The Sparta Aquifer in Arkansas' Critical Ground-Water Areas—Response of the Aquifer to Supplying Future Water Needs

Key Points

- The Sparta aquifer is a confined aquifer of great regional importance that comprises a sequence of unconsolidated sand, silt, and clay units extending across much of eastern and southeastern Arkansas and into adjoining States.
- Water use from the aquifer has doubled since 1975 and continues to increase, and large water-level declines are occurring in many areas of the aquifer.
- To focus State attention and resources on the growing problem and to provide a mechanism for locally based education and management, the Arkansas Soil and Water Conservation Commission has designated Critical Ground-Water Areas in some counties (see page 6, "What is a Critical Ground-Water Area?").
- Ground-water modeling study results show that the aquifer cannot continue to meet growing water-use demands.
- Dewatering of the primary producing sands is predicted to occur within 10 years in some areas if current trends continue.
- The predicted dewatering will cause reduced yields and damage the aquifer.
- Modeling also shows that a concerted ground-water conservation management plan could enable sustainable use of the aquifer.
- Water-conservation measures and use of alternative sources that water managers in Union County (an area of high demand and growth in Arkansas' initial five-county Critical Ground-Water Area) think to be realistic options result in considerable recovery in water levels in the aquifer during a 30-year model simulation.

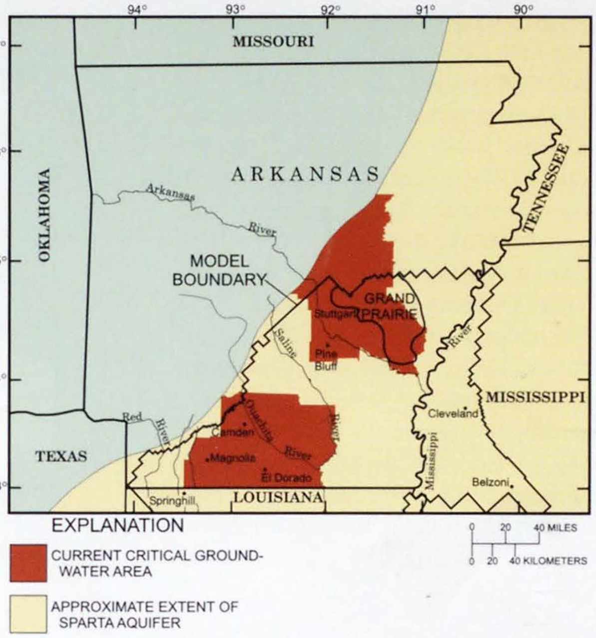

Figure 1. Study area location map showing critical ground-water areas, model boundary, and approximate areal extent of the Sparta aquifer in and near Arkansas.

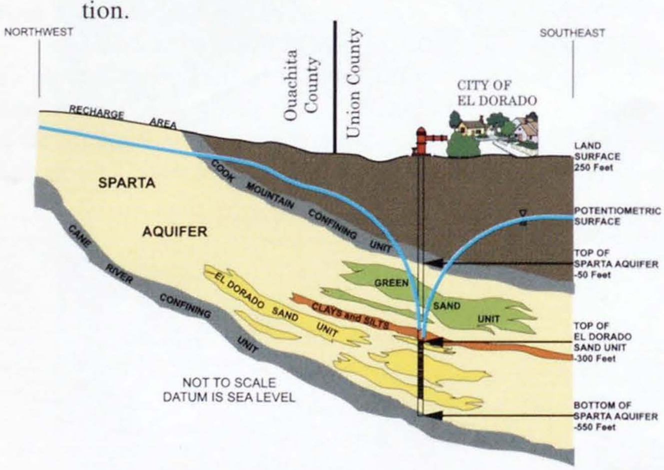

Figure 2. Diagrammatic section of Sparta aquifer in El Dorado area.

What is happening to the Sparta aquifer?

Historically, the Sparta aquifer has provided abundant water of high quality in southeastern Arkansas (fig.1). Withdrawals from the Sparta have doubled since 1975, and the demand for water in some areas significantly exceeds recharge to the aquifer. As a result, considerable decline has occurred in the potentiometric (water level) surface, and water users and managers have begun to question the ability of the aquifer to supply water for the long term. Large cones of depression have developed beneath the Grand Prairie area and the cities of Pine Bluff and El Dorado (Joseph, 1998). In two areas, aquifer conditions meet State Critical Ground-Water Area (CGWA) criteria and have been designated as critical by the Arkansas Soil and Water Conservation Commission (ASWCC) (fig. 1). Figure 2 presents a diagrammatic section illustrating the condition of the potentiometric surface in the El Dorado area. Water levels in the aquifer have declined at rates greater than 1 foot per year (a CGWA criterion, see page 5) for more than a decade in much of southern Arkansas and are now below the top of the formation (a second CGWA criterion) in parts of Union and Columbia Counties. Potential problems related to overdraft in the Sparta include increased drilling and pumping costs, well interference, loss of yield, and saltwater intrusion.

What tools can help in management and planning for the use of the Sparta aquifer?

Annual collection of water-level data for the Sparta aquifer enables close monitoring of aquifer conditions. The U.S. Geological Survey (USGS), in cooperation with the ASWCC and the Arkansas Geological Commission, has collected and analyzed water-level data for more than 50 years. Ground-water flow models are used to evaluate water-level changes in an aquifer resulting from increases or decreases in pumpage. In 1985, the USGS, in cooperation with the ASWCC and the Louisiana Department of Transportation and Development (LADTD) began a project to evaluate the regional effects of increased pumpage on water levels in the Sparta aquifer. The primary product of the project was a computer model of ground-water flow in the Sparta aquifer (Fitzpatrick and others, 1990). In 1997, the USGS and cooperating parties reverified and updated the model to evaluate potential pumping scenarios (Hays and others, 1998). The updated Sparta model offers an excellent tool for evaluating aquifer management scenarios. The model can help us to understand the probable effects upon water levels of continued increase in pumpage as well as the benefits of decreased pumpage resulting from conservation measures and/or finding alternate sources of water.

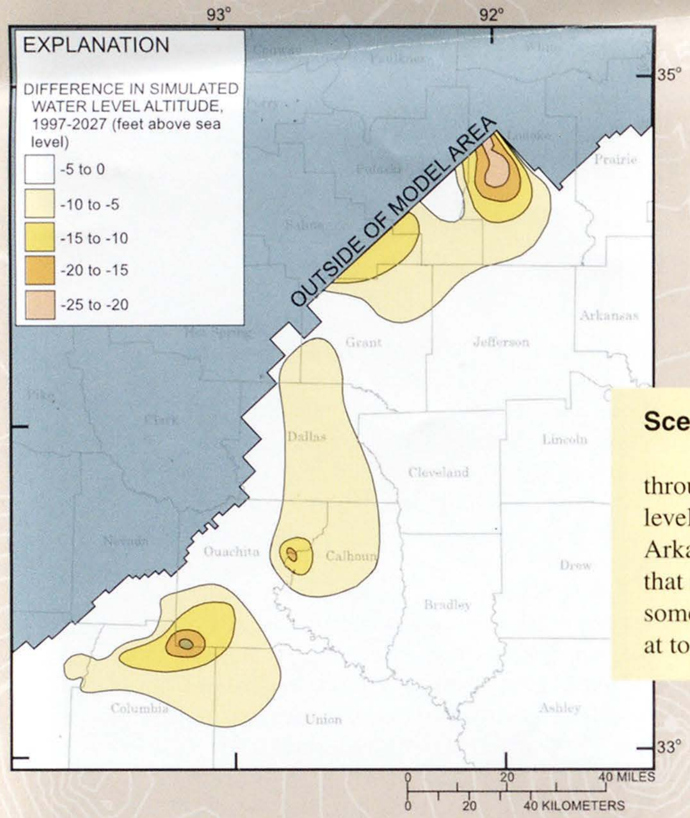

Figure 3. Contoured difference in simulated 1997 and 2027 water levels for scenario 1.

What is a ground-water model?

Using hydrologic and geologic data and ground-water pumpage information, a ground-water model calculates the distribution of water levels and flow across an area through time. The Sparta model is a regional scale, digital ground-water flow model that uses a finite-difference approach to solving the equations for flow; this means that the aquifer system is divided on a grid into rectangular blocks and the equation for flow is solved for each block. Flow models may be used to determine the limitations of an aquifer in meeting current and future needs and also are valuable for testing hypothetical conservation and management scenarios.

How do we know ground-water model results are accurate?

Water levels calculated by the model are compared with actual water levels observed in the field. When data input to the model have been adjusted such that the model closely simulates real, observed conditions, the model is termed "calibrated" and results can be used with a degree of confidence. There will always be a difference between model and observed results. This difference is termed the model error. Model error determines how much confidence can be placed in results; the lower the error, the more dependable the results. Model output for the Sparta model compared very well with observed data, and the model error is very reasonable for a large-scale, regional model.

What does the model tell us about future effects of potential water-use scenarios on the Sparta aquifer?

The model was used to predict the effects of five pumping scenarios on water levels over the period 1998-2027. To ensure that the predictive scenarios are realistic and could be instituted, representatives of major water-using facilities in the five-county (Bradley, Calhoun, Columbia, Ouachita, and Union) Critical Ground-Water Area in south Arkansas were asked to describe possible water-use changes that could occur at their facilities in the future. Possible changes included facility growth, water conservation, use of alternative water sources, and any other factor that could affect the amount or location of water pumped from the Sparta aquifer. The five pumping scenarios represented (1) current pumping rates, (2) current rates of change in pumping, (3) decreased pumping in the five-county area, (4) increased pumping in the five-county area, and (5) redistribution and increase of pumping in selected areas.

Scenario 1- Baseline

If current (1997) pumping rates are held constant through the year 2027, model results indicate that water levels would decline slightly across most of southeastern Arkansas (fig. 3; table 1). Results of this scenario show that current withdrawals exceed recharge, and that in some areas the aquifer cannot continue to provide water at today's rate of withdrawal indefinitely.

Scenario 2 - Continuing Current Rate of Change—The Current Reality

If pumping continues to increase at the current rate through 2027, water levels would decline throughout much of southeastern Arkansas, and large declines would occur near major pumpage centers (fig. 4, table 1).

During the 1998-2027 model period, predicted water levels decline substantially near El Dorado and Pine Bluff (table 1). Well yields would be adversely affected by the declines predicted in this scenario; by 2027, water levels would approach or drop farther below the top of the Sparta Formation near several pumping centers, including El Dorado and Pine Bluff. Water levels, which are already below the top of the Formation near El Dorado, would approach the top of the primary producing sand (locally termed the El Dorado Sand Unit, fig. 2) by 2009. As water levels drop below the top of the El Dorado Sand Unit, well capacity will decrease and the aquifer will be damaged, diminishing its ability to transmit water.

Thus, the results of this scenario—which represents the current trend of water use—imply that a regional management plan that reduces withdrawals would be necessary to achieve a sustainable yield in the aquifer. Withdrawals could be reduced through some combination of use of alternative water sources and conservation.

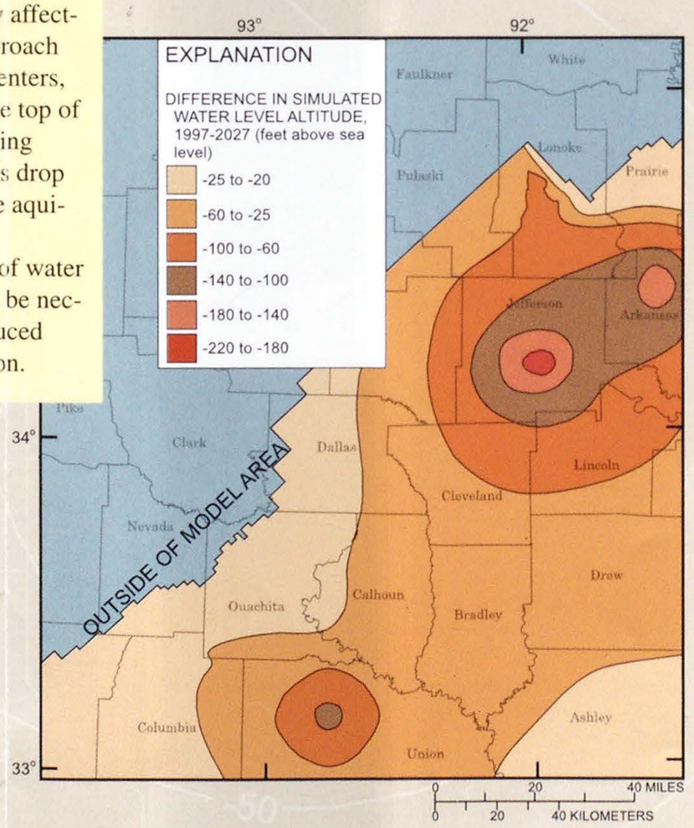

Figure 4. Contoured difference in simulated 1997 and 2027 water levels for scenario 2.

Scenario 3-Minimum Estimated Water-Use

If minimum water-use rates—supplied by major water-use facilities in the five-county Critical Ground-Water Area—are applied in the model, water levels in the cones of depression near El Dorado would be substantially higher in 2027 than in 1997 (fig. 5). This scenario was intended to estimate the effect of potential water-use minimization strategies (such as conservation and use of alternative sources) identified by water managers. Thus, whereas scenario 2 depicts a rather unfavorable outcome for use of the Sparta aquifer, scenario 3 demonstrates the positive effects that planning and management of water-use patterns can have on water levels.

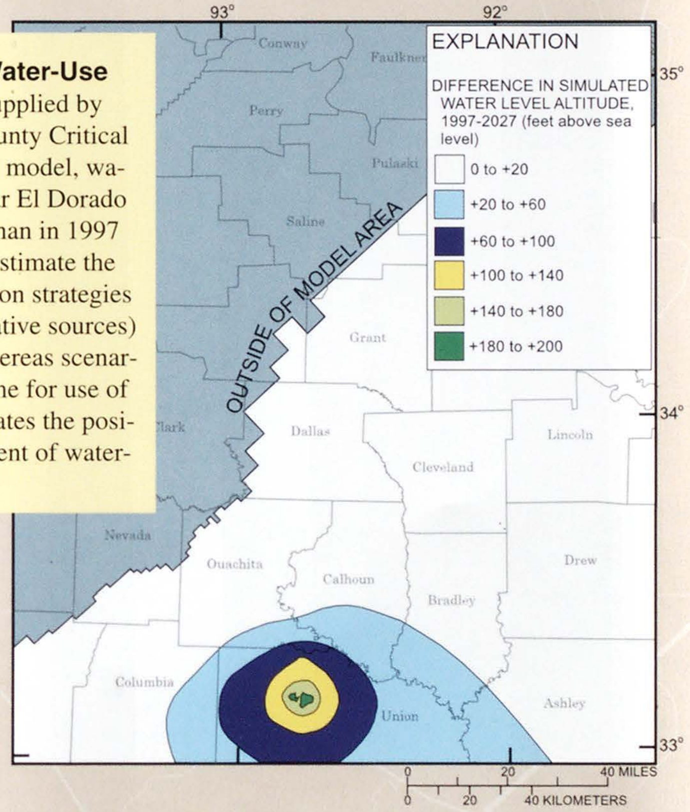

Figure 5. Contoured difference in simulated 1997 and 2027 water levels for scenario 3.

Table 1. Selected pumpage and water-level altitude data from model cells representative of cone-of-depression centers for reverification run (1997) and for predictive scenario runs (2027)

[pumpage in million cubic feet per day; water-level altitude in feet relative to sea level datum]

		Scenario				
	1997	1	2	3	4	5
Pumpage	33.1	33.1	52.9	30.1	36.2	52.9
Water-level altitude						
El Dorado	-307	-311	-438	-123	-421	-378
Pine Bluff	-58	-61	-277	-60	-63	-261
Magnolia	-102	-106	-115	-86	-243	-109
Lonoke County	72	69	-25	70	68	-35

Scenario 4-Maximum Estimated Water-Use

If maximum water-use rates supplied by major water-use facilities in the five-county Critical Ground-Water Area are applied in the model, water levels in the cone of depression near El Dorado would be substantially lower in 2027. The maximum estimated water-use rates described by water-use managers are very close to those obtained by extending the current water-use rate of increase into the future (as done for scenario 2). Consequently, simulated water-level declines in scenarios 4 and 2 are similar. A substantial difference in effects of the minimum- and maximum-estimated water-use scenarios on water-level distribution is seen by comparing scenarios 3 and 4 (fig. 6). The comparison underscores the potential effectiveness of water-management planning and water-use minimization strategies.

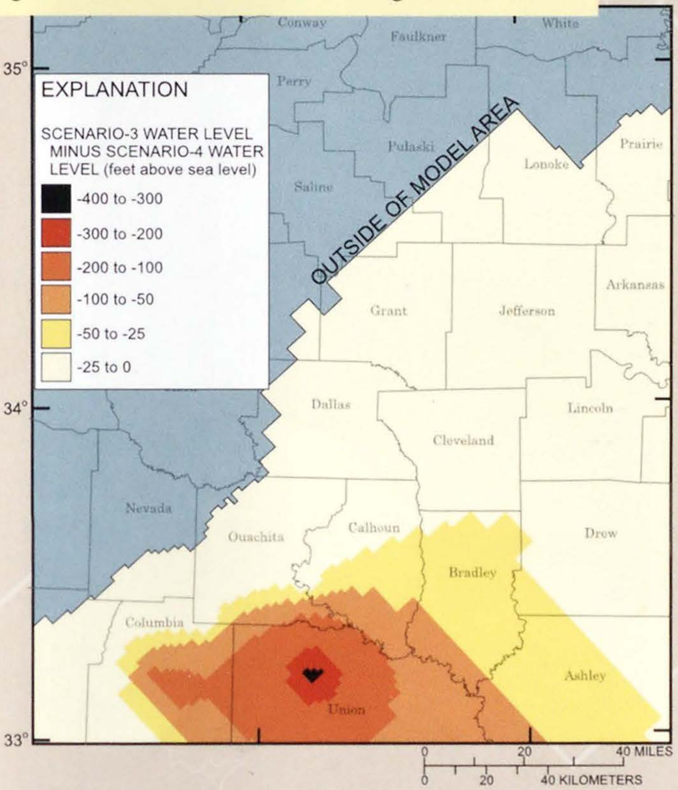

Figure 6. Cell-by-cell difference in simulated 2027 water levels for scenarios 3 and 4.

Figure 8. New wells drilled outside cone of depression spread pumpage and decrease maximum drawdown depth, but do not decrease the stress on the aquifer, that is, the total amount of water removed is not decreased.

Scenario 5-Lonoke-, El Dorado-, Monroe-Shuffle

If pumpage is redistributed in the El Dorado area, but continues at the current rate of increase, and the current rate of pumpage increase in Lonoke and central Prairie Counties is doubled, minimum water levels near El Dorado would be higher (fig. 7), but a new cone of depression would be initiated. Water levels in Lonoke and Prairie Counties would decline substantially (fig 7, table 1).

This scenario represents shifting some withdrawals in the El Dorado area to a new well field located northeast of the city. The model shows that no reduction in demand coupled with a simple redistribution of pumpage merely delays the negative impacts upon the aquifer by deferring the date at which water levels drop below the top of the El Dorado Sand Unit (fig. 8).

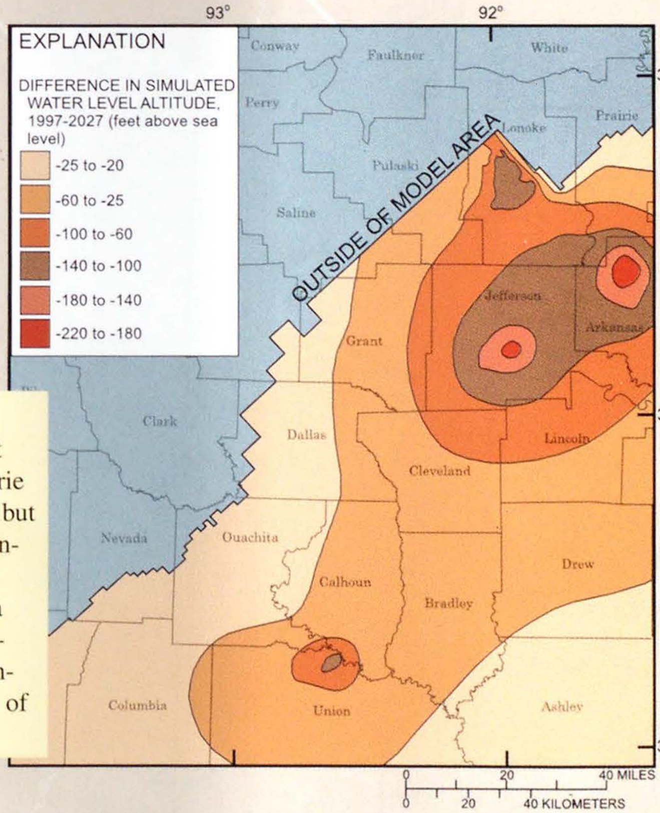

Figure 7. Contoured difference in simulated 1997 and 2027 water levels for scenario 5.

Figure 9. In areas where large water-level declines have occurred in the Mississippi River Valley alluvial aquifer, the Sparta aquifer—which has much less storage—is being used to augment agricultural water needs and consequent declines are occurring in the Sparta aquifer also.

What are the consequences of overstressing and dewatering a confined aquifer such as the Sparta?

The Sparta aquifer and overlying units constitute a very large mass. Pressure head (water pressure exerted within the pores of the aquifer that reduces the effective stress on the aquifer matrix) and the buoyant force of water within the aquifer support part of the weight of this mass while water levels are high (near original values and above the top of the aquifer) (Lofgren, 1961,1968; Green, 1964). This support prevents compaction and allows the aquifer framework to remain porous and open and maximizes the ability to transmit water. When water is removed, this support is removed and compaction in the aquifer and its confining layers can occur proportionally with declining water levels. Aquifers containing significant amounts of fine-grained materials—as the Sparta aquifer does—are most susceptible to compaction (Green, 1964). With this compaction, irreversible damage occurs to the aquifer's ability to transmit water (Lofgren, 1961). Hydraulic conductivity (which defines the ability of an aquifer to transmit water) decreases. Notable subsidence, which is sometimes associated with dewatering and compaction of an aquifer, has not been documented in the Sparta aquifer. However, a very small amount of compaction can result in a dramatic decrease in hydraulic conductivity; for example, a 1 percent change in density (or porosity) can result in as much as a 1,000- fold decrease in hydraulic conductivity (Ingles and Grant, 1975; Dewhurst and others, 1998). In the El Dorado area, water levels are currently below the top of the Formation, and below the top of the Green Sand unit. Notably, the Sparta aquifer flow model predicts that by 2009 water levels will approach the top of the El Dorado Sand Unit (the primary producing sand unit) and dewatering of that unit will begin. At this point, effective stress on the aquifer framework will approach a maximum, and buoyant support of the aquifer material will begin to be lost—conditions that will favor compaction and loss of hydraulic conductivity.

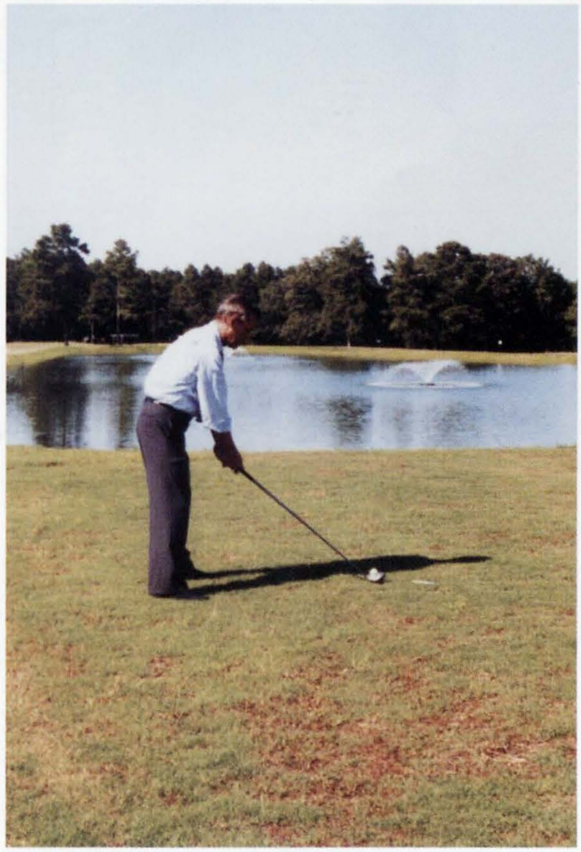

Figure 10. Sparta aquifer water users are undertaking water-conservation public education programs with support and input from Federal, State, County, and local levels and are enacting more direct water-reuse and conservation actions such as use of treated wastewater for irrigation purposes at a local golf course.

What is a Critical Ground-Water Area?

In 1991,the State of Arkansas enacted the Arkansas Ground Water Protection and Management Act (Act 154). This Act provided the ASWCC with additional ground- water protection and management authority to: 1) designate Critical Ground-Water Areas (CGWAs), 2) establish the authority for withdrawals, 3) establish ground-water rights, 4) set fees, and 5) provide a mechanism for locally based ground-water management. As a result of this action, the ASWCC began updating the Arkansas Water Plan on a yearly basis, focusing on ground-water protection concerns. The update is accomplished using annual data collection and analysis results from a statewide monitoring network of approximately 1,200 wells—of which about 300 are screened in the Sparta aquifer. This information is presented in an annual report, and includes recommendations to the ASWCC concerning CGWAs.

Each year the ASWCC staff evaluates the status of the Sparta and other aquifers with regard to the CGWA designation criteria. These criteria are related to water-level and water-quality factors and target areas where ground-water declines or water-quality trends are at a considerable level, specifically, areas where declines of greater than 1 ft/yr are occurring or where water levels are below the top of the formation containing a confined aquifer. In addition to these criteria, ground-water flow model projections and the safe yield of the aquifer are considered as auxiliary factors in designation of CGWAs.

When CGWA designation is recommended, the ASWCC conducts public hearings in accordance with Arkansas' Administrative Procedure Act and considers comments by interested parties. The ASWCC then determines if designation of a proposed area as critical is appropriate. Once the CGWA designation is in place, the ASWCC is able to focus resources in the critical area and provide for greater protection and management of the resource. CGWA designation emphasizes prevention and a coordinated, proactive approach to resource protection (fig. 10).

The ASWCC designated the first and second CGWAs in the State in February 1996 and July 1998 (fig. 1). The 1996 southern Arkansas CGWA designation focused on the Sparta aquifer; the 1998 central eastern Arkansas CGWA designation included the Sparta and Mississippi River Valley Alluvial aquifers.

Ground-water regulation is not a part of the CGWA program. Initiating regulation of ground-water use is a separate process requiring a separate phase of analysis, reporting, and public hearings. With effective planning and management, Arkansas may avoid regulation and the problem of continued ground-water decline, and may achieve sustainable yields relying on conjunctive use of ground and surface water.

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For more information on ground water and CGWAs, contact the Ground-Water Section, ASWCC (501-682-3900), or District Chief, USGS (501-228-3600).

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