
# GROUND-WATER RESOURCES FOR THE FUTURE

# Atlantic Coastal Zone

Ground water is among the Nation's most important natural resources. It provides drinking water to urban and rural communities, supports irrigation and industry, sustains the flow of streams and rivers, and maintains riparian and wetland ecosystems. In many areas of the Nation, the future sustainability of ground-water resources is at risk from overuse and contamination. Because ground-water systems typically respond slowly to human actions, a long-term perspective is needed to manage this valuable resource. This publication is one in a series of fact sheets that describe ground-water-resource issues across the United States, as well as some of the activities of the U.S. Geological Survey that provide information to help others develop, manage, and protect ground-water resources in a sustainable manner.

Ground-water resources along the Atlantic coastal zone of the United States are vulnerable to saltwater intrusion and to contamination by nutrients. Saltwater intrusion, the movement of saline water into freshwater aquifers (fig. 1), is most commonly caused by ground-water pumping near the coast. Nutrient contamination results from many human activities and has caused widespread increases of nitrate in shallow ground water nationwide (U.S. Geological Survey, 1999). High salinity or nutrient concentrations can make ground water unfit for public consumption. Moreover, discharge of nutrient-contaminated ground water to coastal waters can trigger dense algal blooms that result in habitat changes and oxygen depletion, ultimately affecting the structure and function of coastal ecosystems.

This fact sheet reviews some of the issues associated with saltwater intrusion and discharge of nutrient-contaminated ground water along the Atlantic coastal zone. Also described are some of the activities of the U.S. Geological Survey (USGS) that provide scientific information for sustainable management of ground-water resources in this coastal area. Ground-water sustainability is defined as developing and using ground water in a way that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences (Alley and others, 1999).

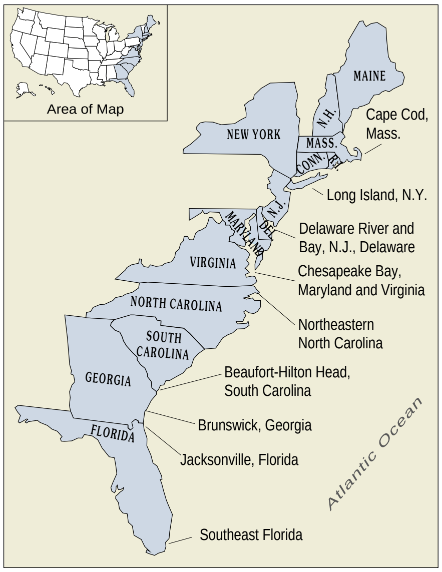


**Figure 1.** Selected areas along the Atlantic coast where saltwater has intruded into freshwater aquifers.

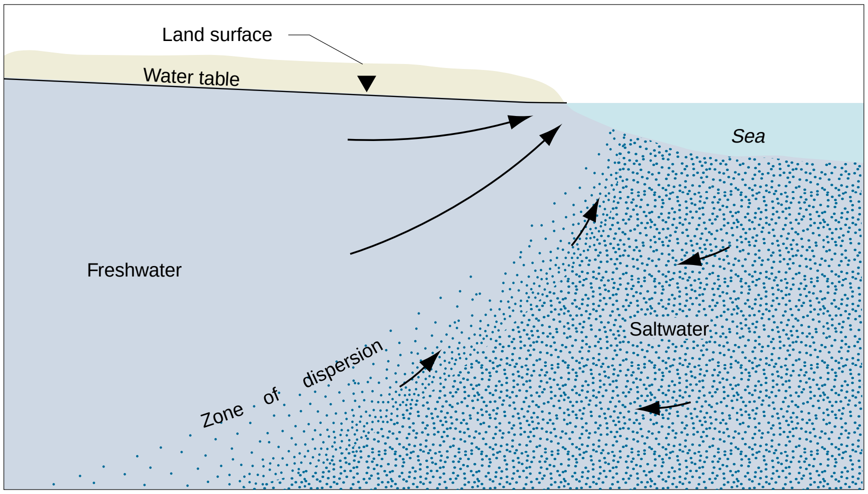


**Figure 2.** Ground-water flow patterns and the zone of dispersion in an idealized coastal aquifer. A circulation of saltwater from the sea to the zone of dispersion and then back to the sea is induced by mixing of freshwater and saltwater in the zone of dispersion. (Modified from Cooper, 1964.)

## Saltwater Intrusion

Freshwater aquifers along the Atlantic coastal zone are among the most productive in the United States, supplying drinking water to an estimated 30 million people from Maine to Florida. These freshwater aquifers are bounded at their seaward margins by saltwater (fig. 2). Because freshwater has a lower concentration of dissolved solids than does saltwater, it is less dense than saltwater and tends to flow on top of surrounding or underlying saltwater.

Under natural conditions, the seaward flow of freshwater prevents saltwater from encroaching coastal

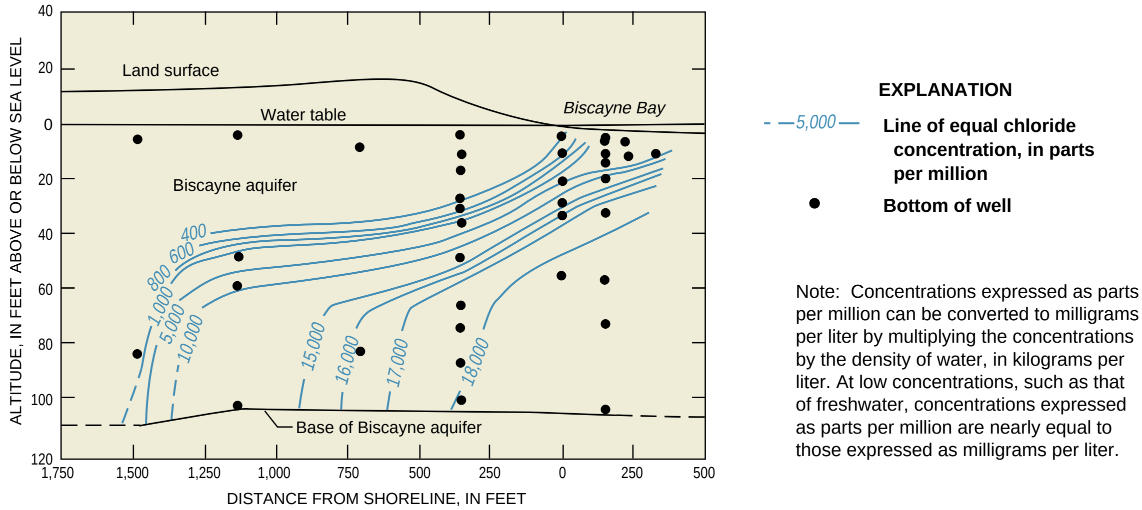


**Figure 3.** The zone of dispersion in the Biscayne aquifer near Miami, Fla. Chloride concentrations in the zone of dispersion range from freshwater containing 16 parts per million to seawater containing 19,000 parts per million. (Modified from Kohout, 1964.)

aquifers, and the boundary between freshwater and saltwater is maintained near the coast or far below land surface. Typically, this boundary is not sharp but rather is a diffuse zone where freshwater and saltwater mix (figs. 2 and 3). The zone can be narrow, such as the approximate 1,500-foot width shown for the Biscayne aquifer in figure 3, or as wide as several miles, such as in parts of the New Jersey Coastal Plain.

The pumping of ground water lowers water levels and can cause saltwater to be drawn toward the areas of stress (figs. 4 and 5). As indicated by the directions of ground-water flow in figures 4 and 5, saltwater contamination can occur by lateral flow of saltwater from the sea or by vertical flow of saltwater from deeper, more saline zones of a ground-water system. Saltwater intrusion reduces fresh ground-water storage and can lead to the abandonment of supply wells when concentrations of dissolved ions exceed drinking-water standards. For example, the concentration of chloride in average seawater is about 19,000 milligrams per liter, whereas the recommended drinking-water limit for chloride is 250 milligrams per liter.

Saltwater intrusion has been documented throughout the Atlantic coastal zone, but the degree of saltwater intrusion varies widely among localities and hydrogeologic settings. In many cases, the area contaminated by saltwater is limited to small parts of the aquifer and has little or no effect on wells pumped for ground-water supply. In other cases, contamination is of regional extent, with substantial effects on ground-water supplies. For example, in Cape May County, N.J., more than 120 supply wells have been abandoned since 1940 because of saltwater contamination (Lacombe and Carleton, 1992).

Although most saltwater intrusion along the Atlantic coast has been caused by pumping, lowering of the water table by drainage canals has led to saltwater encroachment in a few locations, notably southeast Florida. Drainage canals not only lower the water table but can convey saltwater inland when the canals lack salinity-control structures. Salinity-control structures have been effective in slowing or reversing saltwater encroachment along canals in southeast Florida.

Many States and communities along the Atlantic coast are taking action to manage and prevent saltwater intrusion so supplies can be maintained in the future. These actions can be grouped into three general categories: scientific monitoring and assessment, engineering techniques, and regulatory actions. A traditional engineering approach to

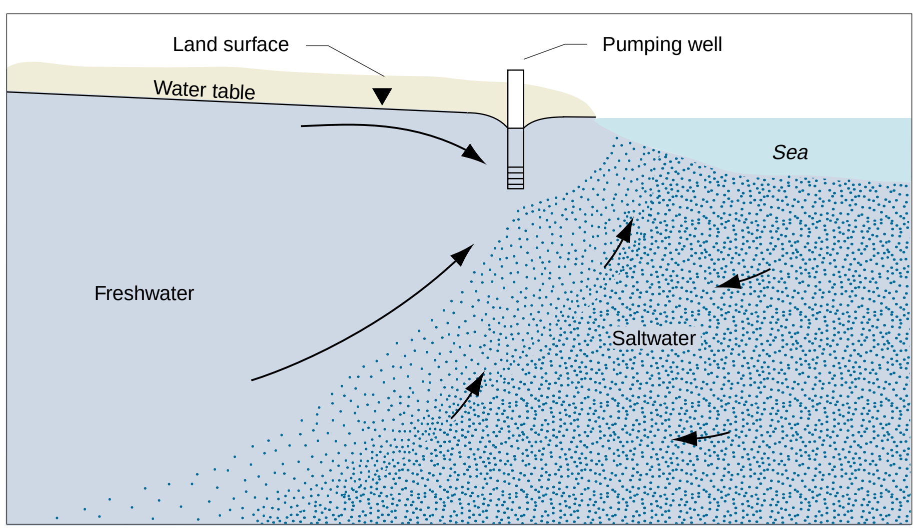


**Figure 4.** Ground-water flow patterns near a pumping well in an idealized coastal aquifer. Ground-water levels around the well are lowered in response to pumping and the saltwater zone moves toward the well.

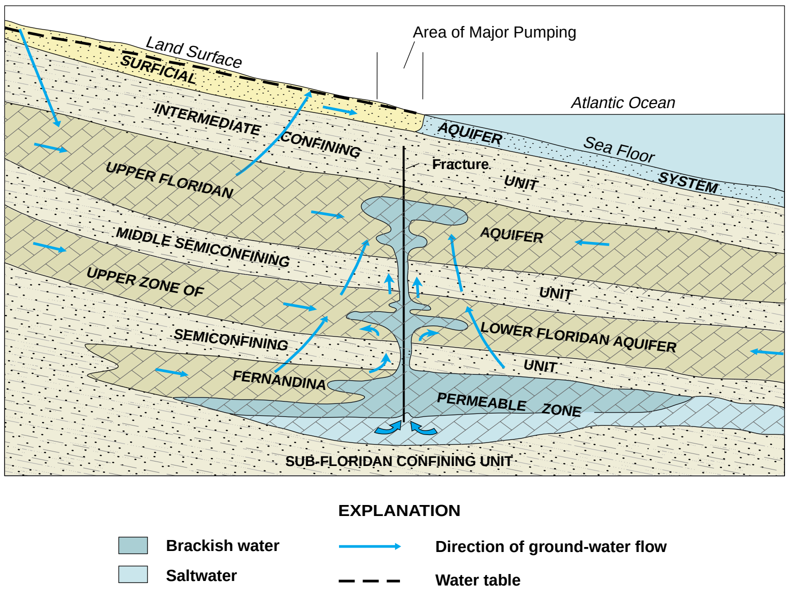


**Figure 5.** Simplified model of saltwater leakage along fractures and other structural deformities in the Floridan aquifer system in northeastern Florida and southeastern Georgia. The fractures and other structural deformities provide a conduit between freshwater zones and deeper, more saline zones. Saltwater flows upward through the nearly vertical zones in response to ground-water pumping in the uppermost aquifers. (Modified from Krause and Randolph, 1989; and Spechler, 1994.)

reversing saltwater intrusion has been to decrease or discontinue pumping from coastal wells. In such cases, alternative water sources are sought for coastal communities. In New Jersey, for example, the Manasquan Reservoir was built in 1989 as a supplemental water source in response to declining ground-water levels and saltwater intrusion in parts of Middlesex, Monmouth, and Ocean Counties.

As population increases along the Atlantic coastal zone and new freshwater sources become more difficult to obtain, innovative approaches for managing saltwater intrusion are becoming more widespread. Such approaches include artificial-recharge systems, desalination plants, and blending of waters of different quality. Some States along the Atlantic coast also have begun to regulate and restrict withdrawals of coastal ground water or to mandate or encourage water conservation. For example, the State of Georgia has established an Interim Strategy for Managing Saltwater Contamination in the Upper Floridan aquifer that caps ground-water use in the Savannah and Brunswick areas at 1997 rates and encourages water conservation and reduced water use in areas along the Georgia coastline.

## Discharge of Nutrient-Contaminated Ground Water to Coastal Environments

Nutrients are essential for plant and animal growth but in elevated concentrations can degrade water quality. Contamination of coastal ground water by nutrients occurs as a consequence of activities such as wastewater disposal from septic systems, agricultural and urban uses of fertilizer, and agricultural use of manure. Nutrients carried by ground water can be discharged to coastal waters and wetlands or to drinking-water supply wells.

Often, water-quality concerns for coastal ecosystems have focused on surface-water sources of nutrients and other contaminants. Increasingly, however, the importance of ground water as a source of contaminants to coastal environments is becoming evident. To design effective coastal water-quality monitoring networks and to manage and protect coastal environments, information is needed on the relative importance of ground water as a nutrient source compared to other sources. Because ground water moves slowly, the flushing of nutrient-contaminated ground water from an aquifer can take many years, even several decades.

In many coastal ecosystems, the mechanisms and rates of ground-water discharge and nutrient loading are not well understood. Knowing the specific path by which ground water discharges to a coastal ecosystem is important because the natural removal of dissolved nutrients from ground water depends on the sediments and geochemical conditions that the ground water contacts before discharging to the ecosystem. Figure 6 illustrates the variety of ground-water flow paths below a tidal salt marsh in New England.

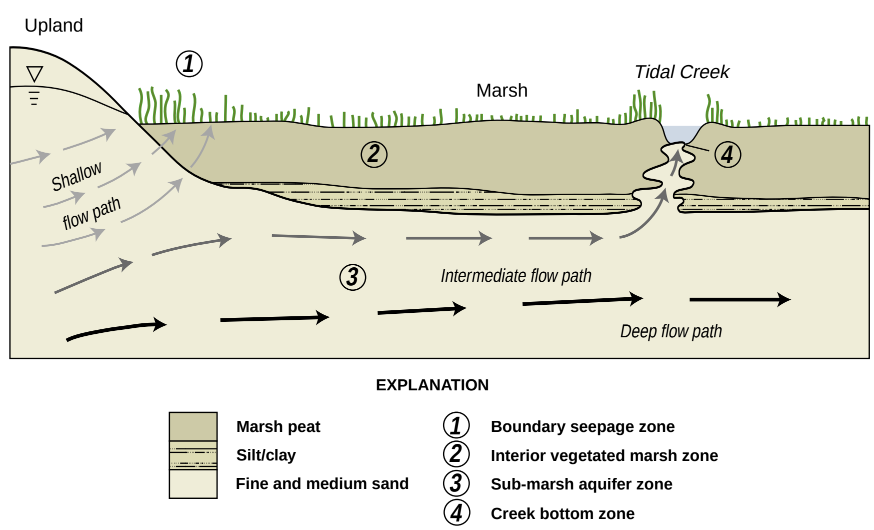


**Figure 6.** Diagram of ground-water flow paths and discharge locations below a tidal salt marsh in New England. Ground-water discharge is concentrated at the boundary between the marsh and upland areas and in the tidal creek. In these two zones, the marsh peat is thinnest and the hydraulic properties of the marsh and aquifer materials are most favorable for ground-water flow. (Modified from Howes and others, 1996.) (Copyright John Wiley & Sons Limited. Reproduced with permission.)

Photograph courtesy of David Wilson, Maryland Coastal Bays Program.

## Activities of the USGS

Through its national, State, and local programs, the USGS provides scientific information to help others develop, manage, and protect ground-water resources in a sustainable manner. Along the Atlantic coastal zone, the USGS uses geophysical, geochemical, and ground-water-level measurements to define the boundary between freshwater and saltwater and to monitor saltwater intrusion. Monitoring networks of this type have been established by the USGS in collaboration with State and local agencies in areas of New Jersey, Maryland, Delaware, Virginia, South Carolina, Georgia, and Florida.

USGS scientists also are working to better understand the geologic, geochemical, and hydrologic controls on saltwater intrusion and on ground-water discharge and nutrient loading to coastal environments:

- In Virginia, USGS scientists are working with others to understand how the recently discovered Chesapeake Bay impact crater affects regional ground-water flow paths and ground-water salinity of a large part of the Virginia Coastal Plain (Poag, 1999; Powars and Bruce, 1999).
- Near Savannah, Ga., and Hilton Head Island, S.C., the USGS is conducting a program of offshore drilling to delineate the freshwater/saltwater boundary and is developing computer models to simulate and evaluate saltwater movement in coastal aquifers.
- In several coastal environments from Cape Cod, Mass., to the Everglades in southern Florida, USGS scientists are using field measurements and computer-modeling techniques to map coastal sediments, quantify ground-water discharge rates and nutrient fluxes to coastal waters, and predict the effects of management alternatives on ground-water discharge and nutrient fluxes.

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