87	5	--	--	--	--	K320	1,100	4.138	3.948	2.35
16	03-12-87	2	93	30	<1	<.1	96	--	2.746	2.606	2.62
	03-12-87	<3	--	--	--	--	96	--	2.665	2.425	4.72
	06-20-87	<6	--	--	--	--	5	350	3.725	3.517	2.88
	10-02-87	5	--	--	--	--	700	180	4.011	3.715	3.84
17	03-19-87	<1	25	40	<1	<.1	26	360	1.212	1.250	-1.51
	03-19-87	<3	--	--	--	--	26	360	1.202	1.263	-2.48
	05-07-87	<6	--	--	--	--	54	K3,400	2.351	2.199	3.36
	10-01-87	<5	--	--	--	--	K3	K23	2.573	2.587	-.26

Table 7.--Organic chemical analyses of ground water from springs in northwestern Boone County, Arkansas

[mg/L, milligrams per liter; µg/L, micrograms per liter; --, not measured; five digit numbers in parentheses are STORET parameter codes used for computer storage of data; GC/FID, gas chromatograph/ flame ionization detector; USGS, U.S. Geological Survey]

Site number	Station number	Geologic unit	Agency collecting sample (code number) (00027)	Agency analyzing sample (code number) (00028)	Date	Time	Carbon, organic dissolved (mg/L as C) (00681)	GC/FID scan no. of peaks >10 percent of internal standard	Para-chloro-meta cresol total (µg/L) (34452)	2-chlorophenol total (µg/L) (34586)
1	362506093135701	Batesville Sandstone	USGS	USGS	03-19-87	1245	2.4	--	--	--
2	361753093110401	Boone Formation	USGS	USGS	03-18-87	1300	3.3	--	--	--
3	361900093162201	Boone Formation	USGS	USGS	03-13-87	0945	0.9	--	--	--
4	361923093103801	Boone Formation	USGS	USGS	03-18-87	1400	1.0	--	--	--
5	361942093134701	Boone Formation	USGS	USGS	03-13-87	0845	0.6	--	--	--
6	362226093102201	Boone Formation	USGS	USGS	03-18-87	1515	1.0	--	--	--
7	362304093123001	Boone Formation	USGS	USGS	03-19-87	1330	2.0	--	--	--
8	362455093103201	Boone Formation	USGS	USGS	03-19-87	1100	1.2	--	--	--
10	362607093111001	Boone Formation	USGS	USGS	03-20-87	1030	--	--	<5.0	<6.0
12	362648093072801	Boone Formation	USGS	USGS	03-12-87	1630	0.5	--	--	--
13	362658093121001	Boone Formation	USGS	USGS	03-11-87	1345	4.6	49	<5.0	<6.0
14	362714093125101	Boone Formation	USGS	USGS	03-18-87	1615	1.2	0	<5.0	<6.0
15	362823093140401	Boone Formation	USGS	USGS	03-19-87	0930	0.8	--	--	--
16	362923093081001	Boone Formation	USGS	USGS	03-12-87	0900	1.2	--	--	--
17	362945093124801	Boone Formation	USGS	USGS	03-19-87	0830	1.1	--	--	--

Site Number	Date	2-nitrophenol total (µg/L) (34591)	2,4-dichlorophenol total (µg/L) (34601)	2,4-dimethylphenol total (µg/L) (34606)	2,4,-dinitrophenol total (µg/L) (34616)	2,4,6-trichlorophenol total (µg/L) (34621)	4-nitrophenol total (µg/L) (34646)	4,6-dinitro-ortho-cresol total (µg/L) (34657)	Phenol (C6H-5OH) total (µg/L) (34694)	Pentachlorophenol total (µg/L) (39032)
10	03-20-87	<6.0	<6.0	<6.0	<20.0	<5.0	<30.0	<30.0	<6.0	<30.0
13	03-11-87	<6.0	<6.0	<6.0	<20.0	<5.0	<30.0	<30.0	<6.0	1,200
14	03-18-87	<6.0	<6.0	<6.0	<20.0	<5.0	<30.0	<30.0	<6.0	<30.0

Table 8.--Physical properties and inorganic chemical analyses of ground water from wells in northwestern Boone County, Arkansas

[Condition, indicates wet and dry seasonal samples used in statistical analysis and quality assurance (QA) samples; --, not measured; deg C, degrees Celsius; wh wat, whole water; tot fld, total field; cols./100 mL, colonies per 100 milliliters; mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; meq/L, milliequivalents per liter; five digit numbers in parentheses are STORET parameter codes used for computer storage of data; UofA, University of Arkansas; USGS, U.S. Geological Survey]

Site number	Station number	Local identifier	Owner	Latitude	Longitude	Geologic unit	Agency analyzing sample	Date	Time	Condition
18	362106093151201	20N21W31BAC1	Burns, J.	36 21 06 N	093 15 12 W	Boone Formation	UofA	06-20-87	1345	Other
							UofA	09-17-87	1300	Other
19	361722093141401	19N21W20BDC1	Wilson, B.	36 17 22 N	093 14 14 W	Cotter Dolomite	UofA	05-08-87	1830	Wet
							UofA	09-18-87	1330	Dry
20	361915093122001	19N21W10BCA1	Trammell, W.	36 19 15 N	093 12 20 W	Cotter Dolomite	UofA	05-08-87	1800	Wet
							UofA	09-16-87	1030	Dry
21	362053093123801	20N21W33ACD1	Noble, D.	36 20 53 N	093 12 38 W	Cotter Dolomite	UofA	05-08-87	1630	Wet
							USGS	08-07-87	1200	QA
							UofA	09-17-87	0845	Dry
22	362227093080401	20N20W20BCA1	Sublett, G.	36 22 27 N	093 08 04 W	Cotter Dolomite	UofA	06-21-87	1230	Wet
							UofA	09-16-87	1130	Dry
23	362231093142901	20N21W19ADD1	Fancher, D.	36 22 31 N	093 14 29 W	Cotter Dolomite	UofA	06-21-87	1630	Wet
							UofA	09-17-87	1015	Dry
24	362318093162701	20N22W13CBD1	Skaggs, B.	36 23 18 N	093 16 27 W	Cotter Dolomite	USGS	03-19-87	1500	QA
							UofA	03-19-87	1501	Other
							UofA	05-08-87	1000	Wet
							UofA	09-18-87	1230	Dry
25	362319093115001	20N21W15CAA1	Edwards, D.	36 23 19 N	093 11 50 W	Cotter Dolomite	USGS	05-07-87	1330	QA
							UofA	05-07-87	1331	Wet
							USGS	08-08-87	1331	QA
							UofA	09-17-87	1345	Dry
26	362351093142101	20N21W17BBB1	Gearhart, J.	36 23 51 N	093 14 21 W	Cotter Dolomite	UofA	05-08-87	1715	Wet
							UofA	09-17-87	0900	Dry
27	362436093055301	20N20W03CCA1	Horensky, S.	36 24 36 N	093 05 53 W	Cotter Dolomite	USGS	03-19-87	1630	QA
							UofA	03-19-87	1631	Other
							UofA	05-08-87	1230	Wet
							UofA	09-16-87	1200	Dry
28	362500093175001	20N22W03DDA1	Tipton, D.	36 25 00 N	093 17 50 W	Cotter Dolomite	UofA	06-20-87	1445	Wet
							UofA	09-17-87	0945	Dry
29	362654093101601	21N21W26ADB1	Cobb, J.	36 26 54 N	093 10 16 W	Cotter Dolomite	UofA	06-21-87	1345	Wet
							UofA	09-16-87	1530	Dry
30	362706093043501	21N20W23CDD1	Kain, J.	36 27 06 N	093 04 35 W	Cotter Dolomite	UofA	06-21-87	1430	Wet
							UofA	09-16-87	1415	Dry
31	362807093081101	21N20W17CCC1	Sanders, R.	36 28 07 N	093 08 11 W	Cotter Dolomite	UofA	06-21-87	1515	Wet
							UofA	09-16-87	1300	Dry
32	362841093115101	21N21W15BDA1	Matlock, L.	36 28 41 N	093 11 51 W	Cotter Dolomite	USGS	05-07-87	1430	QA
							UofA	05-07-87	1431	Wet
							USGS	08-04-87	1500	QA
							UofA	09-17-87	1500	Dry
33	362911093160201	21N22W12DCC1	Arnold, D.	36 29 11 N	093 16 02 W	Cotter Dolomite	USGS	05-07-87	1515	QA
							UofA	05-07-87	1516	Wet
							UofA	09-17-87	1530	Dry
34	362935093034501	21N20W12BBA1	Donnelly, J.	36 29 35 N	093 03 45 W	Cotter Dolomite	USGS	03-12-87	1245	QA
							UofA	03-12-87	1246	Wet
							UofA	09-16-87	1500	Dry

Table 8.--Physical properties and inorganic chemical analyses of ground water from wells in northwestern Boone County, Arkansas--Continued

Site number	Date	Elevation of land surface datum (feet above sea level) (72000)	Depth of well, total (feet) (72008)	Depth below land surface (water level) (feet) (72019)	Temperature water (deg C) (00010)	Specific conductance (μS/cm) (00095)	pH (standard units) (00400)	Calcium dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Hardness (mg/L as $CaCO_3$) (00900)	Hardness noncarb wh wat tot fld (mg/L as $CaCO_3$) (00902)	Sodium, dissolved (mg/L as Na) (00930)	Sodium adsorption ratio (00931)
18	06-20-87	1,100	40.00	--	20.0	420	7.40	78	1.4	200	21	2.7	0.1
	09-17-87	1,100	40.00	--	19.0	460	6.70	79	1.7	200	16	2.9	.1
19	05-08-87	1,420	460.00	--	16.0	580	7.20	74	19	260	10	11	.3
	09-18-87	1,420	460.00	--	15.5	575	7.00	75	18	260	17	17	.5
20	05-08-87	1,425	550.00	--	17.0	560	7.00	92	7.8	260	16	12	.3
	09-16-87	1,425	550.00	--	18.0	520	7.40	65	11	210	0	24	.8
21	05-08-87	1,360	400.00	--	16.5	438	7.30	40	20	180	2	15	.5
	08-07-87	1,360	400.00	334.00	--	--	--	--	--	--	--	--	--
	09-17-87	1,360	400.00	--	17.0	438	7.30	40	21	190	10	15	.5
22	06-21-87	1,365	444.00	--	19.0	560	7.30	62	30	280	15	1.6	0
	09-16-87	1,365	444.00	--	18.0	540	7.60	59	31	280	22	1.6	0
23	06-21-87	1,510	510.00	--	17.5	430	7.30	54	18	210	29	4.4	.1
	09-17-87	1,510	510.00	--	17.0	375	7.20	42	18	180	27	2.6	.1
24	03-19-87	1,300	475.00	--	15.0	458	8.20	47	24	220	0	8.9	.3
	03-19-87	1,300	475.00	--	15.0	458	7.50	42	25	210	0	8.2	.3
	05-08-87	1,300	475.00	--	16.0	430	7.30	43	22	200	1	10	.3
	09-18-87	1,300	475.00	--	18.0	460	7.20	44	25	210	6	8.4	.3
25	05-07-87	1,320	455.00	--	18.5	520	7.60	--	--	--	--	--	--
	05-07-87	1,320	455.00	--	18.5	520	7.60	60	31	280	56	1.9	0
	08-08-87	1,320	455.00	180.00	--	--	--	--	--	--	--	--	--
	09-17-87	1,320	455.00	--	19.0	538	7.00	60	30	280	55	2.4	.1
26	05-08-87	1,410	520.00	--	15.0	395	7.20	46	19	190	28	2.9	.1
	09-17-87	1,410	520.00	--	15.0	370	7.30	42	20	190	22	2.9	.1
27	03-19-87	950	240.00	--	15.0	650	7.60	69	42	350	12	6.5	.2
	03-19-87	950	240.00	--	15.0	650	7.20	65	42	340	8	6.9	.2
	05-08-87	950	240.00	123.25	16.5	680	6.80	77	47	380	49	3.2	.1
	09-16-87	950	240.00	--	19.0	680	6.90	73	50	390	49	2.8	.1
28	06-20-87	1,150	400.00	--	22.0	478	7.50	59	18	220	0	6.1	0.2
	09-17-87	1,150	400.00	--	17.0	480	7.00	58	19	220	20	6.4	.2
29	06-21-87	1,320	675.00	--	19.0	620	7.10	74	34	320	63	1.6	0
	09-16-87	1,320	675.00	--	17.0	640	6.90	73	36	330	64	1.8	0
30	06-21-87	760	--	--	19.5	599	7.20	63	35	300	31	1.8	0
	09-16-87	760	--	--	19.0	560	7.10	61	33	290	23	1.6	0
31	06-21-87	1,320	755.00	--	17.5	580	7.20	60	32	280	36	2.6	.1
	09-16-87	1,320	755.00	--	19.0	580	7.20	56	34	280	30	2.2	.1
32	05-07-87	1,360	705.00	--	16.0	360	7.90	--	--	--	--	--	--
	05-07-87	1,360	705.00	--	16.0	360	7.90	37	20	170	44	1.9	.1
	08-04-87	1,360	705.00	254.00	--	--	--	--	--	--	--	--	--
	09-17-87	1,360	705.00	--	18.0	362	7.20	38	21	180	71	1.4	0
33	05-07-87	1,300	550.00	--	16.5	365	7.50	--	--	--	--	--	--
	05-07-87	1,300	550.00	--	16.5	365	7.50	40	22	190	25	1.5	0
	09-17-87	1,300	550.00	--	19.0	380	7.20	40	21	190	33	1.6	0
34	03-12-87	890	185.00	--	13.5	590	6.80	70	40	340	37	1.9	0
	03-12-87	890	185.00	22.40	13.5	590	6.80	67	39	330	33	2.6	.1
	09-16-87	890	185.00	--	20.0	700	7.00	72	47	370	77	5.0	.1

Table 8.--Physical properties and inorganic chemical analyses of ground water from wells in northwestern Boone County, Arkansas--Continued

Site number	Date	Potassium, dissolved (mg/L as K) (00935)	Alkalinity wh wat tot fld (mg/L as $CaCO_3$) (00410)	Carbon dioxide dissolved (mg/L as CO_2) (00405)	Chloride, dissolved (mg/L as Cl) (00940)	Sulfate dissolved (mg/L as SO_4) (00945)	Fluoride, dissolved (mg/L as F) (00950)	Nitrogen, ammonia dissolved (mg/L as N) (00608)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N) (00631)	Phosphorus, ortho, dissolved (mg/L as P) (00671)	Silica, dissolved (mg/L as SiO_2) (00955)
18	06-20-87	2.0	180	14	63	3.4	--	0.02	0.36	.02	--
	09-17-87	2.6	188	73	4.8	3.0	--	< .01	2.36	.01	--
19	05-08-87	1.3	254	31	8.0	28	--	.01	.36	.01	--
	09-18-87	1.3	246	48	8.9	33	--	.06	.38	< .01	--
20	05-08-87	3.0	246	48	4.5	18	--	.03	.21	.02	--
	09-16-87	6.3	234	18	5.9	21	--	.01	.20	< .01	--
21	05-08-87	5.1	180	17	3.0	21	--	.37	< .04	.01	--
	08-07-87	--	--	--	--	--	--	--	--	--	--
	09-17-87	5.4	176	17	3.5	21	--	.14	.08	< .01	--
22	06-21-87	1.3	262	25	.5	17	--	< .01	< .04	.01	--
	09-16-87	1.6	254	12	1.5	20	--	.01	.06	< .01	--
23	06-21-87	1.5	180	18	4.3	31	--	< .01	< .04	.01	--
	09-17-87	2.7	154	19	4.1	17	--	< .01	.06	< .01	--
24	03-19-87	5.4	222	2.7	2.9	18	0.9	--	.23	< .01	8.8
	03-19-87	5.6	213	13	2.1	17	--	.05	.18	.02	--
	05-08-87	6.2	197	19	1.5	20	--	.30	.04	.04	--
	09-18-87	6.0	206	25	2.5	19	--	.10	.20	< .01	--
25	05-07-87	--	--	0	--	--	--	--	--	--	--
	05-07-87	1.6	221	11	4.5	33	--	<0.01	0.32	0.01	--
	08-08-87	--	--	--	--	--	--	--	--	--	--
	09-17-87	2.5	220	43	6.5	37	--	.01	.56	.01	--
26	05-08-87	3.8	164	20	1.5	22	--	.01	.54	< .01	--
	09-17-87	3.7	164	16	1.5	19	--	< .01	.06	.01	--
27	03-19-87	.8	332	16	9.9	9.3	0.1	--	1.60	< .01	14
	03-19-87	1.2	328	40	7.5	13	--	< .01	.73	.01	--
	05-08-87	1.0	336	102	3.3	26	--	< .01	.10	.01	--
	09-16-87	1.4	338	82	4.5	23	--	.18	.24	.01	--
28	06-20-87	3.5	192	12	6.0	17	--	.05	2.01	.01	--
	09-17-87	3.9	202	39	8.7	17	--	.10	3.24	.01	--
29	06-21-87	3.0	262	40	2.0	52	--	< .01	.32	.01	--
	09-16-87	3.8	267	65	3.2	68	--	.20	.28	.01	--
30	06-21-87	3.3	271	33	1.0	18	--	< .01	.06	.01	--
	09-16-87	5.6	264	41	1.5	19	--	.10	.04	.01	--
31	06-21-87	5.5	246	30	.5	42	--	.02	.05	< .01	--
	09-16-87	6.1	250	31	1.7	55	--	.16	.06	< .01	--
32	05-07-87	--	--	0	--	--	--	--	--	--	--
	05-07-87	2.3	131	3.2	1.2	36	--	.03	< .04	< .01	--
	08-04-87	--	--	--	--	--	--	--	--	--	--
	09-17-87	2.4	110	13	1.2	37	--	< .01	< .04	< .01	--
33	05-07-87	--	--	0	--	--	--	--	--	--	--
	05-07-87	1.0	164	9.9	2.5	14	--	< .01	.16	.01	--
	09-17-87	1.2	154	19	2.8	15	--	< .01	.16	< .01	--
34	03-12-87	2.6	297	93	3.5	34	.1	--	.45	< .01	9.4
	03-12-87	3.0	295	90	2.0	29	--	< .01	.15	.02	--
	09-16-87	3.7	297	58	5.8	72	--	.16	1.42	< .01	--

Table 8.--Physical properties and inorganic chemical analyses of ground water from wells in northwestern Boone County, Arkansas--Continued

Site number	Date	Solids, residue at 180 deg C dissolved (mg/L) (70300)	Solids, sum of constituents, dissolved (mg/L) (70301)	Arsenic dissolved (µg/L as As) (01000)	Boron, dissolved (µg/L as B) (01020)	Cadmium dissolved (µg/L as Cd) (01025)	Chromium, hexavalent, dissolved (µg/L as Cr) (01032)	Cobalt, dissolved (µg/L as Co) (01035)	Copper, dissolved (µg/L as Cu) (01040)	Zinc, dissolved (µg/L as Zn) (01090)	Iron, dissolved (µg/L as Fe) (01046)	Lead, dissolved (µg/L as Pb) (01049)
18	06-20-87	--	--	--	--	<1	--	<4	<3	3	7	4
	09-17-87	--	--	--	--	<1	--	<4	<2	150	5	<2
19	05-08-87	--	--	--	--	1	--	<4	3	930	11	4
	09-18-87	--	--	--	--	<1	--	<4	<2	1,000	16	<2
20	05-08-87	--	--	--	--	1	--	4	6	710	7	16
	09-16-87	--	--	--	--	<1	--	<4	<2	130	1	<2
21	05-08-87	--	--	--	--	<1	--	<4	<3	610	29	4
	08-07-87	--	--	--	--	--	--	--	--	--	--	--
	09-17-87	--	--	--	--	<1	--	<4	<2	170	19	<2
22	06-21-87	--	--	--	--	<1	--	<4	<3	1,100	4	10
	09-16-87	--	--	--	--	1	--	<4	<2	300	12	2
23	06-21-87	--	--	--	--	<1	--	<4	3	1,300	11	10
	09-17-87	--	--	--	--	<1	--	<4	<2	260	27	<2
24	03-19-87	230	252	1	210	<1	<1	<1	9	1,500	6	<5
	03-19-87	--	--	--	--	<1	--	<1	6	1,100	4	13
	05-08-87	--	--	--	--	<1	--	<4	3	880	14	16
	09-18-87	--	--	--	--	<1	--	<4	<2	520	5	<2
25	05-07-87	--	--	--	--	--	--	--	--	--	--	--
	05-07-87	--	--	--	--	<1	--	<4	<3	440	4	4
	08-08-87	--	--	--	--	--	--	--	--	--	--	--
	09-17-87	--	--	--	--	1	--	<4	<2	220	16	2
26	05-08-87	--	--	--	--	1	--	4	<3	570	7	4
	09-17-87	--	--	--	--	<1	--	<4	<2	280	12	<2
27	03-19-87	345	351	<1	<10	<1	<1	<1	4	110	3	<5
	03-19-87	--	--	--	--	<1	--	<1	<2	140	2	5
	05-08-87	--	--	--	--	<1	--	<4	<3	160	4	<4
	09-16-87	--	--	--	--	<1	--	<4	<2	120	5	<2
28	06-20-87	--	--	--	--	<1	--	<4	<3	628	4	10
	09-17-87	--	--	--	--	1	--	<4	<2	290	8	<2
29	06-21-87	--	--	--	--	<1	--	<4	<3	1,900	11	10
	09-16-87	--	--	--	--	<1	--	<4	<2	1,100	5	<2
30	06-21-87	--	--	--	--	1	--	<4	<3	130	22	16
	09-16-87	--	--	--	--	<1	--	<4	<2	67	90	<2
31	06-21-87	--	--	--	--	2	--	<4	<3	1,700	11	16
	09-16-87	--	--	--	--	2	--	<4	<2	1,400	8	<2
32	05-07-87	--	--	--	--	--	--	--	--	--	--	--
	05-07-87	--	--	--	--	2	--	<4	<3	390	4	<4
	08-04-87	--	--	--	--	--	--	--	--	--	--	--
	09-17-87	--	--	--	--	<1	--	<4	<2	180	5	<2
33	05-07-87	--	--	--	--	--	--	--	--	--	--	--
	05-07-87	--	--	--	--	<1	--	4	6	630	4	4
	09-17-87	--	--	--	--	<1	--	<4	<2	270	5	2
34	03-12-87	329	344	<1	<10	<1	<1	<1	3	190	6	<5
	03-12-87	--	--	--	--	1	--	<1	2	180	6	2
	09-16-87	--	--	--	--	<1	--	<4	<2	140	5	<2

Table 8.--Physical properties and inorganic chemical analyses of ground water from wells in northwestern Boone County, Arkansas--Continued

Site number	Date	Manganese, dissolved (µg/L as Mn) (01056)	Nickel, dissolved (µg/L as Ni) (01065)	Strontium, dissolved (µg/L as Sr) (01080)	Aluminum, dissolved (µg/L as Al) (01106)	Selenium, dissolved (µg/L as Se) (01145)	Mercury dissolved (µg/L as Hg) (71890)	Coliform, fecal, mf agar (cols./ 100 mL) (31625)	Streptococci fecal, kf agar (cols./ 100 mL) (31673)	Total cations (meq/L)	Total anions (meq/L)	Percent difference cations/ anions
18	06-20-87	<2	<6	--	--	--	--	3	5	4.177	5.511	-13.77
	09-17-87	<2	<5	--	--	--	--	34	K180	4.275	4.123	1.82
19	05-08-87	2	<6	--	--	--	--	0	1	5.785	5.914	-1.09
	09-18-87	2	<5	--	--	--	--	1	0	6.031	5.881	1.26
20	05-08-87	2	<6	--	--	--	--	0	1	5.832	5.443	3.46
	09-16-87	<2	<5	--	--	--	--	0	1	5.371	5.290	.77
21	05-08-87	4	<6	--	--	--	--	0	1	4.449	4.074	4.40
	08-07-87	--	--	--	--	--	--	--	--	--	--	--
	09-17-87	<2	<5	--	--	--	--	0	3	4.500	4.054	5.21
22	06-21-87	2	<6	--	--	--	--	0	0	5.633	5.575	.52
	09-16-87	<2	<5	--	--	--	--	0	7	5.623	5.545	.71
23	06-21-87	2	<6	--	--	--	--	0	1	4.407	4.366	.46
	09-17-87	2	<5	--	--	--	--	0	2	3.794	3.559	3.20
24	03-19-87	--	2	860	<10	<1	0.4	0	2	4.846	4.956	-1.12
	03-19-87	3	<3	--	--	--	--	0	2	4.629	4.693	- .68
	05-08-87	2	<6	--	--	--	--	0	1	4.551	4.335	2.44
	09-18-87	2	<5	--	--	--	--	0	0	4.756	4.543	1.75
25	05-07-87	--	--	--	--	--	--	0	1	5.397	5.530	-1.22
	05-07-87	<2	<6	--	--	--	--	0	1	5.653	5.253	3.67
	08-08-87	--	--	--	--	--	--	--	--	--	--	--
	09-17-87	2	5	--	--	--	--	0	2	5.666	5.379	2.60
26	05-08-87	<2	<6	--	--	--	--	0	0	4.067	3.816	3.18
	09-17-87	<2	<5	--	--	--	--	0	2	3.931	3.719	2.77
27	03-19-87	--	<1	55	<10	<1	< .1	4	21	7.203	7.246	- .29
	03-19-87	1	<3	--	--	--	--	4	21	7.040	7.066	- .18
	05-08-87	2	<6	--	--	--	--	2	440	7.859	7.298	3.70
	09-16-87	<2	<5	--	--	--	--	0	2	7.883	7.366	3.39
28	06-20-87	4	<6	--	--	--	--	0	1	4.814	4.497	3.41
	09-17-87	<2	<5	--	--	--	--	0	2	4.820	4.878	- .58
29	06-21-87	4	<6	--	--	--	--	0	5	6.638	6.323	2.43
	09-16-87	<2	<5	--	--	--	--	0	95	6.781	6.860	- .57
30	06-21-87	2	<6	--	--	--	--	0	0	6.205	5.829	3.13
	09-16-87	2	<5	--	--	--	--	0	3	5.961	5.712	2.14
31	06-21-87	4	<6	--	--	--	--	0	0	5.882	5.726	1.35
	09-16-87	<2	<5	--	--	--	--	0	4	5.845	6.191	-2.87
32	05-07-87	--	--	--	--	--	--	0	14	3.528	3.623	-1.33
	05-07-87	<2	<6	--	--	--	--	0	14	3.634	3.395	3.41
	08-04-87	--	--	--	--	--	--	--	--	--	--	--
	09-17-87	<2	<5	--	--	--	--	0	3	3.731	2.994	10.97
33	05-07-87	--	--	--	--	--	--	0	0	3.781	3.845	-0.82
	05-07-87	<2	<6	--	--	--	--	0	0	3.865	3.626	3.19
	09-17-87	<2	<5	--	--	--	--	0	3	3.842	3.470	5.08
34	03-12-87	--	3	50	<10	<1	<0.1	0	--	6.935	6.898	.27
	03-12-87	<1	<3	--	--	--	--	0	--	6.748	6.508	1.81
	09-16-87	2	<5	--	--	--	--	0	3	7.790	7.697	.60

Table 9.--Organic chemical analyses of ground water from wells in northwestern Boone County, Arkansas

[MG/L, milligrams per liter; --, not measured; GC/FID, gas chromatagraph/flame ionization detector; five digit numbers in parentheses are STORET parameter codes used for computer storage of data; USGS, U.S. Geological Survey]

Site number	Station number	Geologic unit	Agency collecting sample (code number) (00027)	Agency analyzing sample (code number) (00028)	Date	Time	Carbon, organic dissolved (mg/L as C) (00681)	GC/FID scan no. of peaks >10 percent of internal standard
24	362318093162701	Cotter Dolomite	USGS	USGS	03-19-87	1500	0.5	--
25	362319093115001	Cotter Dolomite	USGS	USGS	05-07-87	1330	--	0
27	362436093055301	Cotter Dolomite	USGS	USGS	03-19-87	1630	1.3	--
32	362841093115101	Cotter Dolomite	USGS	USGS	05-07-87	1430	--	0
34	362935093034501	Cotter Dolomite	USGS	USGS	03-12-87	1245	.5	--