SIMULATION OF GROUND-WATER FLOW AND NITRATE TRANSPORT IN THE UPPER FLORIDAN AQUIFER IN THE SOUTHWESTERN ALBANY AREA, GEORGIA

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Abstract. The Albany Water, Gas, and Light Commission is concerned about high levels of nitrate upgradient of their well field southwest of Albany, Georgia. The U.S. Geological Survey is developing a ground-water flow and particle-transport model in a 1,500-square-mile area surrounding the well field to determine ground-water flowpaths and potential movement of nitrate-contaminated water. Predictive simulations using a variety of pumping and boundary conditions are being used to assess possible pathways of nitrate migration and the potential for the Flint River to contribute water to the well field. Steady-state simulations using MODFLOW–2000 are being calibrated to October 1999 water levels and estimates of baseflow using differential streamflow at successive streamgaging stations. Potential nitrate pathways and rates of movement are being simulated using MODPATH.

INTRODUCTION

To meet increasing water demand, the Albany Water, Gas, and Light Commission (WGL) has developed a large well field southwest of the Albany, Georgia, area to pump from the Upper Floridan aquifer. Water-quality analyses of samples from Upper Floridan aquifer wells upgradient of the well field indicate nitrate concentrations that exceed the 10 milligram per liter (mg/L) maximum contaminant level (MCL) set by the U.S. Environmental Protection Agency (2000; Warner and Lawrence, 2005). WGL is concerned about nitrate contaminated ground water reaching the well field. In addition, because the well field is located about 1.5 miles west of the Flint River, WGL is concerned about possible capture of river water as a result of pumping in the well field.

To determine ground-water flowpaths and potential movement of nitrate-contaminated water in the Upper Floridan aquifer the U.S. Geological Survey (USGS) is developing a ground-water flow and particle-transport model in the well field area. Predictive simulations using a variety of pumping and boundary conditions are being performed to assess potential pathways for nitrate migration and potential for the Flint River to contribute water to the well field. This paper describes the model area and construction, including the model layers, grid, boundary conditions, and calibration data.

PREVIOUS STUDIES

Torak and others (1993) developed a two-dimensional finite-element model of ground-water flow to evaluate the water-resource potential of the Upper Floridan aquifer. Torak and Painter (2006) described the geohydrology of the Upper Floridan aquifer and its overlying and underlying hydrologic units. Jones and Torak (2006) developed a transient finite-element model of ground-water flow to simulate seasonal ground-water flow conditions in the lower Apalachicola–Chattahoochee–Flint River Basin in southwestern Georgia and adjacent parts of Alabama and Florida.

APPROACH

A three-dimensional finite-difference ground-water flow model is being constructed that builds on and is refined from previously developed regional ground-water-flow models of southwest Georgia. The USGS finite-difference ground-water flow simulator, MODFLOW–2000 (Harbaugh and others, 2000) is being used for modeling. MODPATH (Pollock, 1994) is being used to simulate particle transport. The model is based on the hydrogeologic framework of Torak and Painter (2006), and the boundary conditions used in Jones and Torak (2006). The model employs fine discretization in the Albany well field area to enable simulation of detailed hydraulic gradients near individual wells. The production wells in the well field are about 1,850 feet (ft) apart. The model is being calibrated to simulate steady-state conditions during October 1999, using ground-water-level data and baseflow estimated from differential streamflow at successive streamgaging stations.

MODEL CONSTRUCTION

The model includes an approximate 1,500-square-mile area in the Coastal Plain of southwestern Georgia (Fig. 1), which is similar to the area of the finite-element model constructed by Torak and others (1993). The Albany well field is located in the center of the model area between Cooleewahee Creek and the Flint River.

The model is discretized horizontally with irregular grid spacing in order to capture more detail in the well field area than in the rest of the model area. The grid cells are 500 ft on a side in the well field area, and gradually increase to 5,000 ft on each side outside of the well field area (Fig. 1).

The model is divided into two layers representing undifferentiated overburden and the Upper Floridan aquifer (Fig. 2). The undifferentiated overburden is comprised of sand and clay. The thickness of the overburden ranges from a few ft or less at the updip limit of the Upper Floridan aquifer and in some streams where the Upper Floridan aquifer crops out, to more than 120 ft (Hicks and others, 1987). The vertical hydraulic conductivity of the overburden ranges from about 0.0004 feet per day (ft/d) to about 23 ft/d (Torak and others, 1993). The vertical hydraulic conductivity and thickness of the clay controls the level of confinement of the Upper Floridan aquifer. The Upper Floridan aquifer is comprised of the Ocala Limestone and varies in thickness from less than 50 to greater than 200 ft in the study area (Torak and others, 1993). Aquifer tests conducted in the southwestern Albany area indicate that the hydraulic conductivity of the Upper Floridan aquifer ranges from about 1,500 ft/d (Torak and others, 1993) to about 5,000 ft/d (Warner, 1997).

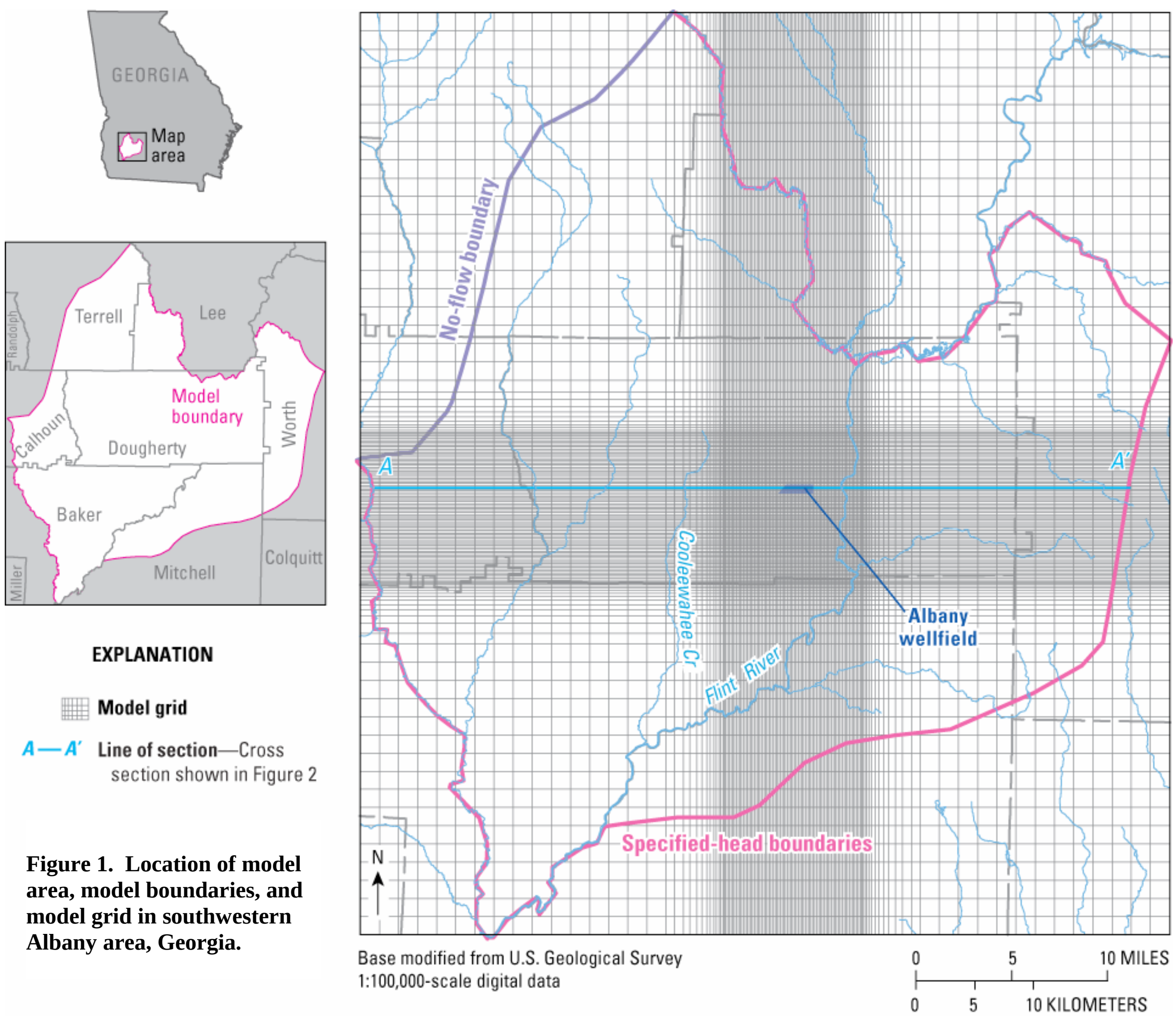

Figure 1. Location of model area, model boundaries, and model grid in southwestern Albany area, Georgia.

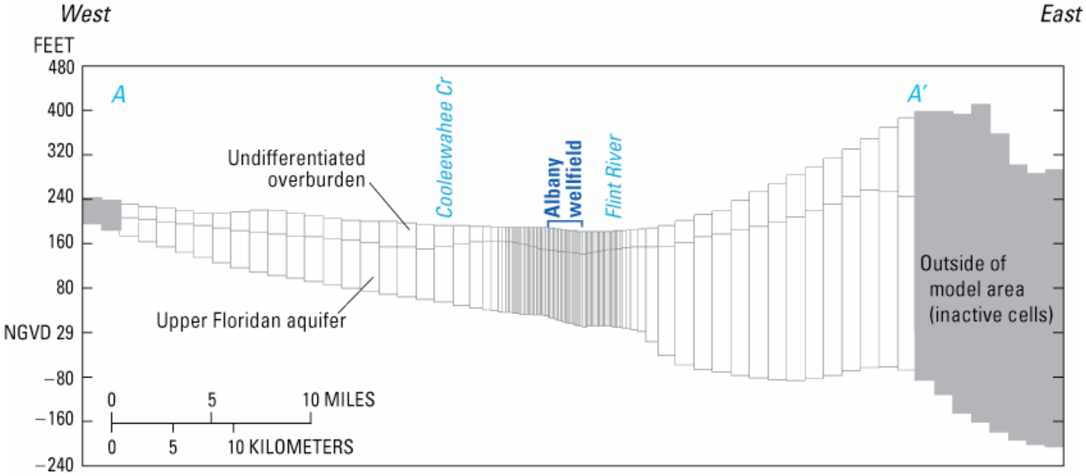

Figure 2. Cross section through the model from west to east showing the three model layers in the southwestern Albany area, Georgia.

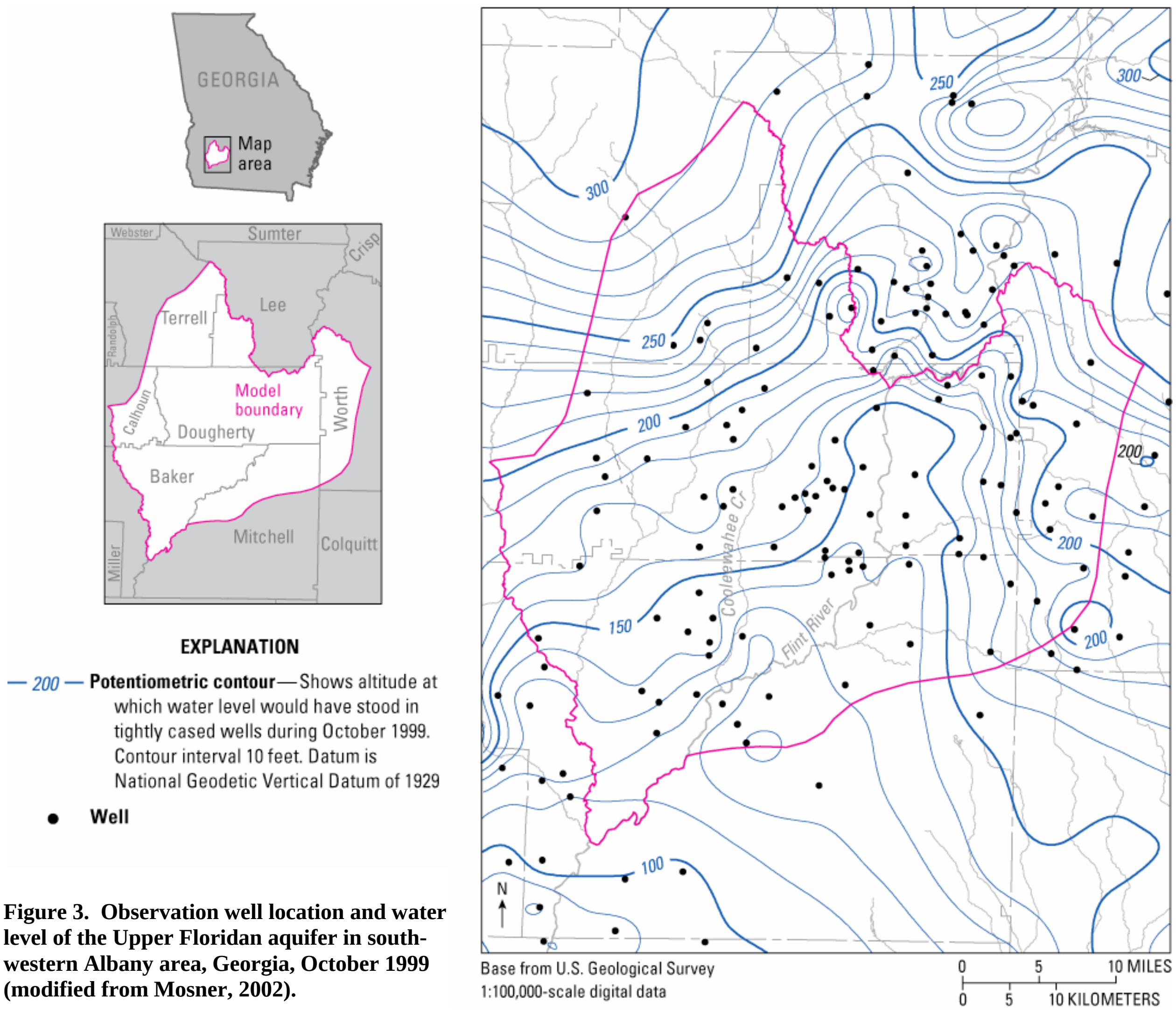

Figure 3. Observation well location and water level of the Upper Floridan aquifer in southwestern Albany area, Georgia, October 1999 (modified from Mosner, 2002).

A variety of hydraulic boundaries will be used to simulate conditions during October 1999. The top layer of the model representing the undifferentiated overburden is a source/sink layer which will allow for the input of recharge. Recharge is applied either from direct infiltration of precipitation (specified flux) or from leakage through the undifferentiated overburden, which acts as a semiconfining unit (head-dependent flux). Recharge is based on the saturated thickness of the semiconfining unit and geohydrologic zones characterized by Torak and Painter (2006). In areas where the thickness of the upper semiconfining unit is less than 10 ft and/or unsaturated, direct recharge (specified flux) will be applied based on precipitation. In transition areas where the thickness of the upper semiconfining unit is between 10 and 30 ft, vertical leakage will be applied during wet periods only (head-dependent flux). In areas where the thickness of the upper semiconfining unit is greater than 30 ft, vertical leakage (recharge or discharge) (head-dependent flux) will be applied. In the bottom layer of the model, representing the Upper Floridan aquifer, several types of lateral boundary conditions are placed along the outside of the model area (Fig. 1). The northwest boundary is at the updip extent of the Upper Floridan aquifer and, thus, assigned a no-flow boundary. The southwest and northern boundaries are specified-head boundaries set to the stage of the streams that flow along those boundaries. The eastern boundary is a specified-head boundary set to potentiometric contours from October 1999 (Fig. 3).

The model is being calibrated to water-level data from about 162 wells completed in the Upper Floridan aquifer in October 1999, a period having the largest number of data points available for calibration. Baseflow estimates from 27 stream reaches also are being used for calibration.

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