The Sparta Aquifer: A Sustainable Water Resource?

Introduction

The Sparta aquifer is an aquifer of regional importance within the Mississippi embayment aquifer system. It consists of varying amounts of unconsolidated sand, interstratified with silt and clay lenses within the Sparta Sand of the Claiborne Group. It extends from south Texas, north into Louisiana, Arkansas, and Tennessee, and eastward into Mississippi and Alabama (fig. 1). On both the west and east sides of the Mississippi embayment, the Sparta aquifer is exposed at the surface (outcrops) and is locally unconfined; it becomes confined as it dips toward the axis of the embayment, generally corresponding with the Mississippi River and southward toward the Gulf of Mexico where it is deeply buried in the subsurface (Hosman, 1968). Generalized ground-water flow in the Sparta aquifer is from the outcrop areas to the axis (center) of the embayment (fig. 2).

In Arkansas, the Sparta aquifer outcrops parallel to the Fall Line at the western extreme of the Mississippi embayment (the Fall Line is a line dividing the mountainous highlands of Arkansas from the lowland area); and the formation dips from its outcrop area to the southeast. The Sparta aquifer supplies water for municipalities, industries such as paper production, and to a lesser degree, irrigation of agricultural crops (fig. 3). This report highlights hydrologic conditions of the aquifer in Arkansas as an example of how water use is affecting water levels.

Hydrogeologic Characteristics

The Sparta aquifer is an excellent source of water because of favorable hydrogeologic characteristics. The thickness of the Sparta aquifer in Arkansas ranges from less than 100 feet (ft) near the outcrop area up to 1,000 ft in the southeastern part of the State (Payne, 1968). Through most of the aquifer’s extent in Arkansas, it is underlain by the Cane River Formation and overlain by the Cook Mountain Formation. These two formations are low-permeability, fine-grained, clay-rich units that confine flow within the much more permeable Sparta Sand in Arkansas, Louisiana, Mississippi, and Texas:


References Cited

Broom, M.E., Kraemer, T.F., and Bush, W.V., 1984, A reconnais-
The primary concern for the Sparta aquifer is sustainability—the development and use of ground water for an indefinite time without causing unacceptable environmental, economic, or social consequences. The term “sustainable yield” is used to define that quantity of water that can be withdrawn from the aquifer in a sustainable manner over a long period of time. A computer model of the Sparta aquifer was created during the late 1980’s (Fitzpatrick and others, 1990). In 1997, the revised model was used to simulate changes in water levels resulting from ground-water pumping from predevelopment to 1997 (Hayes and others, 1999). Water levels then were simulated from 1997 to 2027 using predicted rates of water-use changes. Model simulations indicated that the cone of depression in Arkansas County will continue to grow, and will coalesce with the Jefferson County cone by 2027 if current pumping trends continue (fig. 4). Hydrographs illustrate observed water-level declines from 1961 to 2001 at two wells completed in the Sparta aquifer in north and west-central Arkansas County along with simulated declines extending through 2027 (fig. 7).

A Sustainable Water Resource?

Volumes of water pumped from a ground-water system must come from some change in the water budget. This change occurs in one or more of the following: (1) more water entering the aquifer system (increased recharge), (2) less water leaving the system (decreased discharge), and (3) removal of water stored in the system (water-level declines) (Allen and others, 1999). The total amount of water entering, leaving, and the change in storage in a ground-water system must sum to zero, yielding a balanced water budget. Human activities, such as ground-water withdrawals, change the hydrodynamics of the ground-water system and the system moves toward a new “balance” or equilibrium state which changes the rate of inflow, outflow, and amount of water stored in the ground-water system. In Arkansas, massive cone of depression have formed in the potentiometric surface in areas where pumping has been heavy and have been increasing for decades. As a result, more water must enter through induced recharge attempting to counter balance the withdrawal rates. However, when outflow exceeds recharge, extraction rates exceed ability of aquifer to replenish itself, then water levels decline as water is removed from storage to balance the water budget.

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The aquifer in Arkansas County is confined by the Cook Mountain confining unit. Depth to the Sparta aquifer in Arkansas County ranges from 300 to 500 feet below land surface, with thickness varying from 500 to 800 feet.

Storativity and hydraulic conductivity are used to quantify the ability of an aquifer to store and transmit water. Hydraulic conductivity affects the yield of water to wells. For the Sparta aquifer, hydraulic conductivity generally ranges from 10 to 200 feet per day (ft/day) with an average of about 70 ft/day over the extent of the Mississippi embayment (Hosman and others, 1968). Individual wells completed in the Sparta aquifer (excluding those wells located within areas of large drawdowns) generally yield 100 to 500 gallons per minute (gal/min). The amount of water that can be released from storage in a confined aquifer is measured as storativity and is dependent on aquifer thickness and changes in hydraulic head (decline in potentiometric surface or “water level”). For equal declines in water level, the amount of water that can be released from storage in the Sparta aquifer (assuming confined conditions are maintained) is about 1,000 times less in comparison with that released from an unconfined aquifer like the Mississippi River valley alluvial aquifer (commonly referred to as the alluvial aquifer). Therefore, large water-level declines over extensive areas would be required to achieve equivalent water yields.

**Water Use**

Many industries are located in eastern and southeastern Arkansas because of the availability of abundant water of excellent quality from the Sparta aquifer. Many cities and communities rely exclusively upon the Sparta aquifer for their public water supply and use the water with minimal treatment. However, high salinity, iron, and manganese concentrations limit the usefulness of water from the aquifer in some areas (Hosman and others, 1968).

Withdrawal of ground water from the Sparta aquifer began in the early 1900’s primarily for industry and public supply. Total ground-water withdrawals from the Sparta aquifer in Arkansas have increased from 106 Mgal/d in 1965 to an estimated 265 Mgal/d in 2000 (Halberg and Stephens, 1966; T.W. Holland, U.S. Geological Survey, written commun., 2002). The majority of ground-water withdrawals in Arkansas County is from the more shallow and transmissive alluvial aquifer for rice and soybean crop irrigation because it is more cost effective to pump. However, where water-level declines in the alluvial aquifer are causing decreased well yields, the Sparta aquifer is increasingly used to supplement supplies needed for crop irrigation. In 2000, approximately 45 percent of total ground-water use in Arkansas County came from the alluvial aquifer with the remaining 15 percent from the Sparta aquifer. Withdrawals from the Sparta aquifer in Arkansas County (fig. 4) increased from 17 Mgal/d in 1965 to 97 Mgal/d in 2000, a 471 percent increase.

**Effects of Pumping**

In Arkansas, long-term pumping stresses in the Sparta aquifer have resulted in reduced amounts of water in storage, decreased well yields (Hays and others, 1998), regionally extensive water-level declines, and the formation of regional-scale cones of depression such as the cone that has formed between El Dorado, Arkansas, and Monroe, Louisiana. Additionally, cones of depression have formed in Union and Jefferson Counties and continue to grow; a recent cone of depression has formed in Arkansas County (Joseph, 1997, Joseph, 2000).

In a ground-water flow system, water flows downgradient from potentiometric high areas to potentiometric low areas. Pumping wells cause cones of depression in the potentiometric surface that alter the direction of ground-water flow (fig. 5). Extreme drawdowns have resulted in increased chloride concentrations of some Sparta aquifer wells in Union County (Broom and others, 1984) because of spouting of brackish water from below.

The response of water levels within the Sparta aquifer to heavy pumping stress can be substantial over large areas because of the confined condition of the aquifer. For example, an aquifer test near El Dorado resulted in a 6-ft water-level decline at a distance of 2,400 ft from the pumping well after 3 days of pumping at a rate of approximately 460 gal/min.

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The primary concern for the Sparta aquifer is sustainability—the development and use of ground water for an indefinite time without causing unacceptable environmental, economic, or social consequences. The term “sustainable yield” is used to define that quantity of water which can be withdrawn on a continuing basis without compromising the integrity of the aquifer with respect to agreed upon criteria. In Arkansas, the Soil and Water Conservation Commission
Can the Sparta aquifer be a sustainable resource without violating conditions defined by the CGWA designation? Management of the aquifer as a sustainable resource without violating established constraints is possible through the use of computer optimization modeling currently under development. This modeling will provide an optimal solution of pumping rates called sustainable yield designed to maximize water production without violating CGWA constraints. The sustained yield from the Sparta aquifer, designed to protect the aquifer indefinitively, can then be compared to total water demand to determine any "unmet demand" needed from alternate water sources.

### References Cited


For more information on ground-water conditions in the Sparta aquifer, contact the District Chief, U.S. Geological Survey, 401 Hardin Rd., Little Rock, AR 72211; phone: 501-228-3611. Website: http://ar.water.usgs.gov

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**Figure 1. Regional extent of Sparta aquifer within the Mississippi embayment aquifer system.**

**Figure 2. Generalized schematic of hydrologic west-east cross section illustrating trough-like appearance of embayment and generalized flow directions.**

**Figure 3. Municipalities and industries are principal users of the Sparta aquifer: agricultural use is increasing. (Photos courtesy of U.S. Department of Agriculture Natural Resources Conservation Service and Pine Bluff Chamber of Commerce).**