GROUND-WATER MANAGEMENT IN COASTAL GEORGIA AND ADJACENT PARTS OF SOUTH CAROLINA AND FLORIDA—I. GROUND-WATER RESOURCES AND CONSTRAINTS TO DEVELOPMENT

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Abstract. Current use and future demands for water in the coastal area of Georgia and adjacent parts of South Carolina and Florida affect all three States. Pumpage from the Floridan aquifer system—an extremely permeable, paleokarst, carbonate water-bearing sequence—has resulted in substantial water-level declines and subsequent encroachment of seawater into the aquifer at the northern end of Hilton Head Island, South Carolina; and in saltwater intrusion of the aquifer at Brunswick, Georgia; and near Jacksonville, Florida. Although the mechanisms vary by which encroachment and intrusion occur, all hypotheses indicate that pumpage from the Floridan aquifer system has caused ground-water level decline and a reduction in hydrostatic pressure, and has allowed saltwater to enter the freshwater part of the system. This situation has constrained further development of the Floridan aquifer system in the coastal area.

INTRODUCTION

Water-resource managers in Georgia, South Carolina, and Florida strive for the equitable and fair management and allocation of water for present and future uses in the coastal area of Georgia and adjacent parts of South Carolina and Florida. This State-mandated management and allocation plan is designed to protect and conserve the resource. Water-resources data and information needed by resource managers are provided almost exclusively by the U.S. Geological Survey (USGS). The USGS has been actively involved in the water resources of the coastal area for more than 50 years, collecting data, conducting studies and research—including computer modeling—and disseminating results to interested parties. The main source of water supply in the coastal area is the Floridan aquifer system. The Floridan is an extremely high-yielding aquifer system, which was first developed in the late 1800's, and has been used extensively in the area ever since. Present pumpage from the aquifer in the coastal counties and Wayne County, Georgia, Beaufort County, South Carolina, and Nassau County, Florida, is about 320 million gallons per day (data on file of Georgia Environmental Protection Division, Atlanta, Ga.). This pumpage has resulted in a general decline in the potentiometric surface of the Upper Floridan aquifer in the area, substantial decline near some pumping centers, and is responsible for lateral encroachment of seawater and upward intrusion of saltwater.

Purpose and scope

This paper summarizes hydrogeologic information on the Floridan aquifer system in the coastal area of Georgia and adjacent parts of South Carolina and Florida. Included are descriptions of the conceptual model of the aquifer system as it existed prior to development, as it has changed owing to development, and as it presently exists. Changes in pumpage, ground-water levels, and saltwater movement are described. Lastly, a brief discussion of constraints to future development of the aquifer system is given.

Description of study area

The area of interest in this discussion includes the coastal area of Georgia and adjacent parts of South Carolina and Florida. The area chiefly includes the coastal counties from Beaufort County, South Carolina, to Nassau County, Florida, and Wayne County, Georgia. The study area is in the Coastal Plain physiographic province.

Previous investigations

The hydrogeology of the Floridan aquifer system has been investigated extensively in the coastal area of Georgia and adjacent States. Some of the more recent and comprehensive studies are those by Krause and Randolph (1989), Clarke and others (1990), and Randolph and others (1991). More site-specific studies were conducted by Brown (1984) and Spechler (1994) for the area of northeastern Florida and adjacent part of southeastern Georgia; Randolph and Krause (1990) and Maslia and Prowell (1990) for the Glynn County, Georgia, area; and Hayes (1979), Smith (1988), and Garza and Krause (1996) for the area of Chatham County, Georgia, and adjacent lowcountry of South Carolina.

HYDROGEOLOGY OF THE FLORIDAN AQUIFER SYSTEM

Hydrogeology and aquifer characteristics

The Floridan aquifer system is composed of two water-bearing units: the Upper Floridan aquifer and Lower Floridan aquifer, which includes the Fernandina permeable zone in the southern part of the coastal area of Georgia (Krause and Randolph, 1989). The Upper Floridan aquifer is the major source of freshwater and the preferred water-supply source in the area. The Lower Floridan aquifer is not widely used because it is deeply buried and contains saltwater in places, and because of the comparatively readily available water from the overlying Upper Floridan aquifer. The Floridan aquifer system consists mainly of highly permeable, transmissive carbonate rocks of Eocene age.

Ground-water flow system

Prior to development of the Floridan aquifer system, long-term recharge was assumed to equal natural discharge, and the flow system was at equilibrium or under steady-state conditions. Recharge to the aquifer system generally occurred as downward infiltration of precipitation in areas where sediments that compose the aquifer system crop out or are near land surface. In this part of the area, the aquifer system is unconfined. Downgradient of the recharge area, the aquifer system is confined and under artesian pressure. Ground-water flow was from the inland, recharge areas toward discharge areas offshore. When the aquifer system was first developed, wells throughout the coastal area flowed at land surface.

In the Hilton Head Island area and offshore, the Floridan aquifer system is thin and overlain by thin layers of sediment. Locally, the aquifer system is exposed at land surface, in creek and estuary beds, or on the seafloor. Water from the system discharged as seeps or springs in deeply scoured reaches of creeks and estuaries and as diffuse upward leakage farther offshore.

Development of the Floridan aquifer system in the study area began in the late 1800's; the first well was drilled in 1885, in Savannah, Georgia. The city of Savannah began using water from the aquifer system then, and by 1900, was withdrawing more than 10 million gallons per day for municipal supply. Since that time, development has spread throughout the area and increased to the present at varying rates. Pumpage is concentrated along the coast—at Jacksonville and Nassau Counties, Florida; St Marys, Brunswick, Jesup, and Savannah, Georgia; and the Hilton Head Island area, South Carolina (Krause and Randolph, 1989). The ground-water level declined regionally and in areas of concentrated pumpage, thus reducing the area where wells would flow at land surface. Ground-water withdrawal also has induced additional recharge and reduced natural discharge, having a net effect of increasing total flow through the system. To a lesser extent, ground water that was released from aquifer storage caused minor land subsidence at Savannah, Georgia.

SALTWATER INTRUSION OF THE FLORIDANAQUIFER SYSTEM

As a result of development of the Floridan aquifer system, lateral encroachment of seawater and vertical intrusion of saltwater have occurred at isolated locations along the coast (Krause and Randolph, 1989). Although two distinctively different processes have occurred, their cause is common—a ground-water level decline and a reduction in hydrostatic pressure in the Floridan aquifer system caused by withdrawal of water, chiefly from the Upper Floridan aquifer.

Lateral encroachment of seawater into the Upper Floridan aquifer has occurred in the Hilton Head Island, South Carolina, area. Prior to development, the hydraulic gradient, and hence, ground-water flow in the Upper Floridan aquifer, was seaward. Since development, large ground-water withdrawal from the Upper Floridan aquifer in the Savannah, Georgia, and Hilton Head Island, South Carolina, area has lowered hydraulic heads and reversed the hydraulic gradient in the aquifer, resulting in the migration of the freshwater-saltwater interface laterally along the hydraulic gradient toward the areas of pumping. Lateral seawater encroachment is occurring on the northern end of Hilton Head Island, where saltwater from Port Royal Sound is entering the aquifer and moving horizontally southwestward along the hydraulic gradient toward the pumping center in Savannah. This encroachment also could be occurring elsewhere in the lowcountry area, but data are insufficient to demonstrate this.

Vertical intrusion of saltwater into the Lower and Upper Floridan aquifers has occurred in Brunswick, Georgia, rendering a large part of the aquifer system in the city contaminated. Saltwater intrusion was first noticed in Brunswick in the 1950's as residents noticed a salty taste to the city-supplied water. By the early 1960's, a small plume of water from the Upper Floridan aquifer having high chloride concentration was mapped. Presently, water from the Upper Floridan aquifer in two small areas in Brunswick has a chloride concentration greater than 2,000 milligrams per liter, and in an area of more than 5 square miles within the city, the water has a chloride concentration greater than 250 milligrams per liter—the recommended limit set for drinking water by the U.S. Environmental Protection Agency (1976). Development of the Upper Floridan aquifer regionally and in the Brunswick area had lowered the pressure in both the Lower and the Upper Floridan aquifers and allowed the intrusion.

Saltwater, naturally occurring in the Fernandina permeable zone at a depth of about 2,400 feet, has moved upward and intruded the upper part of the Lower Floridan aquifer and the Upper Floridan aquifer. The intrusion is laterally isolated, occurring as leakage of water moving upward through nearly vertical zones of preferential permeability that have breached the confining units. The conduits that permit intrusion may be solution-enlarged joints, fractures, or faults, or possibly extremely narrow, straight-sided collapse features. Although saltwater is moving upward from depth, upconing below the area's well fields is not occurring; the known locations of

intrusion do not overlie the cones of depression caused by local pumping. Once in the Upper Floridan aquifer, diluted saltwater moves laterally downgradient toward pumping centers (Krause and Randolph, 1989).

Saltwater intrusion also is occurring locally in northeastern Florida. The cause and effects of this intrusion probably are the same as at Brunswick, but the contamination is not as severe.

GROUND-WATER DEVELOPMENT CONSTRAINTS

Seawater encroachment and saltwater intrusion have caused water-resource managers to limit additional development of the Floridan aquifer system. The goal of management is to minimize the problem. To accomplish this, water-resource managers in Georgia will not permit additional withdrawal from the Floridan aquifer system if that withdrawal would cause any decline in water level in the Upper Floridan aquifer at the known location of seawater encroachment on the north end of Hilton Head Island, S.C., or at known locations of vertical saltwater intrusion in Brunswick (Garza and Krause, 1996). In South Carolina, water-resource managers have mandated that ground-water withdrawal from the Upper Floridan aquifer on Hilton Head Island be reduced from about 13 to 9.5 million gallons per day.

The USGS has developed several ground-water flow models to simulate scenarios of various hypothetical or planned pumping patterns to aid water-resource managers in their effort. Results of digital modeling of ground-water flow in the Floridan aquifer system indicate little potential for safely withdrawing additional water from the aquifer system, under those constraints imposed by the States. In areas where ground water provides the only water-supply source, several options were evaluated using computer simulation for redistributing present pumpage so that small quantities of additional ground water could be withdrawn without causing further water-level decline and consequent seawater encroachment and saltwater intrusion.

SUMMARY

Current use and future demands for water in the coastal area of Georgia and adjacent parts of South Carolina and Florida affect all three States. Water withdrawal from the Floridan aquifer system—an extremely permeable, carbonate water-bearing sequence—has resulted in substantial water-level declines and subsequent encroachment of seawater into the aquifer at the northern end of Hilton Head Island, South Carolina; and in saltwater intrusion of the aquifer in Brunswick, Georgia, and near Jacksonville, Florida. Although the mechanisms vary by which encroachment and intrusion occur, extensive data and analysis, including results from several computer models, support similar hypotheses as to the cause. The hypotheses tend to support the causal relation between ground-water withdrawal from the Floridan aquifer system, which totals about 320 million gallons per day, and consequent ground-water level decline, indicating a reduction in hydrostatic pressure. Pressure in the freshwater part of the Floridan aquifer system had been sufficient to maintain equilibrium with the denser, naturally occurring saltwater in the aquifer or offshore prior to development of the Floridan. Presently, however, reduced aquifer pressure is allowing saltwater to enter the freshwater part of the system.

Water-resource managers in the three States strive to minimize further contamination of the Floridan aquifer system, realizing that additional decreases in hydrostatic pressure at the locations of encroachment and intrusion should be avoided.

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