SALTWATER CONTAMINATION IN THE UPPER FLORIDAN AQUIFER AT BRUNSWICK, GEORGIA

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Abstract. A map and cross section showing the potentiometric surface of the Upper Floridan aquifer, the ground-water flow field, and a plume of saltwater underlying downtown Brunswick, Georgia, depict the ground-water flow system and indicate the response to pumpage for industrial and municipal water use. In 1997, pumpage from the Upper Floridan aquifer in Glynn County, Georgia, the primary source of water supply, was about 65 million gallons per day. In 1998, near centers of pumping in north Brunswick, ground-water levels in the aquifer had declined more than 60 feet from estimated levels prior to the onset of pumpage in the late 1800's, and a cone of depression in the potentiometric surface extended to the Atlantic coast, where ground-water flow had reversed from seaward to landward. Saltwater, which began entering the aquifer in the 1950's in south Brunswick and other locations—apparently from deeper, saline water-bearing zones—has migrated laterally over a 2.5-square-mile area toward the pumping centers. In 1998, the maximum chloride concentration in samples from the aquifer in the Brunswick area was 2,590 milligrams per liter.

INTRODUCTION

The Floridan aquifer system is divided into the Upper Floridan and Lower Floridan aquifers; both are in highly permeable, carbonate sediments ranging in age from Late Cretaceous to Oligocene. In southeast Georgia, the Upper Floridan aquifer is separated into the upper and lower water-bearing zones (Wait and Gregg, 1973) by a low-permeability semiconfining unit. The lower part of the Lower Floridan aquifer includes the Fernandina permeable zone, which contains saline water in the Brunswick area (chloride concentration ranging from about 15,000 to 33,000 milligrams per liter (mg/L)). More detailed descriptions of the geology and hydrogeology of the Floridan aquifer system in southeast Georgia are given in Miller (1986) and Krause and Randolph (1989), and some of the following discussion is based on pumpage rates, water-level and chloride-concentration data, and other observations in Maslia and Prowell (1990).

GROUND-WATER FLOW SYSTEM

Before water was withdrawn from the Floridan aquifer system, the confined parts of the system in coastal Georgia probably were in equilibrium. Recharge from precipitation west-northwest of Brunswick was balanced by discharge to the Atlantic Ocean. In the Glynn County area, ground-water flow was probably very slow and uniformly eastward toward the coast.

By 1942-43, in response to long-term ground-water pumpage (about 40 million gallons per day (Mgal/d) in 1943), small, localized cones of depression had developed in the potentiometric surface of the Upper Floridan aquifer near two pumping centers in north Brunswick, where water levels had declined about 30 ft from pre-development conditions. One pumping center in northeast Brunswick includes municipal water-supply wells and production wells of a chemical-manufacturing plant; the other pumping center in northwest Brunswick includes production wells of a pulp and paper mill and a chemical-manufacturing plant (non-operational since 1994). Away from pumping centers, ground-water flow in the Glynn County area remained very slow and seaward.

Increases in withdrawal at Brunswick between 1943 and 1966 (to about 75 Mgal/d) caused the two small cones of depression to coalesce into a single broad, deep depression that includes the two small cones at the pumping centers. Based on the configuration of the regional potentiometric surface of the Upper Floridan aquifer, in 1966 nearly all ground water entering Glynn County through the aquifer was being withdrawn in northern Brunswick, and the water level had declined an additional 45 feet (ft) near one of the pumping centers (Gregg and Zimmerman, 1974). Also, along the coast, seaward flow of water in the aquifer had reversed direction to landward toward the pumping centers in north Brunswick.

Since 1966, the configuration of the potentiometric surface has remained generally the same, although total withdrawal in the Brunswick area has fluctuated moderately. The depth and steepness of the broad, deep depression vary depending on total pumpage, and the relative size of the two small cones is not constant. Pumpage has caused ground-water level declines in the Upper Floridan aquifer ranging from about 20 ft in southernmost Glynn County to as much as 80 ft near pumping centers in north Brunswick. Pumpage from the Upper Floridan aquifer in Glynn County was about 65 Mgal/d in 1997 (Fanning, 1999). Based on water levels measured in May 1998, the central part of the broad, deep depression in the potentiometric surface of the Upper Floridan aquifer, including the two small cones, is shown in figure 1A.

Water levels in wells that are open only to the lower water-bearing zone of the Upper Floridan aquifer near point *B* on section *A–B–C* are consistently about 5 to10 ft higher than water levels in nearby wells that are open only to the upper water-bearing zone (fig. 1B). The semiconfining unit between the upper and lower water-bearing zones apparently prevents equilibration of water levels between the two zones in this area. Conversely, wells open only to the upper or lower water-bearing zone underlying downtown Brunswick, near point *A*, less than two miles southward, have similar water levels (differing by less than 2 ft; fig. 1B), suggesting the zones may be more hydraulically connected near point *A* than near point *B*.

SALTWATER CONTAMINATION

In the early 1940's, water containing elevated chloride concentration (greater than 50 mg/L) was first detected in the Upper Floridan aquifer in downtown Brunswick (Warren, 1944) between point *A* and Hanover Park (fig. 1A). Although initially isolated, saltwater in the aquifer began to migrate laterally by the 1960's; and by the mid 1970's, a plume of high-chloride water in the Upper Floridan aquifer had migrated toward pumping centers in north Brunswick. In 1998, the plume extended over about a 2.5-square-mile area.

The source of the elevated-chloride water probably is saline water in the Fernandina permeable zone of the Lower Floridan aquifer (Gill and Mitchell, 1979). Saltwater from this zone apparently has migrated upward into overlying zones in response to pumpage. Although the pathway for this upward movement is not known with certainty, it has been suggested that high-angle fractures could allow the upward migration of saltwater from the Fernandina permeable zone, through the upper part of the Lower Floridan aquifer, and finally into the Upper Floridan aquifer (Krause and Randolph, 1989; Maslia and Prowell, 1990). Saltwater apparently has entered the Upper Floridan aquifer at one or more isolated locations and subsequently has moved laterally within water-bearing zones.

During the late 1950's and early 1960's, the highest chloride concentration in ground water sampled near Hanover Park in downtown Brunswick was 860 mg/L, and the plume of elevated-chloride ground water extended downgradient to a few wells about one mile northward. Wells in the vicinity of pumping centers in north Brunswick were not contaminated.

A network of monitoring wells was established in the Brunswick area in the 1960's, and has been sampled periodically to determine the movement of the plume of saltwater. Most wells within the network are open to the upper and/or lower water-bearing zones of the Upper Floridan aquifer. Accurately delineating the vertical distribution of the saltwater plume within the Upper Floridan aquifer is hampered by mixing of ground water in wells open to both zones and a paucity of wells open only to the lower water-bearing zone. Consequently, depictions of the saltwater plume at Brunswick usually are based solely on chloride concentrations in more numerous samples from the upper water-bearing zone of the Upper Floridan aquifer.

By 1965, a few wells near industrial pumping centers in northwest and northeast Brunswick also had become contaminated (chloride concentration of samples greater than 50 mg/L). The location of these contaminated wells suggested that there could be more than one plume of elevated-chloride ground water and possibly several points where saltwater might be entering the Upper Floridan aquifer. By 1975-76, the multiple plumes had coalesced into a single plume that extended from near Hanover Park in downtown Brunswick almost due northward to a point between the two pumping centers, then divided into two branches, one extending eastward toward the pumping center in northeast Brunswick, and one extending westward toward the pumping center in northwest Brunswick.

From 1976 to the present (May-June 1998) (fig. 1A), the plume has maintained the same general areal distribution, originating in downtown Brunswick, extending downgradient, initially northward, and eventually dividing into an eastern and a western branch. Chloride concentrations have increased gradually within the plume during this period (reaching a maximum of 2,590 mg/L in 1998), but the shape of the plume has remained relatively stable because

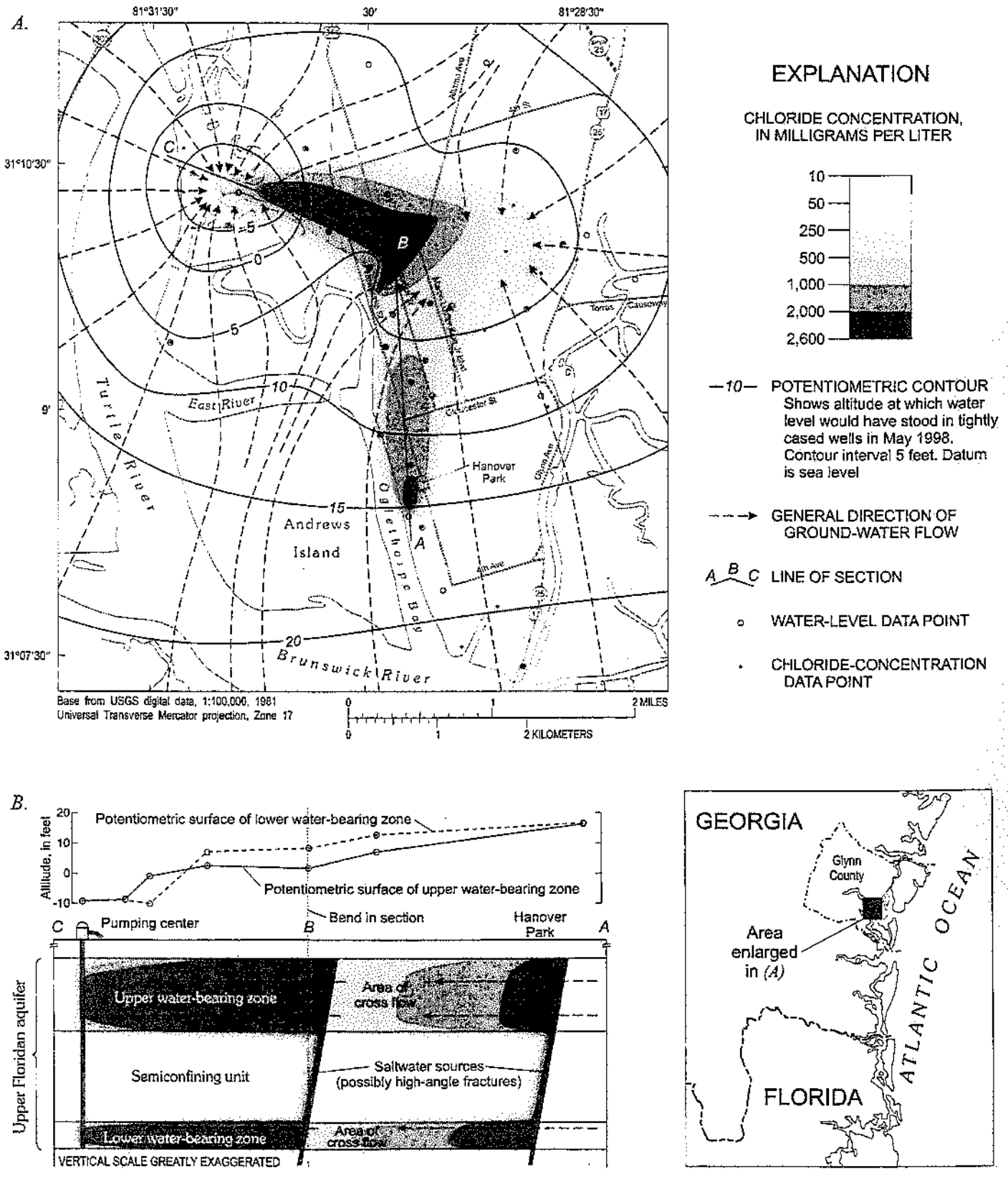

Figure 1. Potentiometric surface, ground-water flow directions, and chloride concentration for the Upper Floridan aquifer at Brunswick, Georgia, May–June 1998; *(A)* plan view of upper water-bearing zone, *(B)* conceptual model of section *A–B–C* from downtown Brunswick to pumping wells in northwest Brunswick.

ground-water flow directions have not substantially changed—saltwater entering the aquifer is withdrawn at pumping centers in north Brunswick.

A conceptual model of the saltwater distribution in both the upper and lower water-bearing zones of the Upper Floridan aquifer across section *A–B–C* is shown in figure 1(B). Decreasing chloride concentrations from point *A* to point *B* probably are due to the eastward flow of uncontaminated ground water across the northern part of plane *A–B*, causing part of the plume to move eastward toward the pumping center in northeast Brunswick (fig. 1A,B). A second source of saltwater near point *B* probably accounts for the high chloride concentrations from near point *B* to the pumping center near point *C* in northeast Brunswick. Earlier maps of the saltwater plume indicate there may be another source of saltwater in the Upper Floridan aquifer near the pumping center in northeast Brunswick.

SUMMARY

Long-term trends in the ground-water flow system in the Upper Floridan aquifer in the Glynn County and Brunswick, Georgia area, include the slow development of two small cones of depression centered in north Brunswick; the eventual coalescence of the two cones, and the deepening and broadening of the resulting depression in response to increased ground-water pumpage; and reversal of ground-water flow from seaward to landward along the coast of Glynn County. Water-level differences in wells open only to the upper or lower water-bearing zones of the Upper Floridan aquifer at Brunswick indicate that the semiconfining unit separating the two zones is more effective in some areas than others. A chloride-concentration map illustrates the downgradient migration of saltwater in the Upper Floridan aquifer from a source near Hanover Park in downtown Brunswick, initially northward, then dividing into an eastward and a westward branch toward pumping centers in northeast and northwest Brunswick. One or more other sources in an area between the pumping centers probably also contributes saltwater to the Upper Floridan aquifer. A thorough understanding of the many complexities of the ground-water flow system in the Upper Floridan aquifer and other parts of the Floridan aquifer system in the area is needed for informed management and protection of the resource.

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