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A Preliminary Investigation of Rural-Use Aquifers Of Boone, Carroll, and Madison Counties, Arkansas

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ABSTRACT

Approximately 500 water wells having driller's lithologic logs were plotted in Boone, Carroll, and Madison Counties, Arkansas. Three aquifers were found to be used by the rural residents and smaller communities. The most shallow of these is the Mississippian Boone-St. Joe aquifer. This aquifer is generally the least productive having a range of .25 to 60 gpm but a median productivity of only 5 gpm. Well depths for the Boone-St. Joe range from 46 to 464 ft. and have a median depth of 225 ft. The Boone-St. Joe aquifer is unconfined to semi-confined and yields sufficient quantities of water only when there is an adequate saturated thickness (generally >100 ft.) and/or a fracture or water-filled cave is intersected.

The next aquifer is the first sand below the Chattanooga Shale which can be composed on one to three of the following sandstones: upper Everton, Clifty, and/or Sylamore. The range in yield for this newly designated aquifer is 1 to 70 gpm with a median productivity of 10 gpm. Well depths for the aquifer range from 150 to 824 ft. with a median depth of 460 feet. An isoch map was prepared for this sandstone aquifer zone. There is a rapid thinning trend to the north from 250 ft in central Madison County to 0 ft near the Missouri border. If there is insufficiency or permeability of this aquifer, residents must drill deeper to the Cotter Dolomite.

The Cotter-Jefferson City Dolomite is the next aquifer below the Sylamore-Clifty-Everton aquifer. This aquifer zone has a range in yield of 1.5 to 200 gpm and a median yield of 15 gpm. Well depths range from 130 to 1010 ft. with a median depth of 475 feet.

A statistical correlation procedure was made among well yield (gpm), photo-lineament proximity, and regolith thickness for all these aquifers in Boone County. The results indicate that more water can be obtained in areas of deep weathering and that deeper weathering is found closer to photo-lineaments. A strong relationship between lineament proximity and yield exists when the aquifers are combined but not for each of the individual aquifers.

INTRODUCTION

Ground water is extensively used by rural residents and communities of Carroll, Madison, and Boone Counties, Arkansas. Few detailed hydrogeologic reports have been written about the study area. Purdue and Miser (1916) first mentioned ground water in Carroll and Boone Counties, but only in a cursory manner. A short list of water well depths and estimated yields was made by Branner (1937) in the study area. Isophachous and structural contour maps of some of the formations discussed in this report were made by Caplan (1957). A reconnaissance survey by Lamonds (1972) used sparse data to produce a piezometric surface map for Roubidoux Formation and Gunter Sandstone member of the Gasconade Formation.

Numerous hydrogeologic theses have been produced at the University of Arkansas, but none pertain directly to the study area of this report. Water chemistry of the Boone-St. Joe aquifer has been investigated by Grubbs (1974), Coughlin (1975), and Brooks et al. (1979) in Washington and Benton Counties. A water table map of the Boone-St. Joe aquifer was produced along the western edge of Beaver Lake by Hunt (1974). Hanson (1973) and Gaines (1978) have performed a fracture analysis of northern Arkansas and compared fracture proximity to well yield for the Boone-St. Joe and Roubidoux aquifers, respectively. A recent detailed analysis of the Boone-St. Joe aquifer in Benton County by pumping tests, water analyses, and fracture mapping has been performed by Brooks et al. (1979) and Rezaei et al. (1979).

This investigation presents the results of a preliminary investigation of three important aquifers used by a large majority of the people of Carroll, Boone, and northern Madison Counties.

LOCATION AND GEOLOGY

The study area is located in Carroll, Boone, and northern Madison Counties, Arkansas (Figure 1). Mississippian, Devonian, and Ordovi-

cian rocks are exposed at the surface. The generalized stratigraphy of the study area is shown in Figure 2. Unconformities are common in the stratigraphy, sometimes making it difficult to determine the exact formations present in a well.

The study area is composed of portions of several physiographic provinces. There are three dissected plateau surfaces, and two major escarpments separating the plateaus (Figure 2). The rocks in the study area dip gently on the southeastern flank of the Ozark Dome with little deformation. Normal faults are found, but they are not a common structural feature. There is extensive karst developed in the carbonate rocks such as the Boone, St. Joe, Powell, Cotter, and Jefferson City formations. Caves, springs, dolines, and losing streams are common landforms. Joints have been enlarged by solution, thus enhancing the permeability and increasing groundwater storage and movement within the carbonate formations.

METHODS

Records of water wells were obtained from the Arkansas Geologic Commission for Carroll, Madison, and Boone Counties. Approximately 500 wells were accurately plotted with the aid of county plat books and rural directories. From the gross lithologic log reported on each record, it was possible to determine the aquifer(s) that supplied water to each well. The occasional absence of formations due to unconformities generally did not significantly hamper determination of the studied aquifers since they are usually composed of more than one geologic formation that is easily distinguished by marker horizons. Other important information provided by each well record was: (1) the depth to water, (2) driller's estimate of yield (gpm), and (3) the depth to bedrock.

Photo-lineaments were drawn from 1:20,000 BXW aerial photographs of Boone County. The Spearman-Rank Correlation Coefficient test (Siegel, 1956) was then used to make preliminary tests among the following parameters: (1) well yield, (2) photo-lineament proximity, and (3) depth to bedrock.

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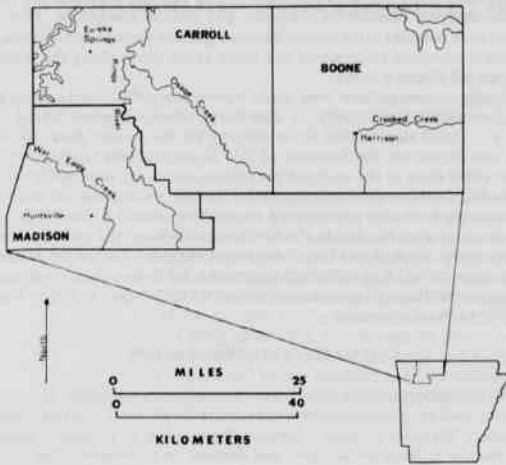


Figure 1. Location of the study area.

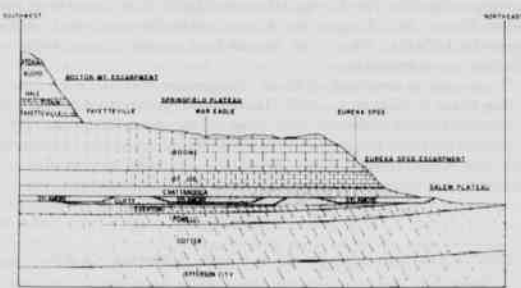


Figure 2. Cross section showing the generalized stratigraphy and physiographic provinces of the study area.

RESULTS

Three important aquifers were found to be used by rural residents in the study area. The most shallow aquifer is the Mississippian Boone-St. Joe Limestone aquifer. Although different formations, the Boone and St. Joe limestones behave collectively as an aquifer. This aquifer is generally the least productive with a range in yield of 0.25 to 60 gpm, and a median productivity of only 5 gpm (Table 1).

Depths for drilled wells in the Boone-St. Joe aquifer range from 40 to 464 feet and have a median depth of 235 feet (Table 1). These figures represent only wells in which drilling began in the Boone. Wells beginning in Pennsylvanian rocks and penetrating the entire thickness of the Boone-St. Joe aquifer indicate that the aquifer achieves a maximum thickness of 476 feet in southern Carroll and Boone Counties. This aquifer is unconfined where exposed at the surface.

The second important aquifer zone is a group of sands below the Chattanooga Shale where the Chattanooga is present, or below the St. Joe Limestone if the Chattanooga is not present. This aquifer can be composed of one to three of the following sandstones: Sylamore, Clifty, and upper Everton (Figure 2). In the western part of the study area where the Chattanooga is present, ground water is obtained commonly within the first 50 feet of the aquifer and is primarily from the Clifty and/or Sylamore. In Boone County, the Clifty and Sylamore are absent, and the upper Everton sandstone beds becomes the dominant water bearing units. Locally, occasional thin beds of limestone and dolomite are found within this upper section of the Everton

Table 1. Summary of measured hydrogeologic parameters in the study area.

Aquifer	Depth (ft.)		Yield (gpm)	
	Range	Median	Range	Median
Boone-St. Joe	46-464	225	.25-60	5
Sylamore-Clifty- Everton	150-824	460	1-70	10
Cotter- Jefferson City	130-1010	475	1.5-200	15

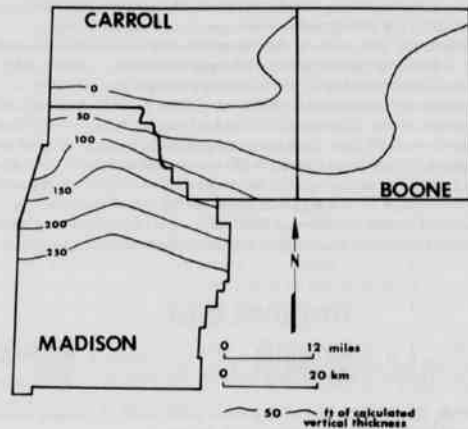


Figure 3. Isopachous map of the Sylamore-Clifty-upper Everton sandstone aquifer.

(Suhm, 1970). East of the study area, the St. Peter Sandstone overlies the Everton and becomes part of this aquifer zone.

The range in yield for the Sylamore-Clifty-Everton aquifer is 1 to 70 gpm with a median productivity of 10 gpm (Table 1). It should be noted that many of these yields include water contributed by the overlying Boone-St. Joe aquifer. Generally, this contribution is slight or else drilling would have ceased in the overlying aquifer. Well depths for the aquifer range from 150 to 824 feet with a median depth of 460 feet (Table 1). These depths most commonly include thicknesses of the Boone-St. Joe formations since the Sylamore-Clifty-Everton is only exposed as a thin band along the Eureka Springs Escarpment (Figure 2). Many of the wells drilled on the Boone covered Springfield Plateau surface go into this second aquifer zone for sufficient quantities of water.

An isopachous map was prepared for the Sylamore-Clifty-Everton aquifer for Boone, Carroll, and northern Madison Counties (Figure 3). There is a rapid thinning trend to the north from 250 feet in central Madison County to 0 feet near the Missouri border. The base of this aquifer zone was defined by the first carbonate unit (usually within the Everton) encountered. If there is insufficient thickness of the aquifer, and/or it is inadequately fractured, drilling must continue to the Cotter and Jefferson City formations. A small number of

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wells obtain water from carbonate units within the Everton and Powell Formations.

The Cotter and Jefferson City Formations make up the third major aquifer in the study area. This aquifer is primarily dolomite and is used mostly where the Cotter Dolomite is exposed on the Salem Plateau surface (Figure 2). The aquifer has a range in yield of 1.5 to 200 gpm with a median yield of 15 gpm (Table 1). Well depths range from 130 to 1010 feet with a median depth of 475 feet. The greater depths represent the few wells that begin in the Boone. Yield values for a few wells contain water contributions from overlying aquifers, but this is generally insignificant.

GEOSTATISTICAL RELATIONSHIPS

The relationships among yield, regolith thickness, and photo-lineament proximity were determined for the hydrologic data accumulated for Boone County, Arkansas, as a means for better well site location. The Spearman-Rank Correlation Coefficient was used for the comparisons with the aid of computer SAS (Barr et al., 1976) procedures.

The first relationship tested was between well yield (gpm), estimated by drillers, and photo-lineament proximity. Parizek (1976) has found a relationship between these two for dolomites in central Pennsylvanian which he attributes to photo-lineaments representing zones of fracturing that cause higher aquifer permeabilities and thus greater well yields. Using the data from each aquifer individually in Boone County, a relationship was not found at an $\alpha = 0.1$ probability level. This may be due to sparse data within an individual data set. When grouped together, the aquifers showed a relationship, but the authors do not feel this is of strong geologic significance.

A comparison between well yields for wells in bedrock and regolith thickness was made. The regolith thickness ranged from 1 to 217 feet with a median of 28 feet. One hundred and sixty-three yield and regolith values from Boone County wells were used in this test. A relationship indicating higher yields for wells drilled in thicker regolith was found at an $\alpha = 0.1$ significance level for the Boone and Sylamore-Clifty-Everton aquifers individually, and the combined well data. In carbonate rocks, weathering takes place deeper along frac-

tures than along unfractured areas, often yielding an irregular regolith-bedrock contact of pinnacles and cutters (Sweeting, 1973). Therefore, a linear relationship between greater yield and thicker regolith is expected since water can more easily move along the more weathered fracture zones.

Finally, a comparison was made between regolith thickness and photo-lineament proximity. A significant relationship was found at an $\alpha = 0.005$ significance level utilizing all the aquifer data. There are two important implications of this significant relationship. The first is that most of the mapped photo-lineaments are accurately representing fracture zones along which deeper weathering has taken place compared with unfractured zones. The second is that by drilling a well where regolith is thicker in a given area, the yield can be expected to be higher even if a photo-lineament cannot be found near a well site. Regolith thicknesses can be determined from exploration drilling and seismic and resistivity techniques to utilize this well site selection method.

SUMMARY AND CONCLUSION

Three important aquifers representing combinations of pre-Pennsylvanian geologic formations exist in Boone, Carroll, and northern Madison Counties. Ranged from oldest to youngest, most productive to least productive, and deepest to shallowest, they are: (1) Cotter-Jefferson City, (2) upper Everton-Clifty-Sylamore, and (3) Boone-St. Joe aquifer zones.

The upper Everton-Clifty-Sylamore aquifer zone is commonly used on the Springfield Plateau when the Boone-St. Joe aquifer lacks adequate production. The Cotter-Jefferson City is used throughout the Salem Plateau of Arkansas, and it is occasionally penetrated on the Springfield Plateau where the Boone-St. Joe and Sylamore-Clifty-Everton are unproductive.

Geostatistical correlations show that greater yields can be found where there is thicker regolith. Increased regolith thickness along photo-lineaments indicates that most of the photo-lineaments accurately represent fractures along which weathering is more extensive than in unfractured areas. Although not statistically confirmed, an increase in yield is also expected along photo-lineaments.

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