STRATEGIES FOR MANAGING WATER RESOURCES IN SALTWATER INTRUSION ENVIRONMENTS

Christopher Paul Foldesi[1], P.G., Richard C. Cyr[2], and Richard K. Spruill[3], P.G., PhD,

AUTHORS [1]Project Hydrogeologist, Groundwater Management Associates, Inc., 4300 Sapphire Court, Suite 100, Greenville, North Carolina 27834; [2]General Manager, Hilton Head Public Service District, Hilton Head Island, South Carolina, 29925, [3]Associate Professor of Geology, East Carolina University, Greenville, North Carolina 27858;
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Abstract. Large regional groundwater withdrawals have induced the migration of saltwater into the previously freshwater portions of the Upper Floridan Aquifer beneath Hilton Head Island. This has caused Hilton Head Public Service District (the District) to lose a significant portion of their fresh groundwater supply. The District has considered several options to reduce saltwater intrusion by managing their existing Upper Floridan Aquifer wellfield. The District has also developed alternative sources that are both reliable and economically viable.

Strategies for managing the existing groundwater supply include the construction of new wells in the Upper Floridan Aquifer away from the saltwater-freshwater interface located near Port Royal Sound. Groundwater modeling has been utilized to guide management of the existing wellfield to more evenly distribute withdrawals, thereby reducing the potential for developing coalescing cones of depression and large-scale inflections on the potentiometric surface. These management strategies reduce the potential for localized saltwater intrusion and/or upcoming, and extend the life of the wellfield.

The Middle Floridan Aquifer is being developed as an alternative source of water to be treated by reverse osmosis (RO). Detailed aquifer testing and analyses were utilized to address regulatory concerns regarding the potential to create further water level declines in the Upper Floridan Aquifer. To investigate the hydrogeologic feasibility of using the Middle Floridan Aquifer as a supply source, the District constructed a Middle Floridan Aquifer production well and two monitoring wells. The primary goal of this testing was to evaluate the hydraulic properties of the Middle Floridan Aquifer and to evaluate the impact of withdrawals from the Middle Floridan Aquifer on water levels in the Upper Floridan Aquifer. Results of this testing program indicated that development of the Middle Floridan Aquifer is feasible and will not create significant impacts on the Upper Floridan Aquifer.

Other potential strategies that have been investigated include the utilization of saltwater extraction wells from the Upper Floridan Aquifer near Port Royal Sound to create a pressure trough to inhibit further saltwater migration beneath Hilton Head Island. Water from extraction wells could be treated with RO and utilized as a water resource. The District has also considered the utilization of Aquifer Storage Recovery (ASR) to create a freshwater pressure ridge to prevent further saltwater migration beneath Hilton Head Island. Reverse osmosis treated water from brackish sources can be utilized during off peak periods to recharge ASR wells, that can be used conjunctively with existing Upper Floridan Aquifer wells to meet peak demands.

The District provides an excellent example of how multi-faceted management strategies can be successfully applied to mitigate saltwater intrusion issues in developed coastal areas. Too often, coastal communities will simply add more treatment to existing sources without addressing the causes of saltwater intrusion and without fully evaluating other economical alternatives.

INTRODUCTION

The District's service area is located in the northeast portion of Hilton Head Island and covers roughly half of the area of the Island. The District relies on fresh water from the Upper Floridan Aquifer as its primary water-supply source. The Upper Floridan Aquifer is a part of a larger group of aquifer systems that are contained in the approximately 4,000-foot thick section of Coastal Plain sediments underlying Hilton Head Island. The District has an overwhelming interest in issues that can affect the water quality and availability of this resource.

Ongoing saltwater intrusion has caused the District to develop management strategies for their Upper Floridan Aquifer withdrawals and to seek new alternatives to this primary groundwater source. Analysis of current trends for encroachment of saltwater into the District's existing Upper Floridan Aquifer water supply wells indicates that a significant portion of the District's capacity could exceed the secondary maximum contaminant level of 250 milligrams/liter (mg/L) for chlorides within the next 10 years. In addition, the District withdrawals from the Upper Floridan Aquifer are capped by the Low Country

Capacity Use Area (LCCUA) regulations enforced by the South Carolina Department of Health and Environmental Control (SCDHEC).

Based upon the impact of the capacity use restrictions and ongoing saltwater intrusion in the Upper Floridan Aquifer wellfield, the District began making provisions for additional capacity from an independent source, the Beaufort Jasper Water and Sewer Authority (BJWSA), which treats surface water from the Savannah River. A transmission system was designed and constructed to provide treated surface water from the BJWSA's distribution system. Currently, the District has a contract with BJWSA to provide up to 4.0 million gallons per day (MGD) through this transmission system.

The District has made efforts to reduce the upconing of saltwater in their existing wells by modifying the operational strategy for the wellfield. The District has located new wells into the Upper Floridan Aquifer in areas that have high yields and that are located away from the saltwater front.

The District has also begun to develop the Middle Floridan Aquifer as an alternative to the Upper Floridan Aquifer. The SCDHEC required comprehensive testing of this source using multiple monitoring wells in the both the Upper and Middle Floridan Aquifers. Extensive aquifer testing and groundwater modeling were required to demonstrate the impact to water levels on the LCCUA regulated Upper Floridan Aquifer.

The District will continue to move forward in expanding its usage of Upper Floridan Aquifer, the BJWSA surface water source, and the brackish Middle Floridan Aquifer source treated via RO to provide water to their customers. The District is currently developing a comprehensive Middle Floridan Aquifer monitoring plan to address potential water quality and water level changes that may occur in response to the operation of the new wellfield. The District will continue to evaluate new strategies for managing these existing sources, including ASR, which can be utilized to simultaneously store and manage water from existing sources and also to impede ongoing saltwater intrusion by creating a pressure ridge near the saltwater front.

BACKGROUND

Withdrawals from the Upper Floridan Aquifer at Savannah began in the late 1890's, when Savannah stopped using surface water from the Savannah River as a source of raw water supply (Krause and Clarke, 2001). Steady increases in withdrawals occurred in the Savannah area until they peaked in 1988 at 88 MGD (Krause and Clarke, 2001).

Significant withdrawals from the Upper Floridan Aquifer at Hilton Head Island began in the 1960s when the Island began to develop as a resort area. Capacity use area regulations developed by the SCDHEC now enforce a 9.75 MGD Island-wide limit on withdrawals from the Upper Floridan Aquifer at Hilton Head Island.

Predevelopment (prior to the early 1900s) equipotential maps published by the United States Geological Survey (USGS) clearly demonstrate that water levels in the Upper Floridan Aquifer were above mean sea level at Hilton Head Island, and that groundwater flowed from the mainland to the northeast end of Hilton Head Island where it discharged primarily at Port Royal Sound (Aucott, 1988, and Aucott and Speiran, 1985). The saltwater/freshwater interface in the Upper Floridan Aquifer was located to the northeast of Hilton Head Island under predevelopment conditions. The natural balance between recharge to the Upper Floridan Aquifer and discharge from the aquifer served to establish the position of the saltwater/freshwater boundary offshore.

The high volume of groundwater withdrawn from the Upper Floridan Aquifer at Savannah has created a regional cone of depression that extends over the majority of the Georgia Coastal Plain, extending into northern Florida, and into South Carolina across Hilton Head Island. The cone of depression associated with withdrawals in the vicinity of Savannah is defined as the area under the influence of pumping where water levels have been significantly depressed when compared with pre-pumping water levels.

Saltwater Intrusion. Saltwater intrusion has been well documented at the northern end of Hilton Head Island since the early 1980s (Burt and others, 1987). Early reports addressed the imbalance in withdrawals at Savannah and indicated that saltwater intrusion was beginning to occur northwest of Hilton Head Island near Pinckney Island and the Colleton River (Counts and Donsky, 1959). Numerous studies have presented detailed information about the saltwater intrusion that is occurring at the northern end of Hilton Head Island, and several computer models have been completed that address the potential for further saltwater intrusion (Burt and others, 1987, Smith, 1993, and Landmeyer and Belval, 1996). Analysis of laboratory samples obtained in the early 1980s from monitoring wells in the Upper Floridan Aquifer at the northern end of Hilton Head Island indicated that chloride concentrations exceeded the secondary drinking water standard of 250 mg/L (Krause and Clarke, 2001). Chloride concentrations have continued to rise in the Upper Floridan Aquifer at Hilton Head Island, and have been recently recorded in excess of 10,000 mg/L (SCDHEC, 2005).

MANAGEMENT STRATEGIES

Optimizing Existing Withdrawals. Groundwater Management Associates, Inc. (GMA) constructed a limited three-dimensional model utilizing Visual MODFLOW to evaluate the effects of the District's Upper Floridan Aquifer withdrawals, and to perform an analysis to optimize pumping rates in the wellfield in order to reduce the potential for saltwater contamination. The model was also used to simulate the effects of different management strategies such as ASR on the Upper Floridan Aquifer. Steady-state model simulations were calibrated to Upper Floridan Aquifer water levels and transient simulations were calibrated to pumping tests performed on District Upper Floridan Aquifer wells. Steady state model simulations of the District's wellfield indicate that inflections in the potentiometric surface of the Upper Floridan Aquifer occur at wells that are pumped at the highest flow rates. There is a greater potential for the upconing of brackish water at well locations with the greatest withdrawals. The model was used to simulate the effects of pumping specific wells at lower rates to more evenly distribute withdrawal affects. Several simulations were performed to simulate the redistribution of withdrawals across the wellfield, thereby reducing cones of depression and inflections on the water level surface. Such management strategies should reduce the potential for localized saltwater intrusion or upcoming and extend the life of the wellfield without the need for desalinization treatment.

New Wells Away From The Saltwater Front The Capacity Use Area permit limits total annual withdrawals, however these requirements do not preclude the drilling of new wells as long as the withdrawal limits are not exceeded. The potential benefits of drilling new wells into the Upper Floridan Aquifer include: the ability to further distribute the withdrawals from the Upper Floridan Aquifer across the District's wellfield, and the potential to develop portions of the aquifer in the District's service area that are less vulnerable to upconing or lateral intrusion of brackish water. The District recently developed a new well site in the Spanish Wells area. The Spanish Wells area is a good location for a new production well because of the productivity of the Upper Floridan Aquifer in this area and because the location of the well is significantly away from the saltwater front. The well was tested at a high flow rate and analysis confirmed a sustained well yield with low chloride concentrations.

Alternative Brackish Aquifer Development GMA and B.P. Barber and Associates, Inc. developed and submitted to the Groundwater Section of SCDHEC a general testing proposal that included the installation of a production well and two monitoring wells, followed by extensive aquifer testing at a site on Jenkins Island, Hilton Head Island. The objective of this work was to utilize information obtained from the exploration and aquifer-testing program to address LCCUA regulations as they pertain to the development of the Middle Floridan Aquifer by the District. The Middle Floridan Aquifer is defined herein as a distinct carbonate aquifer at a depth of approximately 550 to 600 feet below the land surface at Hilton Head Island.

Successful aquifer testing requires a detailed understanding of the hydrogeologic setting of the aquifer and the potential head trends, such as tides and pumping effects from nearby wells. GMA developed a monitoring program designed to collect non-pumping water level data to assess the background water level trends. GMA deployed pressure transducers with built in data loggers in the onsite monitoring wells and the production well for a minimum of one week prior to a 96-hour constant-rate aquifer test. Background water level data allowed for the correction of pumping test data for natural water level changes due to tides. GMA also worked cooperatively with the SCDHEC to collect water level data from several offsite monitoring wells.

GMA and Rowe Drilling Corporation performed the constant-rate (1000 gpm) aquifer test for 96-hours and observed recovery water levels for 12 hours after pumping ceased. Tidally corrected water-level data collected from both the Upper and Middle Floridan Aquifer monitoring wells were used to determine the transmissivity and storage coefficient of the Upper and Middle Floridan Aquifers, and the vertical hydraulic conductivity and storage coefficient of the semi-confining unit (the Middle Confining Unit), which separates these two aquifers.

Tidally corrected data from field-testing indicated a hydraulic connection between the Upper and Middle Floridan Aquifers, as evidenced by approximately 0.25 feet of maximum water level decline in the Upper Floridan Aquifer after a 96-hour sustained withdrawal of 1,000 gpm from the Middle Floridan Aquifer.

Groundwater Modeling In Support Of The New Wellfield GMA used data collected during aquifer testing to construct an updated three-dimensional Visual MODFLOW model to address SCDHEC concerns about the potential impact that a Middle Floridan Aquifer wellfield would have on the Upper Floridan Aquifer. The model was calibrated to recent water levels in the Upper and Middle Floridan Aquifers. A transient calibration was performed by simulating the 96-hour aquifer test on the Middle Floridan Aquifer.

GMA performed simulations of a 3-well Middle Floridan Aquifer wellfield pumping at 4 MGD and found that there was a small, but measurable, impact on the Upper Floridan Aquifer. SCDHEC approved the

construction of the wellfield and has slightly decreased the District's LCCUA Upper Floridan Aquifer allocation to compensate for the lowering of Upper Floridan Aquifer water levels, in response to pumping from the Middle Floridan Aquifer. Monitoring wells in the Upper Floridan Aquifer are being installed at each Middle Floridan Aquifer well site and will be used to gauge future restrictions, if necessary.

Future Directions The District has been proactive in developing alternative resources to the Upper Floridan Aquifer. Development of the Middle Floridan Aquifer provides a sustainable water resource that is the best-cost alternative and does not significantly impact the Upper Floridan Aquifer. The District is now developing a comprehensive Middle Floridan Aquifer monitoring program and is looking towards the future. New technologies that may be employed in the future include:
1) ASR to both store and manage water from existing surface and groundwater sources, and to create a pressure ridge to impede further saltwater intrusion;
2) Saltwater extraction wells to create a pressure trough to impede saltwater intrusion into the District's Upper and Middle Floridan Aquifer well fields; and
3) The development of other alternative aquifers such as the Cretaceous Aquifers.

CONCLUSIONS

Saltwater intrusion is a common problem among coastal communities and these problems will continue to accelerate as these communities grow. A multi-faceted approach to managing surface water and groundwater resources conjunctively, and the utilization of newer technologies such as ASR and membrane filtration (i.e. RO treatment) can provide extended life for existing resources and the development of new resources, such as brackish aquifers.

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Figure 1: Conceptual Model of the Groundwater System in the Hilton Head Island Area After Development