SALTWATER INTRUSION IN THE FLORIDAN AQUIFER SYSTEM, NORTHEASTERN FLORIDA

Rick M. Spechler[1] and G. G. Phelps[2]

AUTHORS: [1,2] Hydrologist, U.S. Geological Survey, 224 West Central Parkway, Suite 1006, Altamonte Springs, Florida 32714
REFERENCE: *Proceedings of the 1997 Georgia Water Resources Conference*, held March 20 through 22, 1997, at the University of Georgia, Kathryn J. Hatcher, Editor, Carl Vinson Institute of Government, The University of Georgia, Athens, Georgia.

Abstract. Saltwater intrusion is a potential threat to the quality of ground water in northeastern Florida and southeastern Georgia. Elevated chloride concentrations have been observed in wells tapping the Upper Floridan and the upper zone of the Lower Floridan aquifers. In Duval County, Florida, increased chloride concentrations in water from wells along the coast and up to 14 miles inland indicate that saline water is gradually intruding into the freshwater zones of the Floridan aquifer system. Several mechanisms may explain this intrusion of saline water and the consequent increase in concentrations of chloride in northeastern Florida. The most plausible explanation for the movement of higher chloride water into the freshwater zones of the Floridan aquifer system is the upward movement of saline water along joints, fractures, collapse features, faults, or other structural anomalies. These features create conduits of relatively high vertical conductivity, providing a hydraulic connection between freshwater zones and deeper, more saline zones. After saline water reaches the freshwater zones, it can then move laterally through the porous aquifer matrix or along horizontal fractures or solution zones.

INTRODUCTION

The Floridan aquifer system is the major source of water supply in northeastern Florida (Figure 1). In 1965, ground-water withdrawals in northeastern Florida totaled 183 million gallons per day. In 1990, ground-water withdrawals totaled 247 million gallons per day, of which 90 percent was withdrawn from the Floridan aquifer system for public, industrial, domestic, and agricultural use (Marella, 1992). The potential effects of increased population growth, industrial expansion, and agricultural irrigation have led to concerns about future availability and quality of the ground-water resources.

The potentiometric surface of the Floridan aquifer system in northeastern Florida has declined at a rate of about one-third to one-half foot per year since the 1940's as a result of increased pumping. Associated with this decline in the potentiometric surface has been an increased potential for saline water intrusion into the freshwater zones of the Floridan aquifer system. Gradual but continual increases in the chloride concentrations in water from the aquifer system have been observed in several inland and coastal areas in Duval County since the 1960's. The potential for saline water intrusion is expected to increase as population growth and potentiometric surface declines continue in northeastern Florida.

HYDROGEOLOGIC FRAMEWORK

Northeastern Florida is underlain by a thick sequence of marine sedimentary rocks that overlie a basement complex of metamorphic strata. The primary water-bearing sediments are composed of limestone, dolomite, shell, clay, and sand, and range in age from late Paleocene to Holocene. Descriptions of major stratigraphic units and corresponding hydrogeologic units are given in figure 2.

The principal water-bearing units are the surficial and Floridan aquifer systems. The two aquifer systems are separated by the clays, silts, and sands of the intermediate confining unit, which includes most of the Hawthorn Formation. The intermediate confining unit contains beds of lower permeability that confine the water in the Upper Floridan aquifer

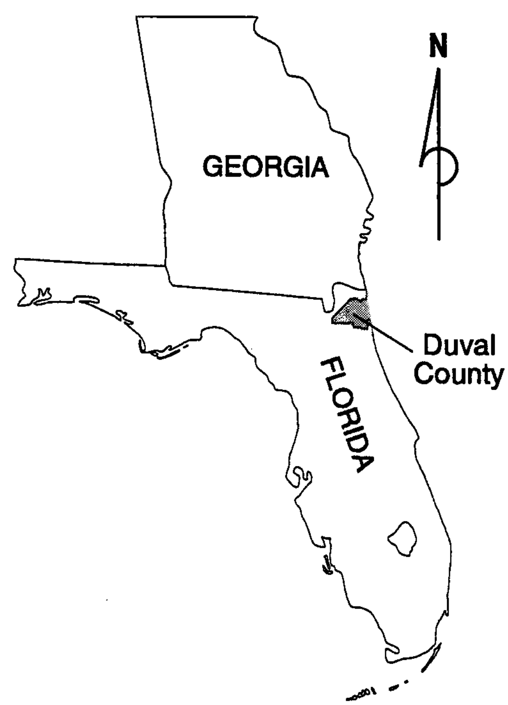

Figure 1. Location of Duval County.

Series	Stratigraphic unit		Lithology	Hydrogeologic unit			Hydrologic properties
Holocene to Upper Miocene	Undifferentiated surficial deposits		Discontinuous sand, clay, shell beds, and limestone	Surficial aquifer system			Sand, shell, limestone, and coquina deposits provide local water supplies.
Miocene	Hawthorn Formation		Interbedded phosphatic sand, clay, limestone, and dolomite	Intermediate confining unit			Sand, shell, and carbonate deposits provide limited local water supplies. Low permeability clays serve as the principal confining beds for the Floridan aquifer system below.
Eocene	Upper	Ocala Limestone	Massive fossiliferous chalky to granular marine limestone	Floridan aquifer system	Upper Floridan aquifer		Principal source of ground water. High permeability overall. Water from some wells shows increasing salinity.
Eocene	Middle	Avon Park Formation	Alternating beds of massive granular and chalky limestone, and dense dolomite	Floridan aquifer system	Middle semiconfining unit		Low permeability limestone and dolomite.
Eocene	Middle	Avon Park Formation	Alternating beds of massive granular and chalky limestone, and dense dolomite	Floridan aquifer system	Lower Floridan aquifer	Upper zone	Principal source of ground water. Water from some wells shows increasing salinity.
Eocene	Lower	Oldsmar Formation		Floridan aquifer system	Lower Floridan aquifer	Semiconfining unit	Low permeability limestone and dolomite.
Eocene	Lower	Oldsmar Formation		Floridan aquifer system	Lower Floridan aquifer	Fernandina permeable zone	High permeability; salinity increases with depth.
Paleocene	Cedar Keys Formation		Uppermost appearance of evaporites; dense limestone	Sub-Floridan confining unit			Low permeability; contains highly saline water.

Figure 2. Generalized geology and hydrogeology of northeastern Florida (modified from Spechler, 1994).

system. The Floridan aquifer system has three major water-bearing zones—the Upper Floridan aquifer, the upper zone of the Lower Floridan aquifer, and the Fernandina permeable zone of the Lower Floridan aquifer, all separated by less-permeable semiconfining units (Brown, 1984).

MECHANISMS OF INTRUSION

Several possible mechanisms could explain the intrusion of saline ground water and the consequent increases in chloride concentrations in ground water in some areas of northeastern Florida. They are: 1) the movement of unflushed pockets of relict seawater within the Floridan aquifer system; 2) lateral movement of the freshwater-saltwater interface off the northeastern coast of Florida; 3) simple regional upconing of saltwater from deeper zones of saline water below pumped wells and; 4) upward leakage from deeper, saline water-bearing zones through semiconfining units that are thin, or are breached by joints, fractures, collapse features, or other structural anomalies.

Geophysical logs of wells in Duval County that penetrate the Upper Floridan aquifer and the upper zone of the Lower Floridan aquifer were used to improve the understanding of the relation between the hydrogeology of the aquifer system and the distribution of saline water. Geophysical log types included caliper, natural gamma, electric, current meter, heat-pulse flowmeter, sonic televiewer, and static and flowing fluid temperature and resistivity.

In general, pockets of unflushed relict sea water are found in strata of relatively low permeability. Geophysical logs of many wells in Duval County indicate, however, that fracture flow zones are the source of saline water to the well. This indicates that unflushed relict seawater is a minor source of saline water in the study area.

Lateral encroachment of recent sea water is an unlikely explanation for the increase in chloride concentrations in the Floridan aquifer system in Duval County. If seawater were moving laterally through the Upper Floridan aquifer from outcrops in the Atlantic Ocean, the saltwater would first be detected in wells nearest the coast. However, many coastal wells have chloride concentrations less than 30 mg/L, while some inland wells have chloride concentrations exceeding 250 mg/L.

Data from geophysical logging indicates that simple regional upconing of saline water apparently is not occurring in Duval County. If upconing were occurring, elevated chloride concentrations in water would typically coincide with cones of depression caused by pumping. Also, chloride concentrations would be expected to increase consistently with depth. However, fluid resistivity logs and chloride samples collected from several wells with elevated chloride concentrations indicate alternating zones of fresh and saline water.

Because of the areal and vertical variability of chloride concentrations, the most plausible mechanism for the movement of saline water into the freshwater zones of the Floridan aquifer system is the upward movement of saline water along discrete geologic features combined with horizontal movement in fracture or solution flow zones (Figure 3). Marine seismic reflection profiles show that the Continental shelf off the northeastern coast of Florida is underlain by solution-deformed limestone of Late Cretaceous to Eocene age (Meisburger and Field, 1976; Popenoe and others, 1984). Dissolution and collapse features are widely scattered throughout the area and are expressed as sinkholes that presently breach the sea floor, sinkholes that breached the sea floor in the past and are now filled with sand; and collapse structures that originated deep within the geologic section deforming the overlying units (Popenoe and others, 1984). The deep dissolution-collapse features are believed to originate in the Upper Cretaceous and Paleocene rocks (Popenoe and others, 1984). Seismic-reflection investigations along the St. Johns River in northeastern Florida by Snyder and others (1989), by the USGS in 1989 (Spechler, 1994), by North Carolina State University in 1990, and in a joint effort between the USGS and North Carolina State University in 1994 also revealed a number of buried collapse features and other karstic features similar to those observed by Meisburger and Field (1976), and Popenoe and others (1984). These features can create zones of relatively high vertical hydraulic conductivity through rocks of otherwise low vertical hydraulic conductivity, thereby providing a hydraulic connection between freshwater zones and deeper saline zones (Figure 3).

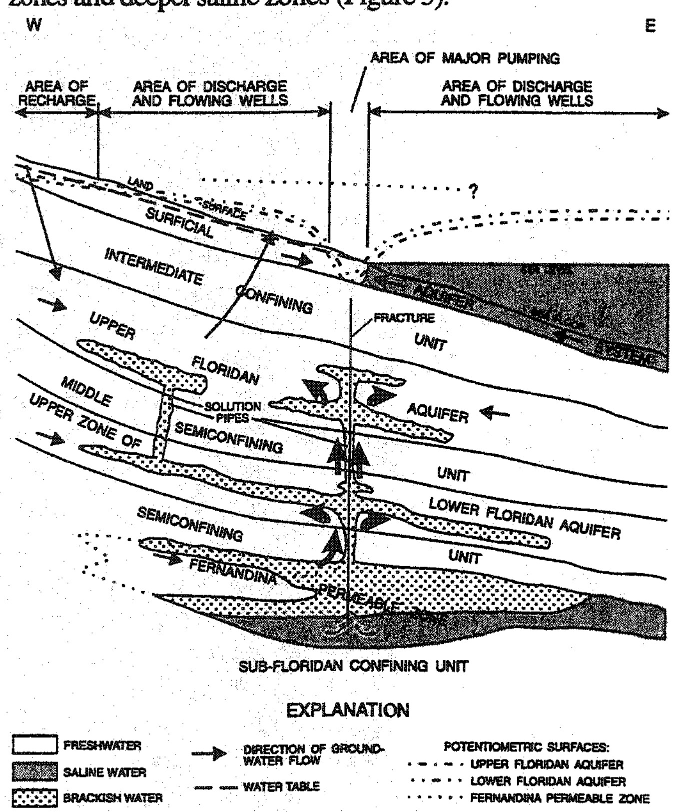

Figure 3. Simplified section of the Floridan aquifer system. (Modified from Spechler, 1994).

CONCLUSION

The areal and vertical variability of chloride concentrations indicates that structural anomalies probably are responsible for the distribution of increased chloride concentrations in the Floridan aquifer system. These features can create zones of relatively high vertical hydraulic conductivity, thereby providing a hydraulic connection between freshwater zones and deeper, more saline zones. Decreasing heads caused by pumping from the shallower freshwater zones of the aquifer can result in an increased potential for upward movement of saline water through nearly vertical zones of preferential permeability. After saline water reaches the freshwater zones, it moves laterally through the porous matrix of the aquifer or along horizontal fractures or solution zones.

SELECTED REFERENCES

Brown, D.B., 1984. Impact of development on availability and quality of ground water in eastern Nassau County, Florida, and southeastern Camden County, Georgia: U.S. Geological Survey Water-Resources Investigations Report 83-4190, 113 p.

Marella, R.L., 1992. Water withdrawals, use, and trends in Florida, 1990: U.S. Geological Survey Water-Resources Investigations Report 92-4140.

Meisburger, E.P. and Field, M.E., 1976. Neogene sediments of Atlantic inner continental shelf off northern Florida: American Association of Petroleum Geologists, v. 60, no. 11, p. 2019-2037.

Phelps, G.G. and Spechler, R.M., 1997. The relation between hydrogeology and water quality of the Lower Floridan aquifer in Duval County, Florida and implications for monitoring movement of saline water: U.S. Geological Survey Water-Resources Investigations Report 96-4242.

Popenoe, Peter, Kohout, F.A., and Manheim, F.T., 1984. Seismic-reflection studies of sinkholes and limestone dissolution features on the northeastern Florida shelf, *in* Proceedings of First Multidisciplinary Conference on Sinkholes: Orlando, Fla., October 15-17, 1984, p. 43-57.

Snyder, S.W., Evans, M.E., Hine, A.C. and Compton, J.S., 1989. Seismic expression of solution collapse features from the Florida Platform: Third Multidisciplinary Conference on Sinkholes, St. Petersburg Beach, Florida, p. 281-297.

Spechler, R.M., 1994. Saltwater intrusion and the quality of water in the Floridan aquifer system, northeastern Florida: U.S. Geological Survey Water-Resources Investigations Report 92-4174, 76 p.