Mapping the threat of seawater intrusion in a regional coastal aquifer–aquitard system in the southeastern United States

Anthony M. Foyle · Vernon J. Henry · Clark R. Alexander

Abstract The Upper Floridan aquifer (UFA) beneath the southeastern US Atlantic Coastal Plain and inner continental shelf is a major source of groundwater for coastal Georgia (GA) and South Carolina (SC), where it supplies over 50% of water requirements. Since pumping from the UFA first began at Savannah, GA in the late 1800s, a large (~50 km radius) cone of depression has developed on the aquifer's potentiometric surface. Where a regional Miocene-age aquitard overlying the UFA is thin or absent within this cone, the opportunity exists for seawater to leak downward through the seabed and into the aquifer. Recently completed marine reflection seismic surveys on the Georgia–South Carolina coast identified 11 areas of concern (AOCs) where the UFA is susceptible to seawater intrusion. Results from this project, and from an AOC test-drilling program recently completed, are contributing to a large database of information and models being developed for the UFA by several agencies and academic institutions. The results will provide input necessary for managing groundwater resources and mitigating potential seawater intrusion on the Georgia–South Carolina coast.

Keywords Georgia · Seawater intrusion · South Carolina · Upper Floridan aquifer

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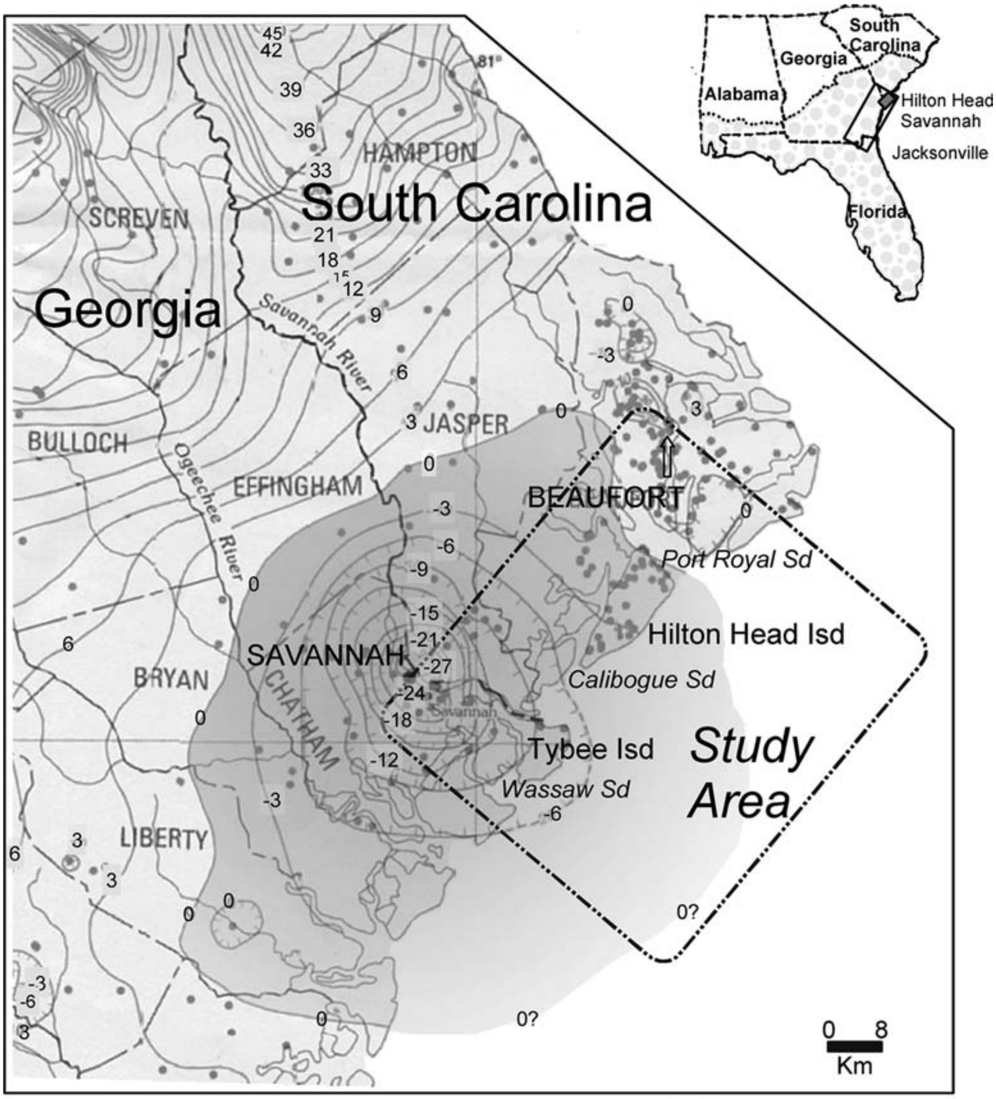
Introduction

In groundwater investigations, geophysics is traditionally used from the well bore to determine well-adjacent formation properties, their contained fluids, and the properties of any associated aquicludes and aquitards. This paper describes the relatively unique application of regional-scale marine seismic reflection surveying to groundwater investigations in the coastal/marine environment. In this paper, reflection seismic data were used to map subsurface depth and topography of the Upper Floridan aquifer (UFA) and map the integrity of the principal overlying Miocene-age aquitard. These data were then used to semi-quantitatively identify sites where seawater may be intruding into the UFA on the Georgia–South Carolina coast.

The Georgia Sound Science Initiative (SSI) is a multi-year (1997–2005) program of state-funded scientific investigations focused on saltwater intrusion problems in the UFA on the Georgia–South Carolina coast that is being administered by the Georgia Department of Natural Resources, Environmental Protection Division (EPD). SSI incorporates groundwater modeling studies, an onshore/offshore test-drilling program, research into seawater intrusion mitigation strategies, identification of alternative water supplies, and geophysical mapping of potential seawater intrusion sites. The geophysics component of the initiative is focused on identifying sites where there is the potential for downward and lateral movement of saline waters from estuaries and shelf areas into the uppermost parts of the UFA. Data from marine seismic reflection surveys described below allowed identification of 11 areas of concern (AOCs) where the UFA is susceptible to seawater intrusion. At each AOC, the aquifer is present at shallow depth, erosion has removed the aquitard, the overlying water column is saline, and the area lies within or adjacent to the Savannah cone of depression. Results from this non-invasive geophysical investigation are contributing to a larger database of information and models being developed under SSI, which will provide input necessary for managing groundwater resources and mitigating potential seawater intrusion in southeast Georgia.

The UFA beneath the southeastern US Atlantic Coastal Plain and inner continental shelf is a major source of groundwater for four coastal states (South Carolina, Georgia, Florida, and Alabama; Fig. 1). It is a particularly important aquifer in coastal Georgia and South Carolina from which 24 coastal counties obtain over 50% of their



Base map modified from Peck and others, 1999

Fig. 1
Location of the study area on the Georgia–South Carolina coast. *Insert map* shows the onshore subcrop map for the Upper Floridan aquifer (UFA), the 24 coastal counties within the Sound Science Initiative (*large box*), and the limits of this marine geophysics study (*small box*). The Savannah cone of depression, highlighted in *gray*, and the associated potentiometric contour patterns, are adapted from Peck and others (1999). The seaward extent of the cone of depression is approximate, and the potentiometric contours are in meters above or below mean sea level (m.s.l.)

water requirements. Previous studies show that most groundwater used for public water supply and industrial needs in coastal GA-SC is supplied from the UFA (Stringfield 1966; Krause and Randolph 1989; Garza and Krause 1997). The aquifer provides approximately 1,300 million l/day of water, a volume that has increased steadily since water was first pumped from the aquifer at Savannah about 115 years ago (Fanning 1999). The progressive increase in groundwater use since the late 1800s has resulted in a large (~50 km radius) cone of depression on the UFA's potentiometric surface that is now centered on Savannah, GA (Peck and others 1999). The cone of depression developed, and continues to persist because pumped groundwater cannot be replaced quickly enough through natural inflow from other parts of the aquifer. The apex of this cone now lies about 30 m below mean sea level (–30 m m.s.l.) and about 40 m below its pre-development elevation at Savannah. In coastal and inner shelf areas where a regional Miocene aquitard overlying the UFA is locally thinned or absent, the depressed potentiometric surface enhances the opportunity for seawater to migrate downward through the seabed and into the UFA. This scenario could potentially lead to contamination of groundwater supplies in the long term (decades to centuries) for a large coastal population approaching 1 million people.

Study area and hydrogeologic setting

The project area covers about 3,600 km^2 of nearshore and estuarine areas between Wassaw Sound, GA, and Port Royal Sound, SC (Fig. 1). Most of the project area lies within the eastern half of the Savannah cone of depression on the UFA, extending seaward from the salt limit for coastal rivers and estuaries to a coast-parallel line approximately 50 km offshore. The Oligocene–Eocene-age UFA consists of semi-consolidated lime marls, limey sands, and consolidated limestone that now underlies the lower coastal plain and continental shelf. In the project area, it lies at depths of –6 to –85 m m.s.l. and ranges from 15 to 60 m in thickness (Hughes and others 1989; Clarke and others 1990; Foyle and others 1999, 2001a, 2001b). It is unconformably overlain by a semi-confining Miocene-age aquitard, which in turn is overlain by generally non-confining Pliocene and Quaternary strata (Fig. 2).

The Miocene-age aquitard overlying the UFA consists mostly of unconsolidated sands, silts, clays, and limestone stringers. The Miocene consists of at least three partly preserved parasequences (Miocene-A, Miocene-B, and Miocene-C in Fig. 2), each shoaling upward from limestone at the base, through clays and silts, to sands at the top. Phosphate lag deposits at the base of each parasequence are inferred to be responsible for the gamma-peaks observed in geophysical logs by earlier workers (Hayes 1979; Clarke and others 1990). While porous and permeable, transmissivities of the aquitard are significantly lower than those of the aquifer and the unit essentially behaves as a "cap rock" for the UFA in the project area. Farther to the south and west on the Georgia coast, thin aquifer horizons are developed within this aquitard and supply water locally to golf clubs and residences. Within the project area, the aquitard can be as much as 50 m thick, but in localized areas it can be thin or absent as a result of two natural processes and two possible anthropogenic processes.

First, in coastal creeks and estuaries on this mesotidal coast (tidal range is ~3 m), tidal currents are of sufficient strength to erode the channel bottoms and cut into or through the aquitard and expose the UFA at the seabed. Some of these tidal-scour holes are as much as 22 m deep. This type of potential seawater intrusion scenario is observed near Beaufort, SC, where the aquifer is shallow and lies on the edge of the Savannah cone of depression (Fig. 3A). Second, during times of lowered Quaternary sea levels, the most recent of which occurred about 18,000 years ago, the Savannah paleoriver and other coastal streams flowed across the exposed continental shelf to paleo-shorelines located 100 to 130 km seaward of where the shoreline is today. At several locations, the Savannah River paleochannels cut down into, and locally through, the aquitard. While the paleochannels have since been filled with post-Miocene silts, sands, and gravels, these younger and less consolidated sediments are not as efficient an aquitard as the Miocene strata (US Army Corps of Engineers 1998). This type of potential seawater intrusion scenario is observed seaward of Hilton Head Island where the aquifer is relatively shallow and lies within the Savannah cone of depression (Fig. 3B).

Third, dredging for navigation purposes is a potential, but still undocumented, cause of seawater intrusion. In the Savannah River, increased dredging over the past several decades has locally removed the uppermost parts of the aquitard (US Army Corps of Engineers 1998), while in the Beaufort River south of Beaufort, SC, dredging during the 1950s recovered material believed to be from the uppermost parts of the UFA (Siple 1960; Hayes 1979). Fourth, mining of Miocene phosphate during the 19th century from rivers just north of Beaufort, SC, also removed probable aquifer material from the river bed (Hughes and others 1989); these areas now lie just outside of the cone of depression. Figure 3 summarizes these scenarios and illustrates that the Miocene aquitard has the greatest probability of being thinnest where the underlying UFA occurs at shallow depth and either (1) modern tidal creeks (or dredged/mined channels) cut down into or through the Miocene (Fig. 3a), or (2) paleochannels incised during glacio-eustatic lowstands of sea level cut down into or through the Miocene (Fig. 3b).

Materials and methods

The principal objective of this geophysical investigation was to identify coastal areas where the Miocene aquitard

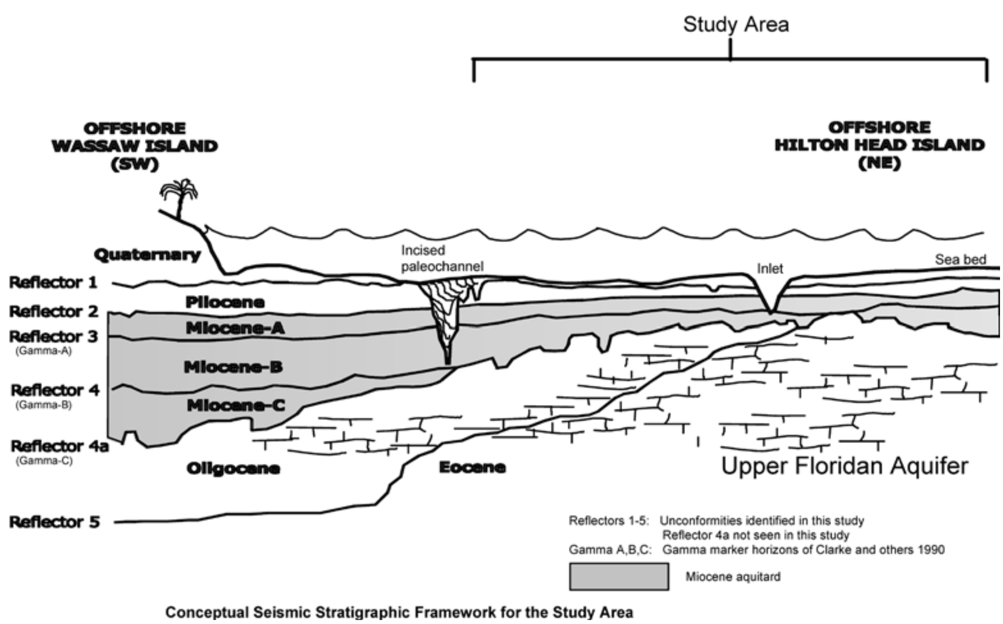


Fig. 2
Schematic illustration of the stratigraphic framework of the UFA, the Miocene aquitard, and the post-Miocene section in northern coastal Georgia and southern coastal South Carolina. Section is oriented approximately parallel to the coast

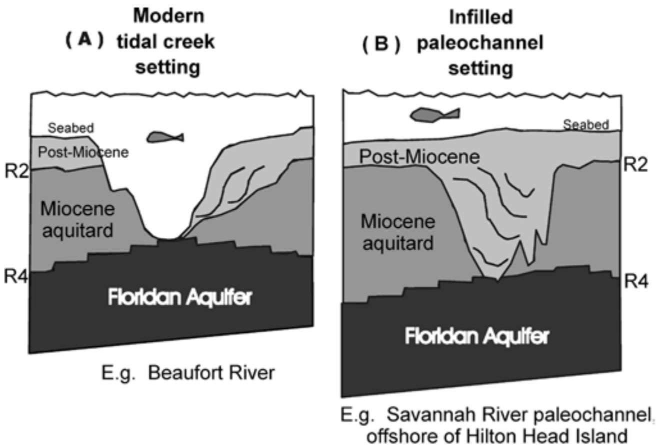


Fig. 3A, B
Schematic illustration of specific scenarios where the Miocene aquitard is thin or absent on the Georgia–South Carolina coast. Note that the aquitard may be absent while the UFA is still separated from the seabed by a relatively thick post-Miocene section. *R2* and *R4* denote seismic reflectors associated with unconformities

overlying the UFA is thin or missing. In areas where the overlying water column is saline (in estuaries and on the inner shelf) and where the potentiometric head on the UFA is negative (within the Savannah cone of depression), this will increase the likelihood of seawater intrusion into the aquifer. This is particularly the case in those areas where the Miocene aquitard is not just thinned, but is totally absent. The primary means of identifying these potential intrusion sites involved the use of marine seismic reflection profiling and seismic sequence stratigraphy. Approximately 1,900 km of sub-bottom, single-channel, seismic reflection data were collected and form the primary dataset (Fig. 4). Data were collected with a state-of-the-art Applied Acoustic Engineering boomer source/receiver system and a Triton Elics International digital acquisition and processing system. For georeferencing, Trimble DGPS and Northstar DGPS differential global positioning systems were used. Surveys were conducted primarily from a 22-m UNOLS vessel (RV *Blue Fin*, Skidaway Institute of Oceanography) at an average survey speed of 7–11 km/h. Seismic data were typically band-pass filtered (generally 750–3,000 Hz) and enhanced with trace stacking and time-variable gain prior to interpretation. For time-to-depth conversions, acoustic velocities of 1,500 and 1,700 m/s were assumed (and confirmed with coring data) for the water and sediment columns, respectively. Standard stratigraphic nomenclature for the southeastern United States (e.g., Miller 1985) and standard methods of

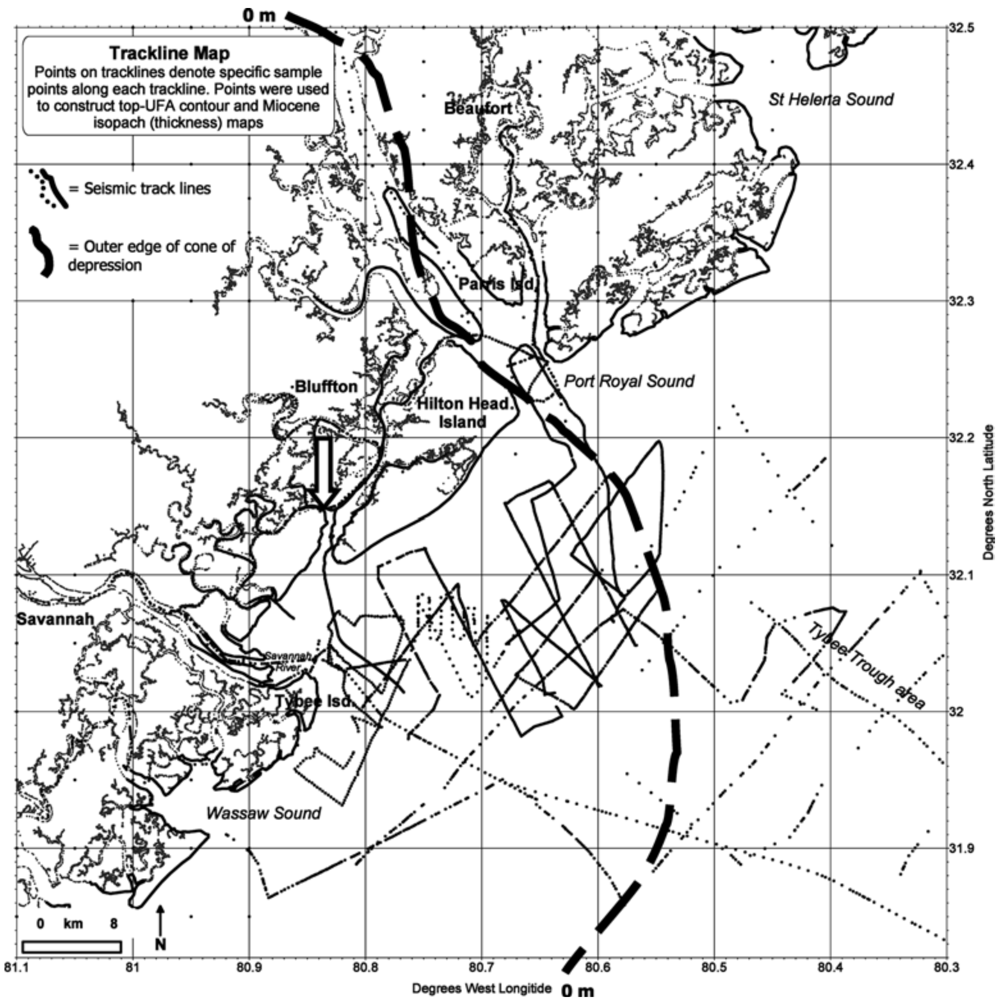


Fig. 4
Locations of seismic-reflection tracklines. Each *dot* denotes a sample point where depths and thicknesses were determined for use in contour and isopach maps. *Arrow* denotes location of the ancestral Savannah River paleochannel section shown in Fig. 5

sequence stratigraphy (Payton 1977; Vail 1987) were used in data interpretation. Seismic reflectors associated with major unconformities were identified at the top of the UFA (generally R4) and at the top of the Miocene aquitard (generally R1 or R2) and were used to map the thickness of the Miocene aquitard and depths to the top of the UFA (Fig. 2). Published borehole lithology-log and gamma-log data were used to ground-truth seismic-stratigraphic interpretations and to provide additional control in areas where seismic coverage was limited. Figure 2 shows a schematic sequence-stratigraphic section for the GA-SC coastal area and how the unconformities identified in marine data from this study correlate with gamma-log-indicated erosional surfaces from onshore wells. Preliminary data from five offshore test-wells drilled by the US Army Corps of Engineers and the US Geological Survey in 2000–2001 further confirm the stratigraphy illustrated in Fig. 4.

Results

Figure 5 shows a good example of the type of digital seismic records acquired during this study. Incised paleochannels, such as this one landward of Hilton Head Island and within the Savannah cone of depression, clearly incise down to the top of the UFA and remove the intervening Miocene aquitard. Complex reflector patterns within the channel fills suggest mixed sand-dominated lithologies, probably deposited within estuary-mouth depositional systems (Foyle and Oertel 1997). Several seismic transects cross this particular paleochannel as it traverses the inner continental shelf and indicate that the thalweg only locally impinges upon the UFA. Impingement occurs primarily at bends in the paleochannel, or at points where paleotributaries join the main channel stem.

Aquifer elevations

Depths to the top of the UFA were mapped by combining onshore well data from previous studies (Hayes 1979; Hughes and others 1989; Clarke and others 1990), and new offshore well data collected by the US Army Corps of Engineers and the US Geological Survey, with coastal and inner shelf seismic data from this study (Fig. 6). Depths to the top of the UFA range from as shallow as –6 m m.s.l. north of Beaufort, SC, to as deep as –85 m m.s.l. offshore and to the southeast of Savannah. The top of the UFA is primarily marked by Seismic Reflector 4 (Fig. 2).

An irregular "karstic" erosional surface characterizes the top of the UFA (Figs. 2 and 6) and local relief can be as much as 6 m over horizontal distances of as little as 100 m (1:17 slope). Onshore in the Beaufort area, sinkholes are developed in the UFA and small apparent sinkholes have been identified in intracoastal data west of Hilton Head Island. Throughout coastal and offshore Georgia, the aquifer everywhere lies at depths of at least –33 m m.s.l. However, on the South Carolina shelf, the aquifer is locally as shallow as –15 m m.s.l. in an area located about 5.5 km offshore and to the southeast of central Hilton Head Island (see Hilton Head high, Fig. 6). This topographic high, previously identified onshore as the Beaufort Arch by Hayes (1979) and Hughes and others (1989), lies within the northeastern quadrant of the Savannah cone of depression. The presence of the Hilton Head high in an area where shelf water depths are at least 6 m indicates that the Miocene aquitard is likely to be significantly thinner than off the axis of this feature. When coupled with the fact that at least two generations of the paleo Savannah River traversed the flanks of this topographic high during Quaternary sea level lowstands (probably 18,000 and 150,000 years ago), the likelihood of the Miocene aquitard being locally absent is enhanced. The delineation of this offshore topographic high early in the fieldwork phase of the project helped focus subsequent survey efforts to better constrain the geometry of thinned Miocene areas

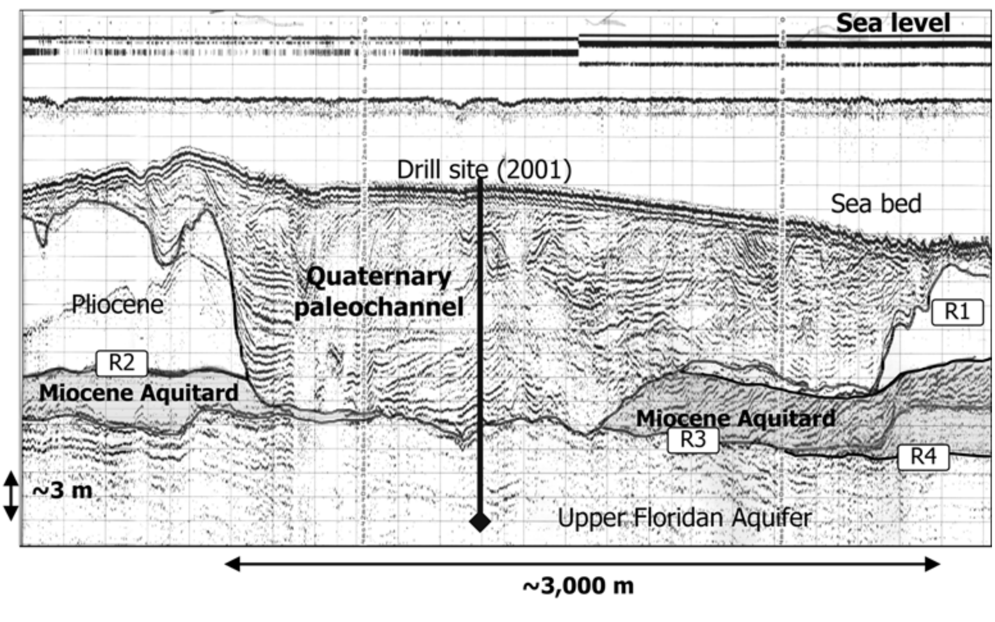


Fig. 5
Interpreted seismic reflection profile crossing an ancestral paleochannel of the Savannah River beneath Calibogue Sound at the south end of Hilton Head Island. The paleochannel is located approximately 15 km north of the modern Savannah River mouth and is inferred to have been incised at least 150,000 years ago. This is one of several seismic profiles crossing AOC 1 (see Table 1). See Fig. 4 for location of this profile

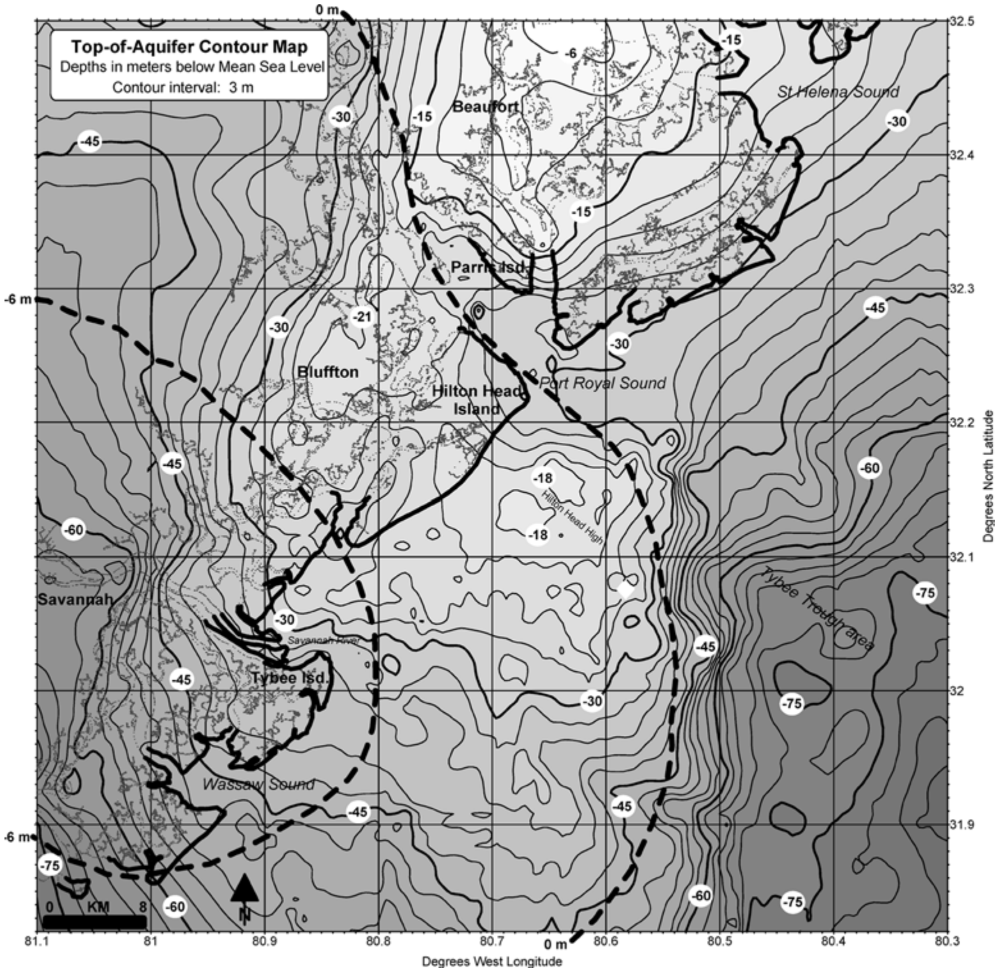


Fig. 6
Contour map showing depths to the top of the UFA in northern coastal Georgia and southern South Carolina. This surface is generally defined by Seismic Reflector 4. *Thick dashed lines* show approximate positions of the –6-m and 0-m m.s.l. potentiometric contours on the UFA derived from Fig. 1

caused by the interaction between shallow UFA topography and deep paleochannel incisions.

Thin-Miocene areas

In the Georgia part of the project area, the Miocene aquitard occurs at depths of –3 to –52 m m.s.l. Seismic data indicate that the Miocene is almost everywhere thicker than 12 m (Fig. 7). The exception to this statement occurs at about ten small localized areas on the lower Savannah River and Navigation Channel just north and northwest of Tybee Island. These localized thin spots (arbitrarily defined as locations where less than 12 m of Miocene are present) mark where buried Quaternary paleochannels cross obliquely beneath the modern-day navigation channel. The principal area of thinned Miocene strata occurs on the Beaufort Arch beneath the South Carolina coast and inner shelf where approximately 1,450 km^2 are underlain by less than 12 m of Miocene. Of this area, approximately 375 km^2 are underlain by less than 6 m of Miocene and approximately 125 km^2 are underlain by less than 3 m of Miocene (Fig. 7). Numerous no-Miocene zones also occur and are described below. Over 50% of the thin-Miocene area (less than 12 m of Miocene present) occurs south and southeast of the Broad River and within the northeastern quadrant of the Savannah cone of depression.

Isopachs in Fig. 7 indirectly show the trend of a (150,000?-year-old) Savannah River paleochannel beneath the inner continental shelf. The narrow, sinuous, thinned-Miocene tract that extends eastward across the shelf from behind Hilton Head Island towards 32.00 N, 80.30 W marks the paleochannel trend. Seaward of AOC 7D (see paragraph below) at 32.07 N, 80.72 W, this older paleochannel is re-occupied by a younger (18,000?-year-old) paleochannel. Landward of AOC 7D, the younger paleochannel diverges towards the west and the modern Savannah River mouth.

No-Miocene areas

Eleven localized sites (AOCs) were identified where the Miocene aquitard is absent. Collectively, these 11 AOCs comprise a total area of about 20 km^2 and delineate where the UFA is inferred to be most susceptible to seawater intrusion. Ten of the 11 no-Miocene areas are within the northeastern quadrant of the Savannah cone of depression. At these ten sites, 3–17 m of the post-Miocene nonconfining unit overlies the aquifer and separates it from the seabed so that seawater is not directly in contact with the top of the aquifer (Table 1). The incised paleochannel, shown in Figs. 3B and 5, is a good example illustrating that the UFA need not necessarily outcrop on the seabed where the Miocene is absent. The 11th and most extensive

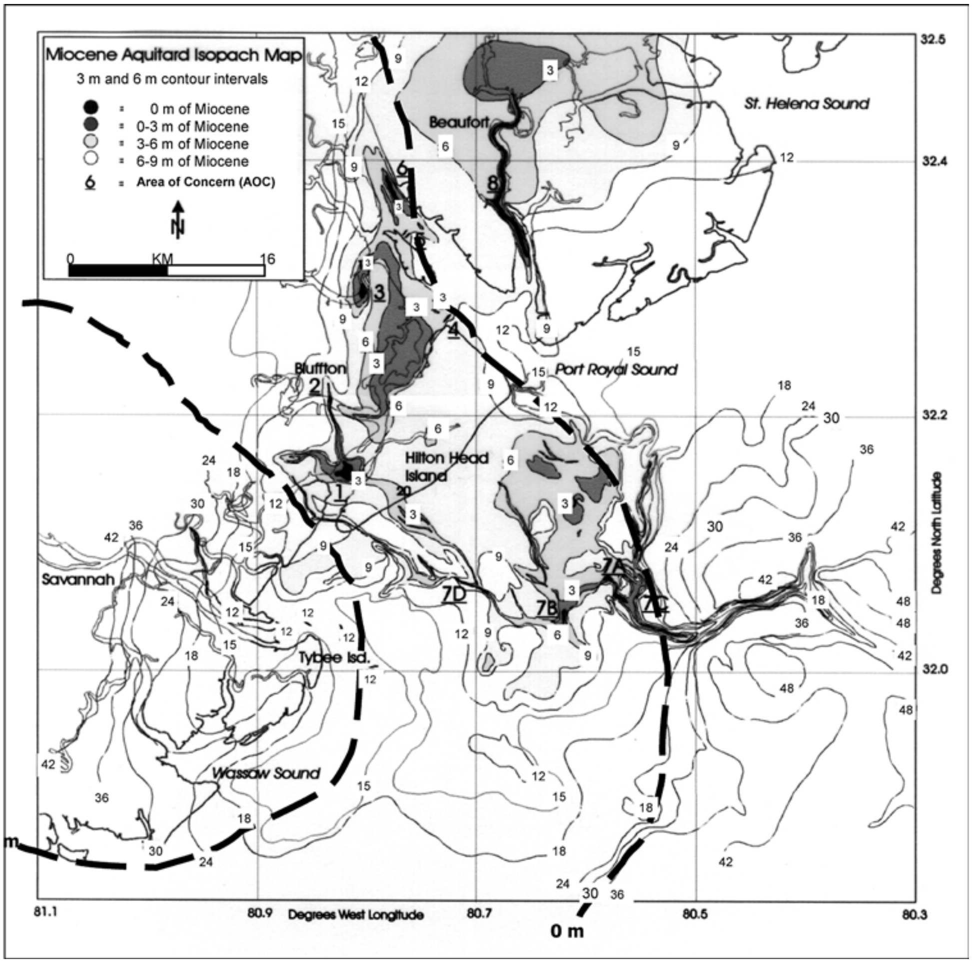


Fig. 7
Miocene aquitard isopach map for northern coastal Georgia and southern coastal South Carolina. Map shows 11 areas of concern (AOCs) where the Miocene aquitard is absent (*shaded black*). AOC dimensions are estimated outside of the plane of the seismic trackline. See Table 1 for summary hydrogeologic data for each AOC. *Thick dashed lines* show approximate positions of the –6-m and 0-m m.s.l. potentiometric contours on the UFA derived from Fig. 1

Table 1
Qualitative ranking of areas of concern (AOCs) based on the amount of seawater recharge possible at each site. Ranking scale: *I* highest, *XI* lowest susceptibility. *K′* for the non-confining material is 2.3×10^{-3} m/day

Location of AOC (see Fig. 7)	Incision length (*L*; m)	Potentiometric change across post-Miocene (*dh′*; m)	Average thickness of non-confining material (*dl′*; m)	Vertical hydraulic gradient (*dh′*/*dl′*)	Potential pseudo recharge (m^2/day)	Potential pseudo recharge Ranking
(1) Cooper River at Calibogue Sound	1,070	–5.8	17	–0.34	0.84	I
(6) Broad River near US Hwy 170 bridge	1,830	–0.6	3.0	–0.2	0.8	II
(3) Colleton River at Victoria Bluff	915	–1.5	9.8	–0.15	0.32	III
(2) Confluence of May River/Bull Creek	150	–4.3	11	–0.40	0.14	IV
(7A) Beaufort Arch offshore Hilton Head	1070	–0.3	7.6	–0.04	0.1	V
(7B) Beaufort Arch offshore Hilton Head	460	–0.3	6.1	–0.05	0.05	VI
(7D) Beaufort Arch offshore Hilton Head	213	–1.5	14	–0.11	0.05	VII
(7C) Beaufort Arch offshore Hilton Head	457	–0.3	12	–0.025	0.026	VIII
(4) Port Royal Sound at Hilton Head	150	–0.6	12	–0.05	0.02	IX
(5) Broad River north of Daws Island	150	–0.6	12	–0.05	0.02	X
(8) Beaufort River north of Parris Island	12,860	0.6	0.6	+1.0	Out-flow	XI

no-Miocene area (AOC 8), located along the axis of the Beaufort River southeast of Beaufort, SC, lies just outside the Savannah cone of depression (Ransom and White 1999). At this site, the Miocene aquitard is absent for about 13 km along the thalweg of the Beaufort River. In this area, the UFA either outcrops at the river/estuary floor or is covered by a thin veneer (0–3 m) of post-Miocene (non-confining) strata. This is the only part of the study area where the UFA was observed to be in direct contact with seawater.

It is notable that AOCs 7A, 7B, 7C, and 7D on the SC inner shelf are within the paleochannel of the Savannah River on the flanks of the Beaufort Arch. AOCs 7A, 7B, and 7C are located in the twice-occupied seaward part of the paleochannel suggesting that fluvial down-cutting during the 18,000-year sea-level lowstand was accompanied by greater fluvial incision than that which occurred during the 150,000-year sea-level lowstand (with which AOC 7D is associated).

Discussion

Based on the geophysical evidence, each of the 11 AOCs described above is an area where the UFA is susceptible to recharge by seawater. Potential recharge by seawater (Q, in m^3/day) could not be consistently and accurately determined at all sites because of uncertainties in the exact areal dimension of each site. However, each AOC is qualitatively ranked in Table 1 using a potential pseudo-recharge rate (Q' recharge per unit width in m^2/day), which is calculated using the length of each incision zone and a normalized incision width of 1 m. This modified Darcy's equation and its component terms are as follows:

$$Q' = |(K')\,(dh'/dl')\,(L)| \qquad (1)$$

where Q' is the quantity of seawater recharge (Q) possible per unit width of incision at each AOC (m^2/day). K' is the vertical permeability for the non-confining material (m/day); an inferred value of 2.3×10^{-3} m/day is used for all AOCs and is an average of the rates measured from Quaternary paleochannel deposits beneath the Savannah River (US Army Corps of Engineers 1998). dh' is the difference in potentiometric elevation (meters) between the top of the UFA and the top of the non-confining material; at each AOC, this number is derived from recent potentiometric maps for the UFA (Peck and others 1999; Ransom and White 1999) and from the assumption that the potentiometric head in the non-confining material is at 0 m MSL. dl' is the average thickness of the non-confining material (meters) above the UFA at each AOC; it is measured from seismic sections. dh'/dl' is the vertical hydraulic gradient between the top and the base of the non-confining material (m/m). L is the length of the incision at each AOC (meters); it is measured from seismic sections.

Based on the stratigraphic relationships determined from the seismic records and the hydrogeologic framework (vertical hydraulic gradient and permeability) of each site, these 11 AOCs are inferred to be the areas most susceptible to seawater recharge on this part of the GA–SC coast. The highest-ranked AOC in Table 1, AOC 1, is located in Calibogue Sound landward of Hilton Head Island and is partly imaged in Fig. 5. While having only a moderate incision length, AOC 1 is close enough to the center of the cone of depression that the vertical hydraulic gradient term is large (Table 1) and exceeds almost all other mapped sites. At the lowest-ranked area, AOC 8, the UFA is exposed at the seabed or is only thinly covered by post-Miocene strata. The elevation of the potentiometric surface on the UFA at AOC 8, however, means that the UFA at this locality would be threatened by seawater intrusion for relatively short time periods during spring high tides, and less frequently by coastal setup of sea level during suitably configured northeasters and hurricanes.

In addition to AOCs 1–8, the extensive thin-Miocene areas shown in Fig. 7 that are defined by the 6-m isopach contour are also sites of potential seawater intrusion. However, the rate of seawater recharge for any given location is expected to be lower (per unit area) than for the AOCs because both the aquitard and the post-Miocene section are present. The susceptibility to intrusion at any particular location would be directly dependent on (1) the vertical permeability of the Miocene aquitard and the overlying non-confining strata, (2) the vertical thickness of aquitard and non-confining strata present, (3) the areal dimension of the location being considered, and (4) the position on the potentiometric gradient within the cone of depression. Until vertical permeability data for the Miocene and post-Miocene strata in the SC intracoastal and shelf areas are better quantified (by other studies and by recent test-drilling under SSI), these thin-Miocene areas cannot yet be meaningfully ranked in terms of susceptibility to seawater recharge.

Conclusions

Eleven AOCs were identified in this study on the basis of sub-bottom reflection-seismic imagery and known or inferred hydrogeologic characteristics. Each AOC, when compared with areas where the Miocene aquitard is well developed, has an enhanced susceptibility to seawater intrusion because (1) the UFA is shallow and near the seabed, (2) the Miocene aquitard is absent, (3) the potentiometric surface for the UFA is near or below mean sea level (i.e., the potentiometric head is negative relative to that of the overlying seawater column), and (4) the overlying water column is saline. The most susceptible site is AOC 1 located in Calibogue Sound about 27 km from the center of the Savannah cone of depression, while the least susceptible site is AOC 8 located in the Beaufort River on the outer edge of the cone of depression.

It should be realized, however, that while both the stratigraphy derived from geophysical data and the hydrogeologic conditions known or inferred for each AOC indicate that conditions are suitable for seawater recharge, groundtruthing is necessary to determine if seawater is present in the UFA at each AOC. Test drilling at AOC 1 and AOC 7D (which are located nearest to Savannah), and at three other offshore sites where the Miocene is thinned, has recently been completed by the Georgia Geologic Survey, the US Geological Survey, the US Army Corps of Engineers, and the South Carolina Department of Health and Environmental Control. Data from the test-drilling program are currently being analyzed to determine the hydrogeologic properties of the post-Miocene, Miocene, and UFA strata. Analysis will also reveal whether or not seawater is in fact present within the UFA at the AOC 1 and AOC 7D breach sites and at the three near-breach sites. Preliminary sedimentological data from the AOC 1 drill site indicates that the paleochannel fill at that site is less permeable than that from similar paleochannels beneath the Savannah River. The fill is also less permeable (muddier) than sequence stratigraphy and the character of the seismic records at AOC 1 (Fig. 5) would predict. In situations such as this, where the post-Miocene strata have low permeabilities, the absence of the Miocene aquitard may be partly mitigated by low-permeability (mud and silt dominated) infill within the incised paleochannels.

The results of this study are currently being utilized in aquifer testing and modeling by state and federal agencies with the ultimate goal of better quantifying water and solute transport rates within the UFA. Approximately 4 years from now, an increased understanding of this coastal aquifer will form the sound scientific basis upon which coastal Georgia's future groundwater management plans can be constructed.

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