# The Arbuckle-Simpson Hydrology Study

## Management and Protection of an Oklahoma Water Resource

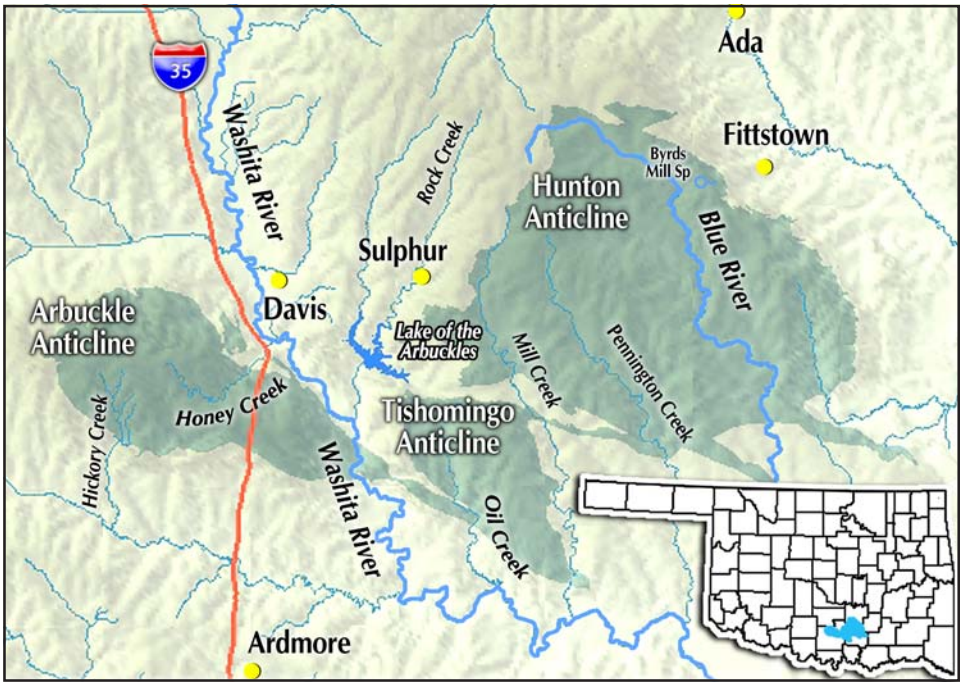
THE OKLAHOMA WATER RESOURCES BOARD November 2003

# Background

The Arbuckle-Simpson aquifer, which underlies more than 500 square miles in south central Oklahoma, is the principal water source for approximately 39,000 people in Ada, Sulphur, and others in the region. The aquifer is also the source of a number of important springs in the region, including Byrds Mill Spring, Ada's primary drinking water source, and those in the Chickasaw National Recreation Area, the destination for about 3.4 million visitors each year. The U.S. Environmental Protection Agency has designated the aquifer's eastern portion as a Sole Source Aquifer, a mechanism to protect drinking water supplies in areas with limited water supply alternatives.

Local, federal, and state agencies and organizations have been lobbying for a comprehensive study of the Arbuckle-Simpson aquifer for more than a decade. However, recent requests for water use permits from the aquifer have generated sufficient concern to make the study a reality. Early in 2002, the Central Oklahoma Water Authority (COWA), consisting primarily of communities in Canadian County seeking future supply, proposed to pump as much as 80,000 acre-feet of water per year from the aquifer and transport it to central Oklahoma.

Although Oklahoma water law considers groundwater the private property of the landowner, local residents, citizens' groups, and the National Park Service are concerned that large-scale withdrawals of water from the Arbuckle-Simpson aquifer will result in declining flow in streams and springs and cause groundwater levels to decline. As a result, the state will also investigate development of a management strategy that would protect the aquifer's current and future benefits yet comply with the basic precepts of Oklahoma water law.




*The general outcrop area of the Arbuckle-Simpson aquifer extends some 500 miles between Ada and Ardmore in south central Oklahoma.*

## Senate Bill 288

Senate Bill 288, passed by the State Legislature in May 2003, imposes a moratorium on the issuance of any temporary groundwater permit for municipal or public water supply use outside of any county that overlays, in whole or in part, a "sensitive sole source groundwater basin." (The Arbuckle-Simpson aquifer is the only such groundwater basin in Oklahoma.)

The moratorium prohibits municipal and political subdivisions outside the basin from entering into contracts for use of the water and it applies to both pending applications and any revalidation of existing temporary permits. The moratorium will remain in effect until the OWRB completes its study of the Arbuckle-Simpson and approves a maximum annual yield that will not reduce the natural flow of water from springs or streams emanating from the aquifer.

SB 288 also adds another requirement for groundwater permit approval for use within the basin: the Board must find that the proposed use is not likely to degrade or interfere with springs or streams emanating from the aquifer. Because current Oklahoma water law does not take into account the hydrologic interaction between surface and groundwater, the legislation sets a new precedent in the OWRB's permit approval process.

# Plan of Study

State and federal water experts agree that information garnered from previous studies of the Arbuckle-Simpson aquifer--concentrating primarily on its geology and hydrology at or near the surface--is inadequate to address the aquifer's complex geology and management issues confronting local users. Investigation of the deeper portion of the aquifer (greater than 1,000 feet) is needed to understand the full extent of the fresh-water zone and the volume of water in storage in the aquifer. In addition, no sufficient information exists to predict the response of springs and streams to groundwater withdrawals. Critical to future study of the aquifer is an understanding of the formation's "plumbing system" that controls the interactions between groundwater levels and springflows.

To understand, as well as quantify, the region's complex geology and hydrology, the investigation will require five years for completion. Funded through a 50/50 state/federal cost-share agreement with the U.S. Bureau of Reclamation, the investigation will be the most intensive analysis of surface and groundwater relationships ever conducted in Oklahoma. Most importantly, study results will provide state and local decisionmakers with the necessary information to determine how water resources in the region should best be utilized while protecting area springs and streams.

The Arbuckle-Simpson study will be coordinated by the OWRB, but will involve participation from dozens of agencies and organizations, as well as private citizens. A technical peer review team consisting of experts from the U.S. Geological Survey, Oklahoma Geological Survey, Oklahoma State University, and EPA will review the scope of work and provide advice to ensure the use of sound science and appropriate methods.

*Vendome Well, an artesian well in the Chickasaw National Recreation Area*

*The goal of the Arbuckle-Simpson study is to acquire understanding of the region's hydrology to enable development and implementation of an effective water resource management plan that protects the region's springs and streams.*

## Study Objectives

1. Characterize the Arbuckle-Simpson aquifer in terms of geologic setting, aquifer boundaries, hydraulic properties, water levels, groundwater flow, recharge, discharge, and water budget.
2. Characterize the area's surface hydrology, including stream and spring discharge, runoff, base flow, and the relationship of surface water to groundwater.
3. Construct a digital groundwater/surface water flow model of the Arbuckle-Simpson aquifer system for use in evaluating the allocation of water rights and simulating management options.
4. Determine the chemical quality of the aquifer and principal streams, identify potential sources of natural contamination, and delineate areas of the aquifer that are most vulnerable to contamination.
5. Construct network stream models of the principal stream systems for use in the allocation of water rights.
6. Propose water management options, consistent with state water laws, that address water rights issues, the potential impacts of pumping on springs and stream base flows, water quality, and water supply development.

# Methods

A variety of methods will be used to characterize the aquifer, including evaluation of petroleum-related information, test well drilling, groundwater and surface water modeling, geochemistry, isotopic age dating of groundwater, and various other methods depending upon findings as the study progresses, as well as available funding. The first year of the investigation will consist of reviewing literature, compiling and reviewing existing data, conducting field investigations, initiating groundwater flow model simulations, and identifying data needs. As a vital tool to furthering understanding of the aquifer and assisting in the water resource decision-making process, development of the digital groundwater flow model will be a key component of the study.

Fieldwork will include installation of two stream gages (on the Blue River and Pennington Creek), updating the current inventory of water wells and springs, and collecting measurements from wells, springs, and streams in the area. A variety of hydrologic tests will be performed, with special emphasis on deep wells. The second and third years will be devoted primarily to field investigation, the fourth year to model development, and the fifth year to reviewing various management options.

Input from the public, especially those residing in the Arbuckle-Simpson aquifer region, will be integral to the study. Landowners and other interested parties will be counted on to provide vital information related to the location of springs, streams, wells, and other components of the aquifer's complex surface/groundwater system. The OWRB will hold public meetings to update citizens on the study's progress and results. In addition, the agency will publish regular Arbuckle-Simpson study newsletters and share the latest study developments through its Web site.

# Hydrogeologic Setting

The Arbuckle-Simpson aquifer is contained within several rock formations. Rocks of the Arbuckle Group consist of limestones and dolomites that were deposited between 520 and 480 million years ago in Late Cambrian and Early Ordovician time. The carbonate sediments were deposited on a vast, shallow-water platform that extended from northeast New Mexico into northeast Canada. Rocks of the Simpson Group consist of sandstone, shale, and limestone that were deposited 480 to 460 million years ago in Middle Ordovician time.

Rocks of the Arbuckle and Simpson Groups are exposed at the land surface in three prominent uplifts separated from each other by large, high-angle faults. The southwestern outcrop is on the Arbuckle Anticline, a geological structure that was formed 300 million years ago when intensive folding and faulting of a thick sequence of Paleozoic rocks formed the ancestral Arbuckle Mountains. Originally rising several thousand feet above the surrounding plains, the mountains have been eroded to their present-day maximum relief of 600 feet. Topography over the steeply dipping strata is very rugged. Road cuts along Interstate 35 provide unique views of the thick sequence of Paleozoic rocks and complex structure of the Arbuckle Anticline.

The eastern outcrop is on several structural features, of which the Hunton Anticline is the most prominent. The central outcrop is on the Tishomingo Anticline. The Structural deformation on these two anticlines is much less pronounced than on the Arbuckle Anticline, and the topography consists of gently rolling plains formed on relatively flat-lying rocks.

*Springs from the Arbuckle-Simpson Aquifer provide base flow to Travertine Creek, a popular recreation spot in the Chickasaw National Recreation Area.*

### *Four (Five) Points of State Groundwater Law*

In Oklahoma, surface water is considered public water while private property rights govern the use and ownership of groundwater. Prior to the OWRB's approval of a groundwater use permit, Oklahoma water law dictates that four points must be satisfied:

1) the applicant must own or lease the overlying land;
2) the land must overlie the groundwater basin;
3) the proposed purpose must be for a beneficial use; and
4) the water must not be wasted.

Senate Bill 288 would add a fifth precept to Board approval:

5) the proposed use is not likely to interfere with streams and springs emanating from a sensitive sole source groundwater basin.

## Groundwater

The complex geologic features of the aquifer affect how water moves through the aquifer. Features such as folds, faults, bedding planes, and solution channels may have local influences on groundwater flow paths and flow rates. The numerous faults affect the movement of water through the aquifer because they can act as barriers to groundwater flow or as conduits through which water travels. The rate at which water moves through the aquifer can vary greatly. Water moves slowly through fine fractures and pores and rapidly through solution-enlarged fractures and conduits.

About two-thirds of the aquifer consists of carbonate rocks (limestones and dolomites), which are soluble. Infiltrating water slowly dissolves the rock, leading to the formation of solution channels and cavities along bedding planes, fractures, and faults. Karst (solution) features, such as sinkholes and caverns, are most common where fractures and bedding planes have enhanced groundwater circulation.

The Arbuckle-Simpson aquifer receives water from infiltration of precipitation and from losing streams that cross the outcrop area. Most of the discharge from the aquifer is to streams, rivers, and springs and some is to well withdrawals, outflow to adjacent aquifers, and to evapotranspiration.

Generally, groundwater flows from topographically high areas to low areas, where it discharges to springs and streams. Groundwater flow in the Arbuckle Anticline region appears to radiate from the crest of the anticline. Regional groundwater flow in the Hunton Anticline region is southeast, but a small component is southwest. Where the Arbuckle-Simpson aquifer dips beneath rocks of lower permeability, the aquifer is confined, and wells that penetrate below the confining layer may be artesian. Several artesian wells flow in the valley of Rock Creek, near Sulphur. The most well known of these wells is Vendome Well in the Chickasaw National Recreation Area.

Groundwater and surface water interact in different ways. In some areas of the Arbuckle-Simpson aquifer, streams gain water from aquifer discharge, and in other areas, streams lose water to the aquifer. Where the altitude of the water table is higher than the altitude of the stream-water surface, groundwater discharges into the stream channels. The groundwater component of streamflow is known as base flow. About 60 percent of the streamflow in the outcrop area of the Hunton Anticline is base flow from the aquifer. Where the altitude of the water table is lower than the altitude of the stream-water surface, surface water recharges the aquifer. In karst aquifers, losing segments of streams commonly occur where streams cross sinkholes or highly fractured rock.

## Hydrologic Budget

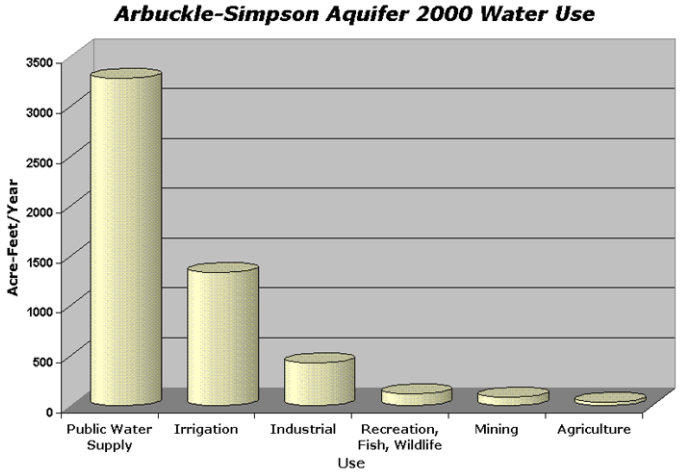
Understanding the hydrologic budget is important for managing and understanding the water resources of the Arbuckle Mountains. The U.S. Geological Survey developed a hydrologic budget of the Hunton Anticline region for a period of record in the 1970s. During this time, 80 percent of the average annual precipitation (38.4 inches) was returned to the atmosphere by evapotranspiration. The remaining 20 percent discharged from the area as surface runoff, of which 12 percent was base flow and 8 percent was direct runoff from land surface. Recharge to the aquifer was estimated from base flow to average 4.7 inches/year.

*Buffalo Spring, part of the national park, is a freshwater spring originating from the Arbuckle-Simpson aquifer.*

## Water Use in the Arbuckle-Simpson

Wells in the Arbuckle-Simpson aquifer commonly yield 25 to 600 gallons per minute (gpm) of water, and deep wells have been known to yield as much as 2,500 gpm. To date, water in the aquifer has been produced in small amounts for municipal, irrigation, industrial, mining, agricultural, stock, and domestic purposes. Permit holders reported using about 5,000 acre-feet of groundwater in 2000, of which 62 percent was for municipal use and 25 percent was for irrigation.

Springs and streams receiving flow from the aquifer supply additional water for municipal, irrigation, industrial, mining, fisheries, recreation, and wildlife conservation purposes. Durant receives its water supply from the Blue River, Tishomingo from Pennington Creek, and Ada from Byrds Mill Spring.




## Surface Water

Major streams emanating from the aquifer are the Blue River and Delaware Creek, which flow into the Red River, and Mill, Pennington, Honey, Hickory, and Oil Creeks, which flow into the Washita River. These streams are sustained throughout the year by groundwater discharge to springs and seeps.

At least 100 springs are known to discharge water from the aquifer to streams that drain the outcrop area. The largest is Byrds Mill Spring, located in the northeastern margin of the Hunton Anticline region, about 12 miles south of Ada. The spring flows an average 20 cubic feet per second (cfs) or 9,000 gallons per minute (gpm) and is the primary source of water for the City of Ada.

Also of importance are the freshwater and mineralized springs in the Chickasaw National Recreation Area. The two principal freshwater springs are Antelope and Buffalo Springs. These springs provide the primary source of flow in Travertine Creek, a popular recreation spot. The water is chemically similar to Arbuckle-Simpson water, and recharge to the springs is most likely from the outcrop of Arbuckle-Simpson rocks to the east. Several springs in the park and Vendome Well produce mineralized water, once valued for its medicinal qualities. Some of the waters have a strong sulfur odor, which is characteristic of hydrogen sulfide. The mineralized water–with large concentrations of sodium, chloride, and sulfate–appears to be a mix of fresh water from the Arbuckle-Simpson aquifer and saline water derived from a regional and/or deeper source.

## Selected References

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For digital data sets, visit the USGS Web site at wwwok.cr.usgs.gov.

For more information, visit the OWRB's Web site at www.owrb.state.ok.us.

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the water agency