OKLAHOMA WATER RESOURCES BOARD

OWRB

the water agency

ARBUCKLE-SIMPSON HYDROLOGY STUDY

Annual Report
Federal Fiscal Year 2005

Submitted to the U.S. Bureau of Reclamation

November 2005

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INTRODUCTION

The Arbuckle-Simpson aquifer, which underlies more than 500 square miles in south central Oklahoma, is the source of several springs and streams, including those in the Chickasaw National Recreation Area and Blue River, Pennington Creek, and Honey Creek (Figure 1). A five-year, comprehensive study of the aquifer and associated springs and streams seeks to understand the geology and hydrology of the aquifer. Study results will provide state and local decision makers with the necessary information to determine how much water can be withdrawn from the aquifer while protecting springs and streams.

Now beginning the third year of the investigation, the Arbuckle-Simpson Hydrology Study (Study) is steadily progressing. As cooperators and researchers from various disciplines and agencies work together, we are gaining a better understanding of the geology and hydrology of the region. This report describes activities that occurred from October 1, 2004 to September 30, 2005, initial findings, and upcoming activities.

Figure 1. General outcrop area of the Arbuckle-Simpson aquifer.

The Study is being conducted by the Oklahoma Water Resources Board (OWRB) in cooperation with U.S. Geological Survey (USGS), Oklahoma State University (OSU), Oklahoma University (OU), and Oklahoma Climatological Survey (OCS) in accordance with interagency agreements. The U.S. Bureau of Reclamation (Bureau) ensures Federal regulatory compliance and provides assistance with technical issues and public involvement activities. In addition to work under contract with the OWRB, studies funded from other sources are also underway. For example, the U.S. Environmental Protection Agency (EPA), Robert S. Kerr Laboratory conducted geophysical logging of wells, and the National Park Service (NPS) has contracted with USGS to conduct geophysical and geochemical studies in the Chickasaw National Recreation Area (CNRA). Table 1 lists cooperating agencies and lead researchers.

Table 1. Cooperating Agencies and Researchers in the Arbuckle-Simpson Hydrology Study

Agency	Lead Researcher/ Contact	Activities
USGS	Scott Christenson	Groundwater flow modeling; compilation of USGS data; aquifer characterization
	Bob Blazs	Stream gages
	Andrew Hunt, David Parkhurst	Geochemistry
	Charles Blome	Geologic modeling
	Dan Scheirer	CNRA gravity survey
OSU	Todd Halihan	Fault and aquifer characterization; literature review; evaluation of existing water chemistry data
	Jim Puckette	Geologic characterization; evaluation of petroleum information
	Surinder Sahai	Seismic data
	Beth Caniglia	Environmental sociology
OU	Aondover Tarhule	Tree ring chronology
	Baxter Vieux	Rainfall-runoff modeling
OWRB	Monty Porter	Streamflow monitoring
	Noel Osborn	Groundwater monitoring; spring and well inventory; water use
Bureau	Mark Treviño	NEPA and NHPA compliance
OCS	Chris Fiebrich	Mesonet weather station
EPA Kerr Lab	Randall Ross	Geophysical logging
NPS	Sue Braumiller	CNRA monitoring

PROGRESS AND SIGNIFICANT RESULTS

A key component of the Study is the development of a digital groundwater flow model, which will be used as a tool to improve understanding of the aquifer and to assist in the water resource decision-making process. Development of the model involves formulating a conceptual model, defining hydrostratigraphic units and the geologic framework, preparing the water budget, and defining the flow system. The field investigation and data collection efforts are therefore focused on obtaining these types of information.

Accomplishments for the second year of Study include installation of a stream gage on Honey Creek and the Fittstown Mesonet weather station. Monitoring efforts were expanded to include three synoptic base flow measurements of streams and three synoptic water-level measurements

from a network of more than 100 water wells. Several studies were initiated. These include a reconnaissance geochemical study, tree ring analysis, rainfall-runoff modeling, and various geophysical surveys. After months of planning, drilling of a deep test well began in September. Progress on the activities of the past year is discussed below.

Literature Review and Data Compilation

OSU continues to update the EndNotes bibliographic database and to scan pertinent documents. Version 2.0 of the database, which was submitted in July 2005, contains 341 references. Of these, 66 are copyrighted material that cannot be scanned and 134 others have not yet been scanned. The database, available as a series of six compact discs, provides researchers and study participants with ready access to pertinent information.

Shayne Cole (OSU) is compiling existing water chemistry data from groundwater and surface water and is entering data into the Envirodata database. She has located several sets of data from USGS, the EPA STORET database, Oklahoma Department of Environmental Quality (ODEQ), Oklahoma Department of Environmental Health (OEH), and various publications.

Scott Christenson (USGS) compiled USGS water quality, spring, and well data for the study area and updated the USGS NWIS database. Carol Becker (USGS) compiled and scanned borehole geophysical logs from about 30 wells on file at USGS.

Monitoring

Monitoring of groundwater, surface water, and climate is critical for model calibration and for water planning and management. In addition to maintaining existing stations, three new monitoring stations were added this year. The current network of stations includes three USGS stream gages, 12 OWRB periodic stream stations, one OWRB continuous station, 12 OWRB wells for monitoring water levels, and one Mesonet weather station (Figure 2).

Streamflow

In October, USGS installed a new gage on Honey Creek below Turner Falls. USGS continued to maintain the project stream gages on Pennington Creek near Reagan, and Blue River near Connerville. These are in addition to other USGS gages at Byrds Mill Spring, Antelope Spring, and Rock Creek at Sulphur. To provide additional precipitation data for the Study, USGS installed rain gages at the Pennington Creek, Honey Creek, Byrds Mill Spring, and Blue River stations. All USGS gage data are available in real time through the USGS NWIS web site: http://waterdata.usgs.gov/nwis.

OWRB continued periodic monitoring of 12 stream stations on Blue River and Delaware, Honey, Mill, Oil, and Pennington Creeks. Nine sites are equipped with wire-weight gages installed on bridges, and three sites are equipped with staff gages or tape-down points. Point discharge measurements and field parameters were measured during a variety of flow conditions, and preliminary rating curves were developed for most stations.

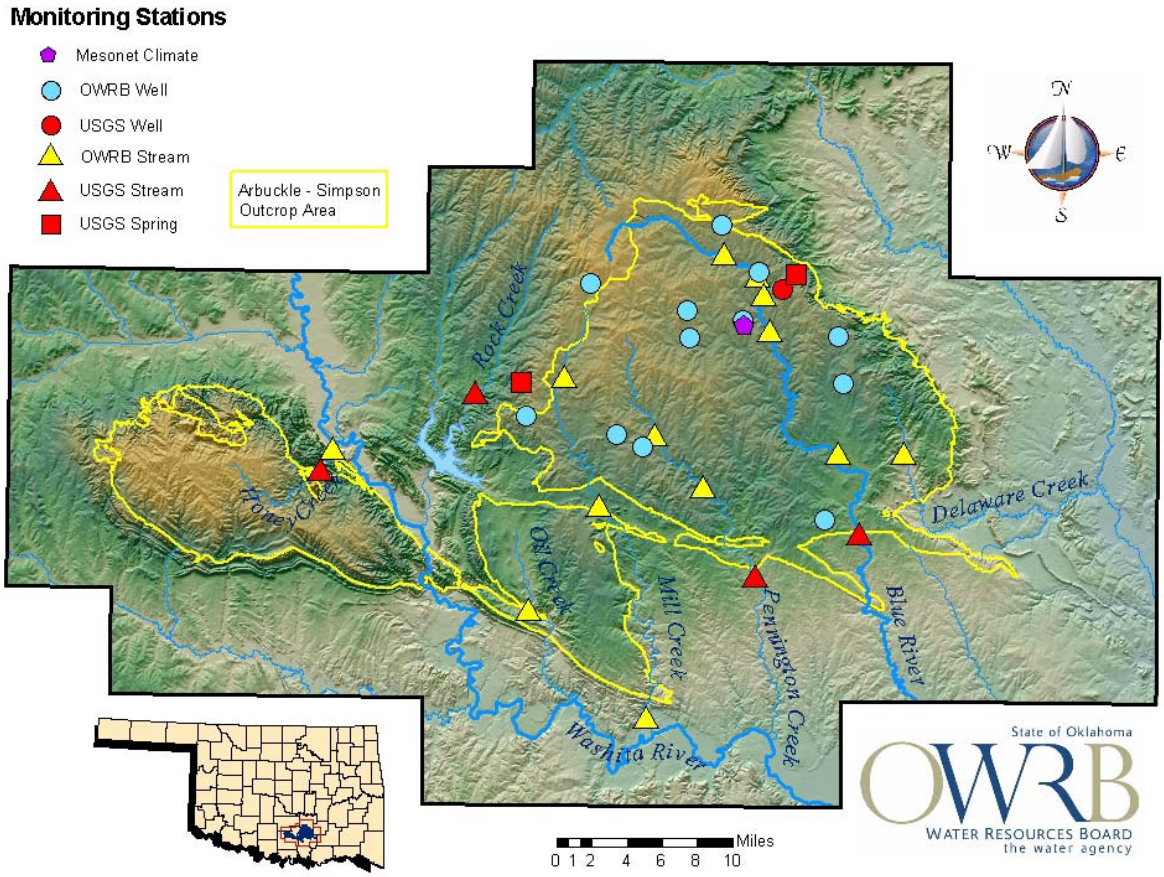

Figure 2. Monitoring stations for the Arbuckle-Simpson Hydrology Study.

One station, located on the upper reach of Blue River, was upgraded for continuous monitoring. In February, OWRB installed a gas purge system that monitors the stream stage, a tipping bucket rain gage, a data logger, and a transmitter. River stage and precipitation are being logged every fifteen minutes. Real-time data can be viewed through the NWS Hydrometeorological Automated Data System: http://www.nws.noaa.gov/oh/hads/. The name of the station is "Blue River near Fittstown 6SSW". The NESDIS ID is AE0013CA, and the NWSLI ID is FTBO2.

OWRB conducted three seepage runs during base-flow conditions, when there was no surface runoff. An aquifer-wide seepage run was conducted January 17-26, when discharge and water quality measurements were collected at 108 streams emanating from the aquifer. September 20-23, OWRB measured flows of about 50 major streams, primarily in the Hunton Anticline region, and NPS staff collected stream measurements in the CNRA. This seepage run coincided with a synoptic water-level measurement event. Data obtained from these investigations will be used for model calibration and for determining the water budget. To assist in selecting the site for the deep test well, base flows at 13 sites along Blue River were measured March 28-30.

Groundwater

Continuous water-level measurements provide information on how the aquifer responds over time to various stresses, such as precipitation and pumping. OWRB replaced older Telog data loggers with new In-Situ units in 10 wells collecting continuous water-level measurements, and installed two more units. Currently, OWRB is maintaining data loggers in 12 wells. OWRB plans to install recorders in 3-4 more wells across the aquifer. In addition to the OWRB data loggers, USGS maintains the Fittstown groundwater-observation well, for which real-time data are available on the USGS web site. NPS maintains data loggers on three wells, and hopes to add a few more. Hydrographs showing average daily water levels are displayed in Figure 3.

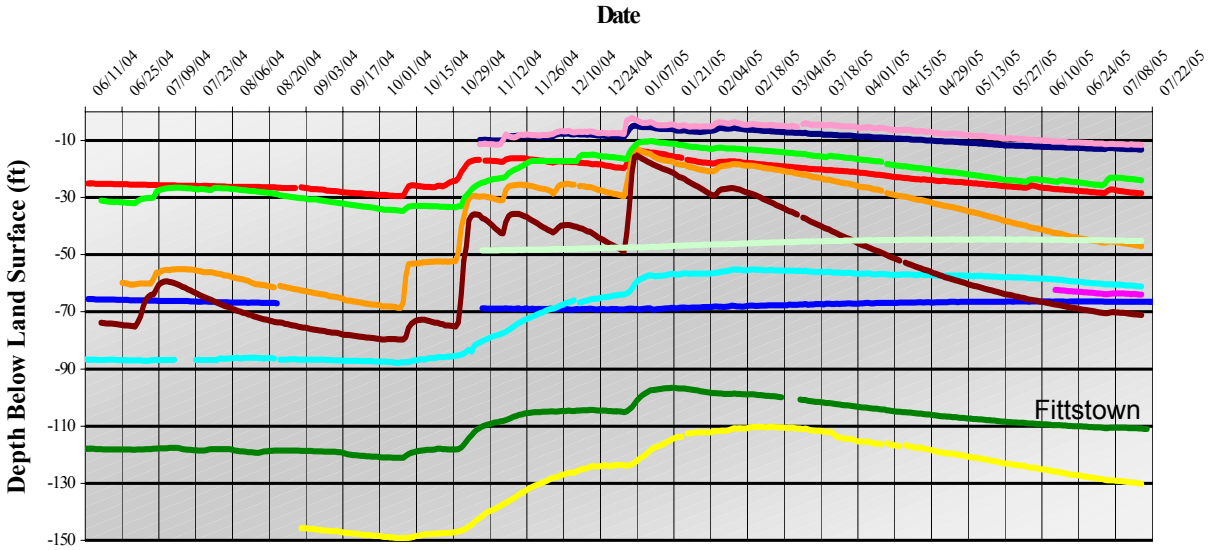

Figure 3. Daily hydrographs of wells completed in the Arbuckle-Simpson aquifer.

Synoptic water-level measurements provide a "snapshot" of the water table for a specific time. In 2005, OWRB conducted three synoptic water-level measurements in the Hunton Anticline region. OWRB measured 63 wells March 23-24. The network of wells was expanded to more than 100 wells for measurements collected July 22-23 and September 22-24. Data from these measurement events are used to construct potentiometric maps of the aquifer, such as the one shown in Figure 4.

Climate

OCS commissioned the Fittstown Mesonet station on May 12. Fittstown is the first Oklahoma Mesonet station located over the outcrop area of the Arbuckle-Simpson aquifer. The station measures precipitation, temperature, barometric pressure, relative humidity, wind speed and direction, solar radiation, soil temperature, and soil moisture. Data are transmitted to a central facility every 15 minutes and can be viewed on the Mesonet web site (www.mesonet.org). These data provide researchers with information essential to understanding the aquifer and how it responds to variations in precipitation and other factors.

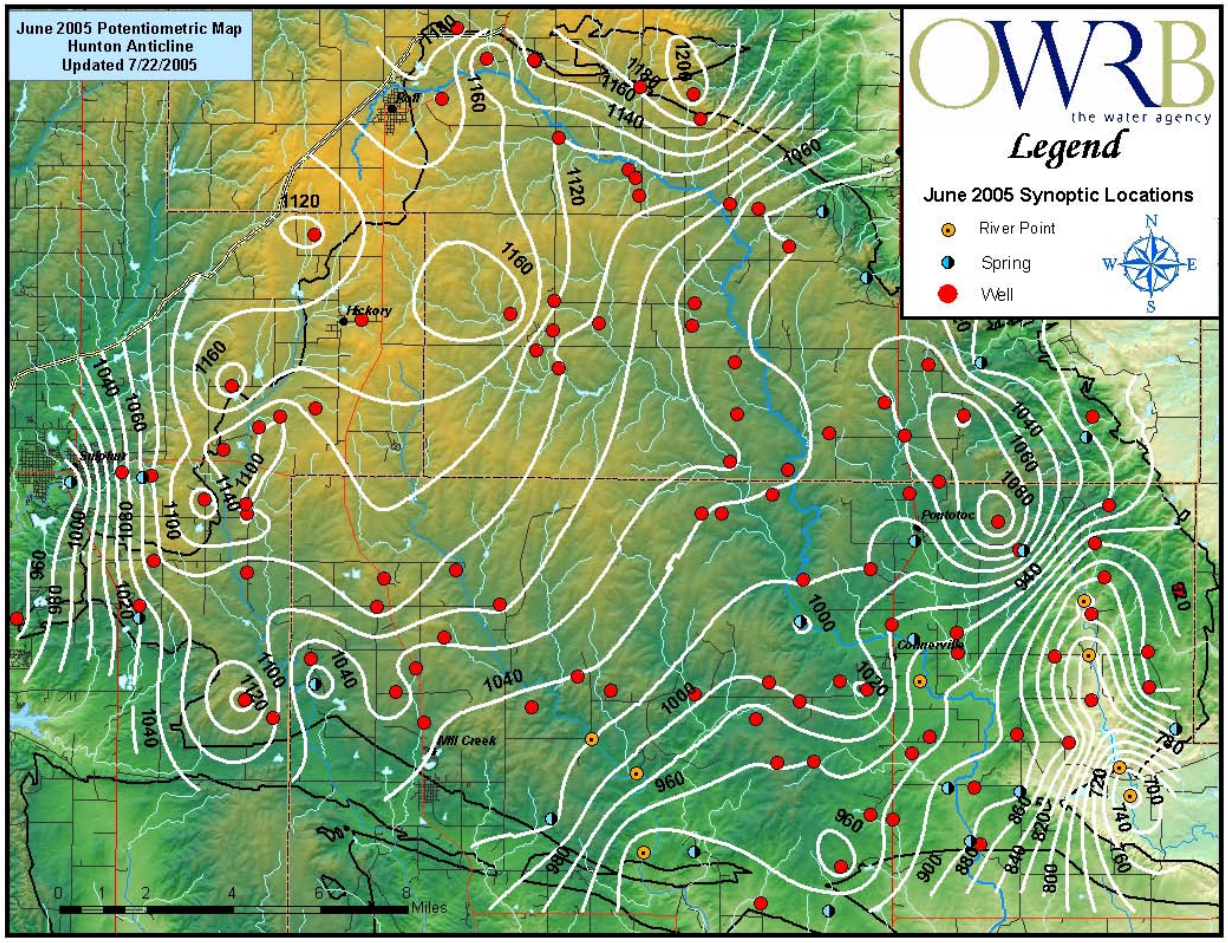

Figure 4. Potentiometric surface from water-level measurements collected June 22-23, 2005 of the Hunton Anticline portion of the Arbuckle-Simpson aquifer (20-feet contour interval).

Modeling

Groundwater

Scott Christenson continued development of the numerical groundwater-flow model (MODFLOW). Two sets of experiments were conducted to assist in the site selection of a deep test well. The experiments indicated that the best location for a test well is at the down-gradient end of the regional flowpath, along Blue River near Connerville.

Rainfall-Runoff

Dr. Baxter Vieux and Camilo Calderon (OU) analyzed long-term streamflow records from the study area to estimate monthly aquifer recharge and evapotranspiration rates. Recharge and base flow were estimated using USGS software RECESS, RORA, and PART. Potential evapotranspiration rates were then estimated with a water budget approach. The short period of the streamflow records at the Blue River gage near Connerville required the use of a synthetic relationship to estimate the recharge for the period of 1937 to 2002.

They then used the V*flo*™ distributed hydrologic model developed by Vieux and Associates to estimate distributed rainfall-runoff and recharge in the Blue River Basin. The model uses

geospatial maps such as soils, landuse, elevation, and rainfall properties. Precipitation data taken from radar rainfall records were used as hourly input values to model the recharge over the period of radar record (1993-2004). Next, the calibrated model will be used to estimate groundwater recharge for input to the MODFLOW groundwater flow model.

Tree Ring Analysis

Dr. Aondover Tarhule (OU) is using tree-ring chronology to reconstruct the precipitation, temperature, and streamflow for the Arbuckle-Simpson study area. He has collected 70 samples of post oak trees. About 20 trees were used to develop a master chronology, with the oldest tree dating from 1747 (257 years).

The results obtained so far suggest that it is feasible to develop a master chronology of tree-ring climate for the Arbuckle-Simpson aquifer. Current and future work will therefore focus on increasing the number of samples in the chronology to about 30 trees to conform to the standards set by the International Tree Ring Data Base. Additionally, there is a need to increase the sample depth particularly for the older time period. For example, currently, only one tree is 257 years old. Several trees within that age frame are needed to assure statistical reliability.

Groundwater Use and Artesian Well Inventory

Joseph Zume (OWRB) is reviewing reported water use records for all groundwater permits in the aquifer. After reported withdrawals and well locations are verified, Geographic Information Systems (GIS) layers of the production wells and their discharge rates will be created for use in the groundwater flow model.

OWRB staff has also been conducting an inventory of flowing artesian wells in the Sulphur area to establish historic trends of groundwater discharge rates. Staff is reviewing historical records and is documenting existing sites by obtaining GPS locations, photographs, and flow rates. Since 1889, about 40 flowing wells have been drilled; however, many no longer flow or have been capped. To date, OWRB has verified 14 wells that still flow freely, including the Townsley Well in Sulphur (Figure 5).

Figure 5. Townsley artesian well in Sulphur.

Geochemistry

In October and November, USGS conducted a reconnaissance sampling of the geochemistry of the Arbuckle-Simpson aquifer. This first round of water sampling, part of a broader analysis of the aquifer's chemical make-up, targeted five springs and 24 wells distributed across the aquifer. Samples were analyzed for major cations and anions, trace metals, nutrients, boron isotopes, dissolved gases, and carbon-14. Sample results will be used to determine the general water quality of the aquifer, identify possible water quality problems, gain insight into the aquifer's flow system, and provide data for more detailed geochemical studies. As a courtesy to the landowners, Dr. Ann Keeley (EPA Kerr Lab) conducted bacteria analyses of the samples. USGS has received all of the analyses and has sent summaries to the landowners.

Preliminary analyses by Dr. Andrew Hunt (USGS Noble Gas Laboratory, Denver) of helium-3/tritium and carbon-14 data indicate a wide range in groundwater residence time. Water from most springs and wells (with depths less than 500 ft) is characterized by modern waters (<60 years in age), and water from two artesian wells (with depths greater than 700 ft) is considered fossil water (>10,000 years in age).

In July, Dr. Hunt sampled bubbles emanating from Buffalo Spring at the CNRA to determine the dissolved gas content (Figure 6). The results indicate that the bubbles are composed primarily of nitrogen and carbon dioxide with trace amounts of argon and other gases.

Figure 6. Dr. Andrew Hunt sampling Buffalo Spring. Study participants looking on (from left to right) are Dr. Puckette, Noel Osborn, Bob Fabian, Dr. Halihan, Dr. Blome, Scott Christenson, Monty Porter, Matt Rawlins, Sassan Mouri, Greg Gromadzki, and Dr. Scheirer.

Scott Christenson is sampling the deep test well for the same suite of constituents that were sampled for the fall 2004 geochemical reconnaissance. He plans to sample about five water zones as the well is drilled. The chemical composition of water samples pulled from the well will tell the story of what has happened along the flow path. Age dating of deep water can determine how lower regions of the aquifer function, how fast water travels, where it comes from, and where it goes.

Aquifer Tests

One method to determine hydraulic characteristics of the aquifer is through aquifer tests, which usually involve pumping a well and observing the change in hydraulic head in the aquifer. Carol Becker compiled historical USGS aquifer-test data and re-evaluated data from 13 recovery tests using AQTESOLVE computer program.

OSU is evaluating aquifer test data from Oklahoma Environmental Health (OEH) for transmissivity and storativity. Preliminary analysis of 20 pumping tests indicates that the aquifer behaves as a leaky aquifer and a confined aquifer at different locations. The storage coefficient of the aquifer is consistently small at each location. Transmissivity of the aquifer is variable and indicates a heterogeneous aquifer system.

In August, Scott Christenson conducted an aquifer test at the City of Ada well field. The City began pumping well 1 on August 1 at a rate of 2,300 gpm. Instrumentation was installed in the City of Ada well 2, about ½ mile from well 1, to monitor draw down, and the Fittstown long-term observation well also was affected by the test. After receiving significant rainfall (5.85 inches at the Fittstown Mesonet station) August 14-16, the City turned off the pump. Water level response obtained from surrounding wells will be evaluated for determination of aquifer hydraulic properties. Scott will try another test if the opportunity arises.

Dr. Todd Halihan (OSU) is evaluating the feasibility of using quarries for large-scale aquifer tests. On September 9, Dr. Halihan and graduate students conducted a survey at the Unimin dolomite quarry south of Mill Creek. They collected water-level measurements from about 32 of the 40 test wells that Unimin drilled within the past year. Unimin was kind enough to provide a CAD dataset of the quarry with elevation data for the pit and the area where the test holes exist. With the data collected, a potentiometric map will be created over the area. The potentiometric map will be evaluated with pumping data to determine aquifer hydraulic properties.

Geologic Interpretation

<u>Petroleum Information</u>

Dr. James Puckette (OSU) is continuing his evaluation of petroleum-related information. He examined four cores from the Arbuckle Group that were taken in oil and gas wells drilled near the Arbuckle Anticline to determine lithology and characterize the pore network. Dr. Puckette examined bit cuttings from two oil and gas exploration wells drilled on the outcrop of the Arbuckle Group strata exposed on the Hunton Anticline. He also completed composite stratigraphic sections from literature sources for the Arbuckle and Timbered Hills Groups on the Tishomingo and Arbuckle Anticlines to identify lithologic or diagenetic signatures that can be used to help establish the stratigraphic framework for the Arbuckle aquifer.

Dr. Puckette constructed a preliminary structural contour map on the top of the Arbuckle Group. Petroleum and ground water wells that provide qualitative data on water type are being identified and correlated to evaluate the structural position of the freshwater/ sulfur water transition in the aquifer.

OSU student researchers Sassan Mouri and Annie Drewry constructed an oil and gas exploratory and development well database that contains over 1,700 wells. The database contains the depth of several key marker beds in the study area as well as surface elevations, which will allow the projection of the altitude of the key marker beds relative to a sea level datum.

Fracture Property Analysis

OSU researchers evaluated the feasibility of collecting fracture data in quarries. A survey of quarries in the Arbuckle-Simpson aquifer was performed to determine locations that fracture properties could be evaluated at an outcrop scale. Unfortunately, the assessment revealed that the quarries were not good candidates for fracture analysis. Because quarry regulations generally require that the walls not be approached, the ability to use the quarry walls to collect data is limiting. Furthermore, the quarry walls have very poor quality exposure and are therefore not good candidates for fracture analysis. Lastly, most of the quarry floors are not bare rock, but gravel, and are not exposed to the level where the fractures can be easily observed.

With the lack of good quarry fracture data, OSU will examine creek beds to determine if they provide good ground truth data to evaluate the regional data provided by the stream segments. Sassan Mouri is analyzing stream orientation as a means to determine fracture characteristics. GIS creek data were evaluated to use as a proxy for regional fracture data. The creek data in the Arbuckle-Simpson GIS dataset were evaluated by converting the creek data into stream segments. More than 60,000 segments were available. The data were initially gridded on a 10 x 10 km scale, which provided grids of 500 to 1000 stream segments. The orientations of the stream segments show strong preferential directions, but are variable throughout the study area. Similarly, the lengths of the segments showed trends through the study area.

Geophysics

Dr. Halihan submitted a preliminary Electrical Resistivity Imaging (ERI) report in October 2004. Initial findings indicate that ERI data collected in the aquifer area are of high quality and provide useful information about the variability of the aquifer. The resistivity of the Arbuckle-Simpson aquifer is highly variable and provides some very conductive areas that are easier to image with the technique. Surface imaging can provide information on fault location along with data about the thickness of soil zone and the soil/bedrock interface. Borehole imaging of the aquifer provides a similar image to the surface images and indicates that vertically conductive zones may exist for large distances into the subsurface. However, the limited number of deep undamaged, unused wells limits the ability to obtain good quality data about the structure of the aquifer at depth.

During the year, Dr. Halihan continued imaging at several sites. Surface imaging of the Unimin and U.S. Silica quarries was performed in conjunction with Ground Penetrating Radar (GPR) surveying. Results indicate that the individual rock units behave reasonably uniformly. Additionally, surface images were collected at Vendome Well, over the Sulphur Fault, and at the

deep test well drilling site. Finally, borehole imaging was conducted in an existing deep well to evaluate the formation in the area.
Dr. Surinder Sahai (OSU) evaluated existing seismic data for the Arbuckle-Simpson aquifer. Data were found to exist in two sources: the SEI (Seismic Exchange, Inc.) and Anschutz Corporation. The data available from SEI were of poor quality and did not cover many key areas of the aquifer. However, the Anschutz data, which cover about 50 miles over the Hunton Anticline, are of significantly higher quality. A decision was made to purchase the Anschutz datasets.

Deep Test Well
Considerable effort during the year was devoted to the planning and drilling of a deep test hole. The purpose of the well is to collect information on the lower portion of the Arbuckle-Simpson aquifer, for which information is sparse. Specific information to be obtained includes:

- rock properties and characteristics (porous zones, solution cavities, fractures),
- stratigraphy (formation thickness and correlation with other wells),
- aquifer properties (hydraulic conductivity),
- vertical flow gradients, and
- water chemistry (salt water interface; geochemistry, age of recharge).

Site Selection
Scott Christenson conducted modeling simulations to assist in the site selection for the well. His simulations indicated that the best location for a test well is at the down-gradient end of the regional flowpath, which would be along Blue River.

Based on the Study's needs, hydrogeology, and the model simulations, several criteria were established for the preliminary site selection. The site should be along a gaining section of Blue River; as far down gradient in the aquifer as possible; within 250 meters of Blue River; in the outcrop of the Arbuckle Group; and not close to a major fault. Other considerations were landowner cooperation and accessibility for the drilling rig. Two potential sites, on the Spears and Easterling ranches (Figure 7), were identified that fit these criteria. Base flow measurements collected March 28-30 on Blue River verified that both sites are situated along gaining sections of the river.

To assist with the final site selection, Scott Christenson conducted additional model simulations along Blue River and presented his results to the study group in Sulphur on July 15. The simulations indicated that although the Easterling site was slightly better for the deep test hole, either site would be suitable to yield the type of information needed from a deep test hole. After further discussion and a visit to the proposed site, the study group decided upon the Spears Ranch. The primary concern of the Easterling site was that the drilling rig might encounter problems in the alluvium, which could then jeopardize drilling as deep as possible. Another concern was that the site is located about ½ mile south of the Sulphur fault, and may not be representative of the main portion of the aquifer on the Hunton Anticline.

The selected site is on the Spears Ranch in section 23-01S-06EI, Johnston County, west of Connerville. The site is approximately 1,300 feet up-gradient from Blue River. The West Spring Creek Formation of the Arbuckle Group is exposed at the surface.

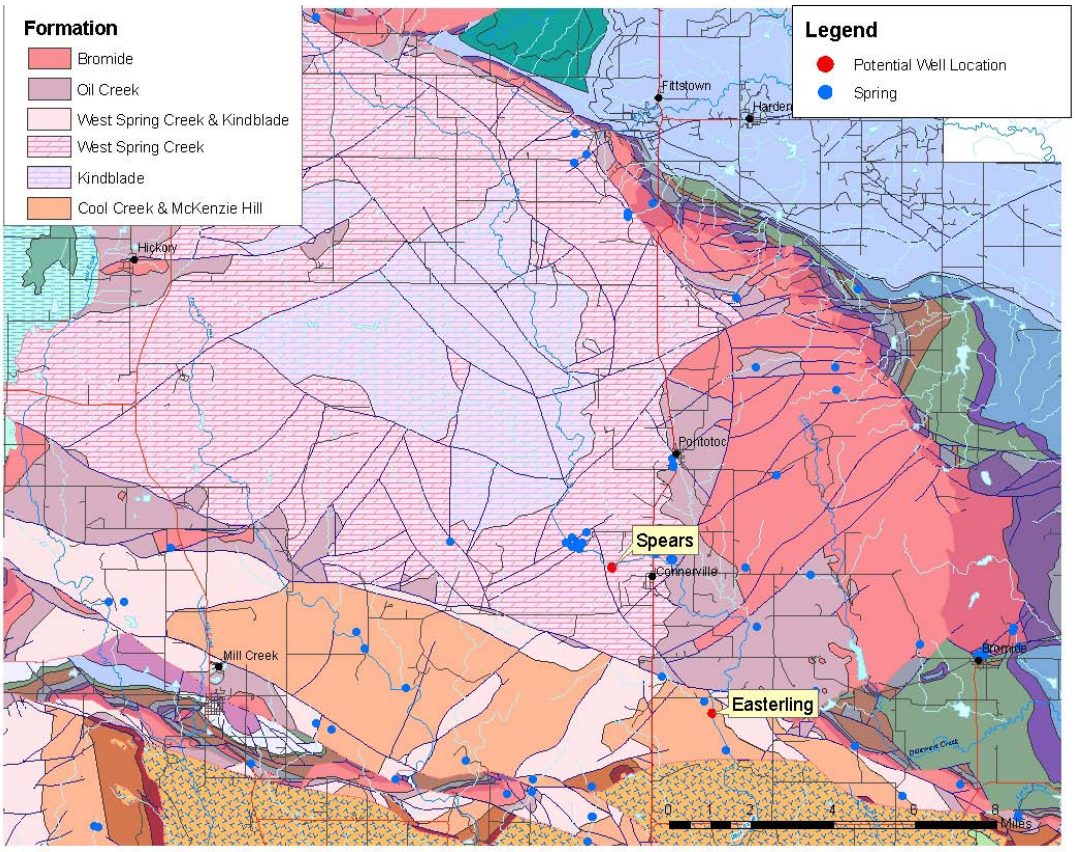

Figure 7. Potential locations for deep test hole.

The Bureau ensured compliance with the National Environmental Protection Act (NEPA) and National Historical Preservation Act (NHPA). OWRB worked with ODEQ to develop best management practices to minimize the amount of sediment entering Blue River from produced water.

Drilling and Testing Program

The cooperative agreement with USGS was amended to include the drilling of the well. USGS Research Drilling Project out of Denver, Colorado was contracted to drill the well to a maximum depth of 3,000 feet, which is the limit of the drilling rig.

Scott Christenson plans to sample 5-6 zones as the well is drilled using single conduct packer tests. When a test interval is reached, USGS will stop drilling, retrieve the drill string, insert the single-packer system, inflate the packer, and test the interval between the packer and the bottom of the test hole. Testing will consist of measuring the hydraulic head and collecting water-quality samples using the same suite of constituents as the fall 2004 geochemical reconnaissance.

After the well is drilled, Dr. Randall Ross will run geophysical logs using the Kerr Lab's logging equipment. The borehole tools include natural-gamma, spontaneous-potential, normal-resistivity (64 in. long-normal; 16 in. short-normal), lateral-resistivity (48 in.), single-point resistance, 3-arm caliper, P-wave sonic, acoustic televiewer, fluid-temperature, fluid-resistivity, and electromagnetic borehole flowmeter. Dr. Halihan will conduct downhole electric resistivity

imaging of the wells. Data obtained from geophysical logging will be used for stratigraphic correlation with logs of numerous petroleum wells in the area; to determine physical properties of the rock matrix and the contained fluids; to characterize fractures; and to obtain hydraulic properties.

Drilling Progress

On September 14, USGS began drilling the Spears Test Hole #1. The well was air rotary drilled to 80 ft, where $6^{5/8}$ inch surface casing was set. The well was then drilled with an air hammer. Scott Christenson sampled the first water zone from 80-110 ft. A fractured zone at 364-366 ft made appreciable water and caused problems with the drilling. In an effort to plug off the fracture zone, about 280 pounds of cement were pumped into the hole. Scott Christenson sampled a second zone from 538-585 ft. On September 24, after struggling with equipment and drilling problems, the driller recommended abandoning the 630-ft hole and starting over with a new, wider-diameter well.

On September 25, drilling commenced on the Spears Test Hole #2, located about 200 ft east of the initial test hole. A 12 ¼ -inch hole was drilled to 35 ft, where 8-inch surface casing was set. The well steadily gained water (>300 gpm), until about 645-700 ft, where a heavily fractured zone was encountered and the well made an estimated 600-700 gpm of water. Drilling continued until September 29, when the air hammer gave out at 875 ft. The following day the crew drilled with air rotary to a depth of 960 ft. On October 1, Scott sampled a third water zone from 916-960 ft. Dr. Ross ran geophysical logs and Noel Osborn (OWRB) examined cuttings for both test holes.

Figure 8. USGS drilling the Spears Test Well #2.

At the time of this report, the depth of the well was 1,473 ft. On October 26, the engine broke down, and the rig was moved to Ardmore for repairs. USGS plans to resume drilling after the rig is repaired. They plan to drill with air rotary as far as possible and then change to hydraulic rotary.

Public Involvement

The OWRB is committed to keep various cooperators and stakeholders informed of the Study's progress. Information is distributed through a variety of media including a project web site, newsletters, press releases, videos, and presentations.

News Media

During the last year, OWRB published two newsletters (December 2004 and June 2005) and issued three press releases: *Old Trees Sought for Arbuckle Tree Ring Study* (December 10, 2004), *New Mesonet Station to Assist Arbuckle Study* (June 1, 2005), and *Deep Well Yields Important Information* (September 12, 2005). All were printed in local papers. The May-June 2005 issue of the OWRB's newsletter Oklahoma Water News featured two articles on the Study: *Geochemistry Unlocking Mysteries of Aquifer's Flow System* and *New Mesonet Station to Assist Arbuckle Study*. OWRB continues to maintain the Study web site, from which all newsletters and press releases are available: http://www.owrb.state.ok.us/studies/groundwater/arbuckle_simpson/arbuckle_study.php. Finally, OWRB produced a video entitled *Oklahoma Water: A Quality of Life*, which includes a segment on the Arbuckle-Simpson Hydrology Study.

Meetings

On October 5, 2004, the Citizens for the Protection of the Arbuckle-Simpson Aquifer (CPASA) group held its annual meeting in Tishomingo, which was attended by Duane Smith, executive director of OWRB, and several OWRB staff. Scott Christenson discussed the upcoming geochemical sampling.

Noel Osborn gave presentations on the Study to the Ardmore Geological Society, the Oklahoma Water 2004 Conference in Stillwater, the Oklahoma City Geological Society discussion group, the Oklahoma Department of Environmental Quality hydrology group, the CPASA group in Ada, the Oklahoma Clean Lakes and Watersheds Association conference at Lake Murray, and the Sierra Club in Norman.

Water Conference 2005 was held September 27-28 in Tulsa. The first session featured the Arbuckle-Simpson Hydrology Study. Speakers included Noel Osborn (study update) Dr. Hunt (helium-3/ tritium ages of groundwater), Dr. Halihan (electrical resistivity imaging), Dr. Tarhule (hydroclimatic reconstruction using tree rings), and Dr. Caniglia (science, development, and public opinion).

Technical Peer Review Team

A technical peer review team reviews the scope of work and provides advice to ensure the use of sound science and appropriate methods. The team consists of Scott Christenson (USGS), Dr. Halihan (OSU), Dr. Neil Suneson (Oklahoma Geological Survey), and Dr. Ross (EPA). Serving

as liaisons between the team and various stakeholders are Dick Scalf, representing CPASA and Clayton Jack, representing landowners over the aquifer.

The technical peer review team met on November 29, 2004, when they received updates on modeling, geochemistry, fault characterization, electrical resistivity imaging, and evaluation of petroleum well information. The team discussed data needs and drilling new wells.

On December 9, Darcy lecturer Dr. Alan Shapiro (USGS) presented *Recent Advances in Characterizing Ground Water Flow & Chemical Transport in Fractured Rock: From Cores to Kilometers* at the OU School of Geology and Geophysics colloquium. In conjunction with the Darcy lecture, OU facilitated a meeting on the Arbuckle-Simpson Study and a discussion of geophysical methods for fracture characterization in carbonates. These open meetings provided an opportunity for the peer review team to discuss the project with Dr. Shapiro and interested faculty and students.

The technical peer review team met again on March 3, 2005, to review progress on modeling, geochemistry, fault characterization, electrical resistivity imaging, and evaluation of petroleum well information. Dr. Charles Blome (USGS Earth Surface Processes Team) gave a presentation on geologic modeling of the Edwards aquifer with Earth Vision software. The team discussed next year's work plan and drilling plans.

On July 14-15, the technical peer review team met with other researchers in Sulphur, where they discussed information regarding the Arbuckle-Simpson Hydrology Study and exchanged ideas. Updates were given on a variety of topics, including modeling, geochemistry, fault characterization, geophysical work, and evaluation of petroleum well information. The group visited Chickasaw National Recreation Area, where they viewed Vendome Well and sampled Buffalo Spring. Another field excursion was made to sites along Blue River, including the test well site, a stream monitoring station, and springs.

Other Activities

In addition to work under contract with the OWRB, studies funded from other sources are also underway. These companion studies provide additional information that augments the Arbuckle-Simpson Hydrology Study.

Environmental sociologist Dr. Beth Caniglia (OSU) received a grant from the Oklahoma Water Resources Research Institute to help fund her study, *Science, Development and Public Opinion: The Adjudication of Groundwater Policy for the Arbuckle-Simpson Aquifer*. The first phase of the study focused on the controversy over the Arbuckle-Simpson aquifer prior to the passage of Senate Bill 288. The study employs data from public comment letters, newspapers and newsletters (2002-present), and in-depth interviews to illustrate the diversity of frames being used by members of different sectors that are interested in or affected by Arbuckle-Simpson aquifer policy. While Senate Bill 288 highlights science as a central arbitrator, the findings of the study suggest that science is not the primary arbitrator of public opinion formation. Instead, water security, sustainable development, wildlife conservation, and property rights are of primary importance among the respondents.

In late April, Drs. Dan and Allegra Scheirer (USGS, Menlo Park, California), under contract with the NPS, continued the geophysical investigation in the Chickasaw National Recreation Area that they began in June 2004. They collected high-resolution gravity measurements to delineate the faults and structures in the park and surrounding areas.

PLANS

In addition to the ongoing field investigation and studies, the following activities are scheduled for the next year:

Mesonet Observation Well
OWRB has awarded a contract to Layne-Western to drill a 250 ft observation well at the Fittstown Mesonet station. Plans are to drill the well the week of October 24. The well will be equipped with a continuous water-level recorder, capable of interfacing with the Mesonet data logger software. Real-time daily water-level measurements and hydrographs will be available on the Mesonet web site, along with the other climatological data.

Geochemical Sampling
USGS will conduct additional sampling of deep wells and springs. Scott Christenson is working with Chaparral Energy Company to obtain a brine sample from a hydrocarbon-producing well west of Sulphur. Analysis of the brine sample will provide an end member of aquifer water, representing saline water that may be mixing with water from the flow path near the CNRA. Scott is also working with the City of Ada to obtain a sample of Byrds Mill Spring.

Geologic Modeling
Dr. Blome will develop a three-dimensional geologic model using EarthVision™, such as that developed by USGS for the Edwards aquifer. This effort would greatly advance our understanding of the structural framework of the Arbuckle-Simpson aquifer. Modeling results will be used to derive boundary layers and to assess flow paths and aquifer properties. He will be coordinating data needs with OSU and other cooperators.

Quarterly Monitoring
OWRB will conduct quarterly seepage runs of streams during low flow conditions. These will be conducted in conjunction with quarterly synoptic water-level measurements. The winter seepage run will be basin-wide, and will include streams emanating from the Arbuckle, Tishomingo, and Hunton anticlines. The spring, summer, and fall seepage runs will focus on streams emanating from the Hunton Anticline region.

Minimum Streamflow
OWRB facilitated a meeting with Dr. Bill Fisher (OSU) on September 8 to discuss methods of determining minimum streamflow for management options. Several methods were considered, including surface water rights, ecological (such as Instream Flow Incremental Methodology), a hydrological statistical approach, indicator water level, and regulatory low-flow minimum (such as Q=7Q2). Dr. Fisher will submit a proposal for IFIM and other options, along with budgets and recommendations.

PROJECT FUNDING

The Oklahoma legislature approved $500,000, which, combined with the $320,000 allocated by the Bureau of Reclamation, will provide $820,000 for funding the third year of the Arbuckle-Simpson Hydrology Study.

Agreements have been approved by OWRB with USGS (stream gages, groundwater flow modeling, geochemical analysis of water samples, well drilling, and aquifer characterization); OSU (literature and data compilation, compilation and evaluation of existing water quality data, evaluation of petroleum information; and fracture, geologic, and aquifer characterization); with OU (continued work on the rainfall run-off model for Blue River and estimation of the distributed recharge, and for completion of the tree ring analysis); and with OCS (operation and maintenance of the Fittstown Mesonet station).

During the past year, the Arbuckle Simpson Hydrology Study received considerable assistance, both financial and in-kind, from a number of sources. The Chickasaw Nation contributed approximately $27,000 to pay for the operation and maintenance costs for three USGS stream gages. USGS contributed a minimum of $45,000 towards the drilling of the deep test well and provided in-kind services for the geochemical work, in that the Study has not been charged for the personnel costs for the geochemist. EPA Kerr Lab donated the use of Randall Ross and the facility's geophysical logging equipment to log wells. NPS contracted with USGS to conduct a geophysical survey of the CNRA. The City of Ada cooperated with USGS in conducting a pump test on one of their municipal water wells, at no cost to the Study. Numerous landowners allowed researchers to conduct work on their property, such as drilling the deep test well and installing the Mesonet station, at no cost to the Study. Furthermore, it appears that these types of contributions will continue into the next year. One significant item is the development of a three-dimensional geologic model by USGS, at no cost to the Study.