Groundwater flow models of the Arbuckle-Simpson aquifer were constructed using the U.S. Geological Survey’s MODFLOW-2000 finite-difference model. The purposes of the models are to test conceptual models of the aquifer and to predict the consequences of aquifer-scale groundwater withdrawals on streamflow. The MODFLOW models simulate the distribution of hydraulic head and the base flow (groundwater discharge) component of stream hydrographs. The models are designed to work at a regional scale and are not intended to simulate the effects of individual wells or well fields.

The geologic framework for the groundwater flow models of the Hunton Anticline was obtained by exporting geologic data from a geologic model and importing that data to the MODFLOW models in order to accurately represent the geology of the Hunton Anticline. The MODFLOW models were discretized using 200-meter node spacing in the X and Y directions and multiple layers in order to simulate the 3-dimensional movement of groundwater within the aquifer.

An initial steady-state model of the Hunton Anticline portion of the aquifer used synoptic measurements of depth to water in wells and streamflow collected in August 1995 as head and flow observations. The observation, sensitivity, and parameter-estimation features of MODFLOW-2000 were used, with parameterization based on geologic units. Nonlinear regression was used to determine model parameters. There were substantial differences between the Arbuckle and Simpson Group hydraulic parameters. Hydraulic conductivity and recharge calculated for the Arbuckle Group were an order of magnitude greater than equivalent parameters in the Simpson Group, which is consistent with geohydrologic observations that the Simpson Group is not as prolific an aquifer as the Arbuckle Group. The model-derived ratio of horizontal to vertical hydraulic conductivity (Kh/Kv) in the Simpson Group was orders of magnitude greater than in the Arbuckle Group. The high ratio of horizontal to vertical hydraulic conductivity is consistent with the geology of the Simpson Group which consists of interlayered limestone, sandstone, and shale. A transient-flow model was constructed to simulate a time period starting on January 1, 2004. This time period was chosen because of the availability of data from stream gages installed in the fall of 2003. Recharge for the transient model was determined using hydrograph separation methods on mean-daily streamflow data from Blue River at Connerville gage. Blue River was chosen because it usually has the largest measured discharge of any stream originating in the study area. The direct-runoff component of streamflow, which was not simulated by the MODFLOW model, was obtained by hydrograph separation analysis.

The transient model used daily time steps in order to compare model-computed base flows to mean daily flows at stream gages. Aquifer hydraulic parameters for the transient model were those derived from the steady-state model. Different values of specific storage in the transient model were tested to match model-computed flows to daily stream-gage data. Flows calculated by the transient flow model reproduced the measured flow at the Connerville stream gage when specific storage was adjusted to values consistent with a fractured-bedrock aquifer such as the Arbuckle Group.

The aquifer hydraulic parameters derived from the steady-state and transient models are similar to aquifer hydraulic parameters determined for the Arbuckle-Simpson aquifer independently by
other methods, such as aquifer tests, analyses of groundwater and surface-water hydrographs, and age dating. Agreement of model and independently derived parameters indicates the model is a reasonable representation of the groundwater flow system. In particular, the storage coefficient derived from the transient groundwater flow model is similar to independent analyses of storage coefficients. The small storage coefficient means that only small volumes of water are available from aquifer storage.

The MODFLOW models will be used during the final year of the Arbuckle-Simpson Hydrology Study to estimate the effects of potential groundwater withdrawals on streamflow. The MODFLOW models will simulate the base-flow component of stream hydrographs and will be coupled with a rainfall-runoff model, which will simulate the runoff component, and thus simulate the total streamflow hydrograph.