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Water supply development for a new 17.5 MGD (66,200 m^3/d) brackish-water RO facility for the City of Hialeah, Florida

Thomas M. Missimer[a]*, W. Scott Manahan[a], Robert G. Maliva[a], Weixing Guo[a], Loren Furland[b], Tory Champlin[b]

[a]*Schlumberger Water Services USA Inc., 1567 Hayley Lane, Suite 202, Fort Myers, Florida 33907, USA*
[b]*Parsons Water & Infrastructure, Fountain Square II, Suite 120, 4925 Independence Parkway, Tampa, Florida 33634, USA*

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ABSTRACT

Freshwater supply limitations in Southeast Florida have caused a change in the water supply strategy for the next 30 years. As a result of the move away from the use of fresh groundwater, a 17.5 MGD (66,200 m^3/d) brackish-water desalination plant is under design for the City of Hialeah, Florida. Feedwater for this facility will be developed from the upper part of the Floridan Aquifer System at depths ranging from 1,080 to 1,480 ft (329–451 m) below surface. The initial water quality is mildly brackish with a total dissolved solids concentration (TDS) of about 2,300 mg/l. The anticipated volume of raw water required to operate the RO plant will be about 23.3 MGD (88,200 m^3/d). The raw water will be obtained from 12 primary production wells and two backup capacity wells. A critical design issue for any RO plant is the maintenance of feedwater quality over the operating life-cycle of the facility. The wellfield water quality is anticipated to change in time because of the upward leakage of greater salinity water from deeper within the aquifer system. The SEAWAT code was utilized to model the anticipated changes in TDS over an operating period of 30 years. Some initial calibration to the model was obtained from the existing City of Hollywood brackish-water wellfield, located about 15 miles (24 km) from the site. The framework of the model utilized both regional aquifer data obtained from various hydrogeologic testing programs conducted in the past and from a detailed aquifer performance test conducted on-site. The solute-transport modeling results indicate that the rate of TDS increase will be gradual and relatively steady over the next 30 years. The TDS concentration is expected to remain low enough so that it will be economic to treat with brackish-water membranes over the proposed operational period of the system. Modeling results were used to determine the well spacing and pumping rates that optimize the cost of construction versus the cost to treat higher salinity water. Solute-transport modeling should not be a one time exercise. Wellfield water quality should be continuously compared to model-predicted values to confirm that salinity trends are staying within the plant design parameters. The solute-transport model can be recalibrated against actual operational data if the data are deviating from predicted trends. In this manner, the refined model can provide a time lead for wellfield modification or changes in the process design as a management tool for wellfield operation.

Keywords: Reverse osmosis; Desalination; Brackish water; Florida

* Corresponding author.

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1. Introduction

Southeast Florida has undergone rapid growth over the past five decades with the population rising from 0.57 in 1950 to 4.19 million in 2006 (Fig. 1). Historically, the source of all public water supplies in Dade County has been from shallow groundwater. Although the water supply source, the Biscayne Aquifer, is one of the most productive aquifers in the world, excessive water use in several areas has caused the intrusion of saline water into the aquifer and has damaged wetland communities adjacent to the Everglades (Fig. 2). The South Florida Water Management District, the agency with regulatory power over water use in South Florida, has mandated that no further use of water from shallow, freshwater aquifers will be permitted. Therefore, the future water supply demands must be met using alternative water supply sources.

The most economical alternative water supply source is brackish-water from the upper part of the Floridan Aquifer System. This aquifer lies about 1,080 ft (329 m) below land surface and has an initial dissolved solids concentration of 2,300 mg/l in the area near the proposed wellfield site. This raw water will be treated using low-pressure reverse osmosis. Concentrate from the treatment process will be disposed of in a deep aquifer that contains seawater. This aquifer is termed the “Boulder Zone” and lies with the Lower Eocene Oldsmar Formation at about 3,200 ft (976 m) below land surface.

A 17.5 MGD (66,200 m^3/d) facility is being developed by the City of Hialeah and is being co-funded by the Miami-Dade Water and Sewer Authority. Delivery of the project will be by the design-build-operate (DBO) scenario to minimize the impact on City staffing and to provide the best possible value to the City rate payers. The facility site is located to the east of the City of Hialeah adjacent to several major roads in a new development area (Fig. 3). The purpose of this paper is to present an evaluation of the raw water supply development for the facility.

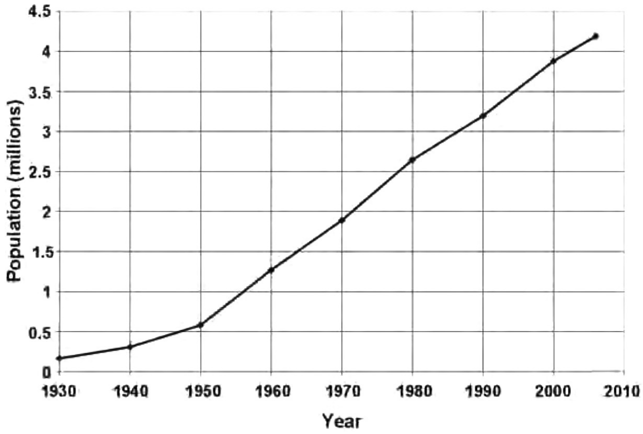

Fig. 1. Combined population of Miami-Dade and Broward counties, Florida.

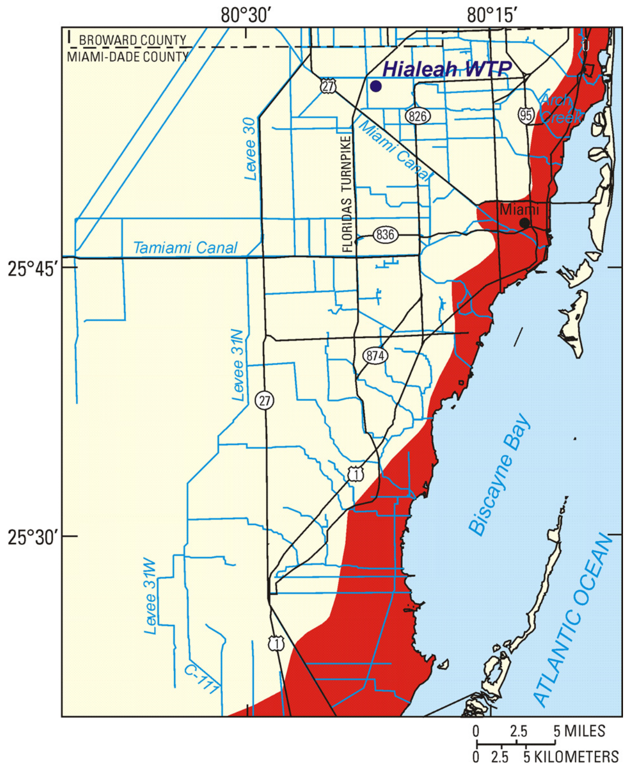

Fig. 2. Map showing extent of saline-water intrusion in 1995 (After [1]).

2. Hydrogeology of the upper part of the Floridan Aquifer System

2.1. Introduction

The Floridan Aquifer System is a regional aquifer underlying all of Florida and parts of Georgia, South Carolina and Alabama [2]. Several regional hydrogeologic investigations were conducted in southern Florida to compile aquifer hydraulic and water quality data [3–6]. Recent hydrogeologic investigations conducted in South Florida show that the system contains at least three separate aquifers with the lowest salinity water occurring at the top of the system and increasing salinity with depth (Fig. 4). Several hydrogeologic investigations were conducted in the vicinity of the City of Hialeah site for evaluation of aquifer storage and recovery of treated freshwater in the upper part of the Floridan Aquifer System [7–11]. Also, additional hydrogeologic data were collected during construction of deep injection wells used to dispose of treated domestic wastewater [12].

2.2. Geology

The Floridan Aquifer System in Dade County occurs within sediments ranging from Eocene to Oligocene in

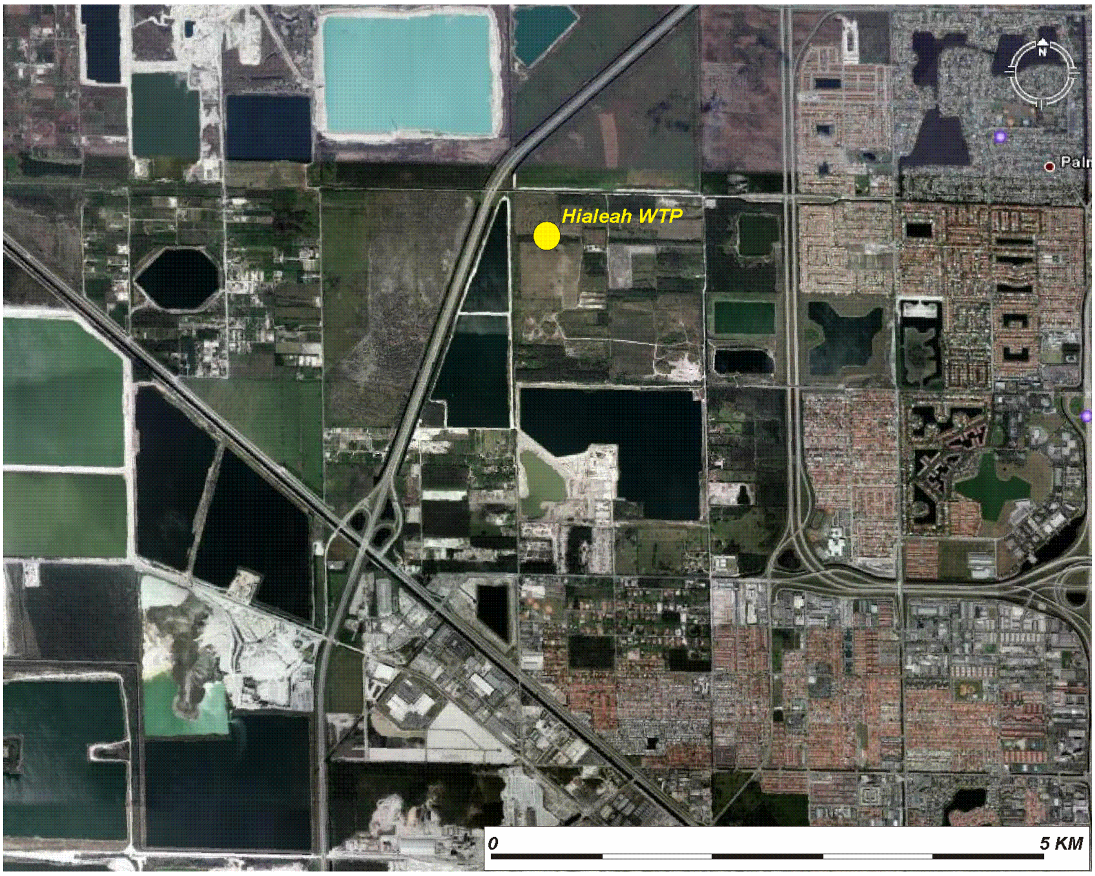

Fig. 3. Aerial photograph of the proposed Hialeah WTP vicinity.

age (Fig. 5). The uppermost aquifer in the system lies within the Avon Park Formation and some small amount of the Suwannee Limestone. A large section of the Oligocene and all of the upper Eocene were eroded away during previous low sea level stands [14]. The upper Floridan Aquifer occurs between about 1,080 and 1,480 ft below sea level (329–451 m) beneath the site.

These sediments are generally heterogeneous both in a horizontal and vertical sense. Typically, the thin nature of the Suwannee Limestone in this vicinity causes it not to be a significant contributor to water inflow into production wells. The uppermost Eocene Ocala Limestone is generally not present in the area as shown in Fig. 5. The Middle Eocene Avon Park Formation contains an interbedded sequence of dolomites and limestones, which are stacked in a series of parasequences that are generally shoaling-upwards. The highest hydraulic conductivities occur in the grainstones or packstones generally occurring at the base of each parasequence. Because of the occurrence of dolomitized mudstones within the section, the overall transmissivities found in the area are not high compared to those found further north within the Floridan Aquifer System [4].

The base of the Upper Floridan Aquifer is formed by thinly bedded limestones and dolomites that have low hydraulic conductivities, especially in the vertical direction. In order to investigate the hydraulic conductivities in the confining unit, as well as the variation of hydraulic conductivity in the aquifer, advanced geophysical logging techniques were used to assess this complex geology.

2.3. Aquifer characteristics

Previous aquifer performance tests conducted on the upper Floridan Aquifer showed the transmissivity ranges from 10,000 to 50,000 ft^2/d (929–4645 m^2/d) [4]. The storativity ranges from 0.002 to 0.0005. Measured leakance values for the intermediate confining unit in the area of the site are less than 2.28×10^{-6} 1/d [4]. The leakage is essentially upward with little or no contribution from above.

3. Water quality

3.1. Introduction

Successful operation of a brackish-water desalination facility is greatly dependant on short and long-term stable water quality. Most wellfields that feed brackish-water membrane treatment facilities tend to produce water that shows a slow increase in salinity over the operational history of the facility. Based on the projected changes in

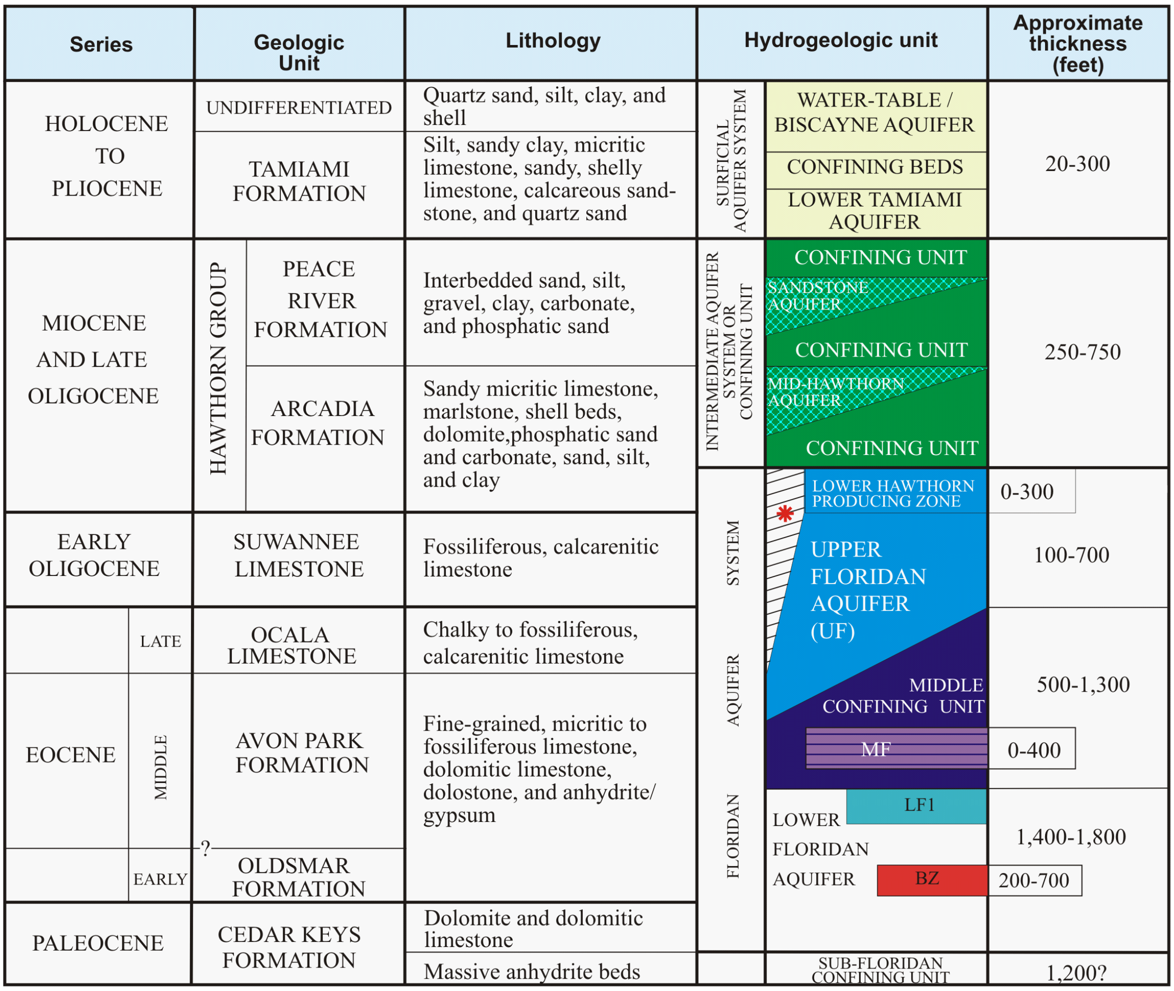

Fig. 4. Hydrogeologic and geologic units of South Florida [13].

water quality, the RO process can be designed to deal with the water quality change without expensive equipment upgrades and changes in the process.

3.2. Aquifer hydraulics and water quality after wellfield development

The uppermost aquifer within the Floridan Aquifer System is classified as a semi-confined or leaky aquifer. When a leaky aquifer is pumped, the drawdown of pressure within the aquifer will eventually stabilize when the pumping rate becomes equal to the rate of leakage into the aquifer. Therefore, the use of a leaky aquifer as a water supply source requires a detailed water quality evaluation be made to assess the salinity of the raw water. The production aquifer will take on the chemical characteristics of the bounding aquifers located either above or below or both over an extended time period (Fig. 6). The flow of water vertically from outside of the production aquifer is controlled by the overall production rate, the leakance of the aquifer, and to a degree by the configuration of the production wells. The leakance is defined as the vertical hydraulic conductivity of the confining units divided by their thickness. The total leakance is the addition of the leakance of the two bounding confining units.

Since the confining unit above the upper Floridan Aquifer is considerably thicker and has a generally lower vertical hydraulic conductivity compared to the lower confining unit, the downward movement of water during pumping can be ignored as trivial compared to the upward movement of water (Fig. 7). Therefore, over a period of time the salinity of the water being pumped for treatment will increase and the overall chemistry of the water will become similar to the next lower aquifer in the system.

The primary design issue for matching the reverse osmosis (RO) treatment process with the raw water supply will be the rate of salinity change with time and an evaluation of changes in other chemical characteristics of the water. Increases in specific ion concentrations,

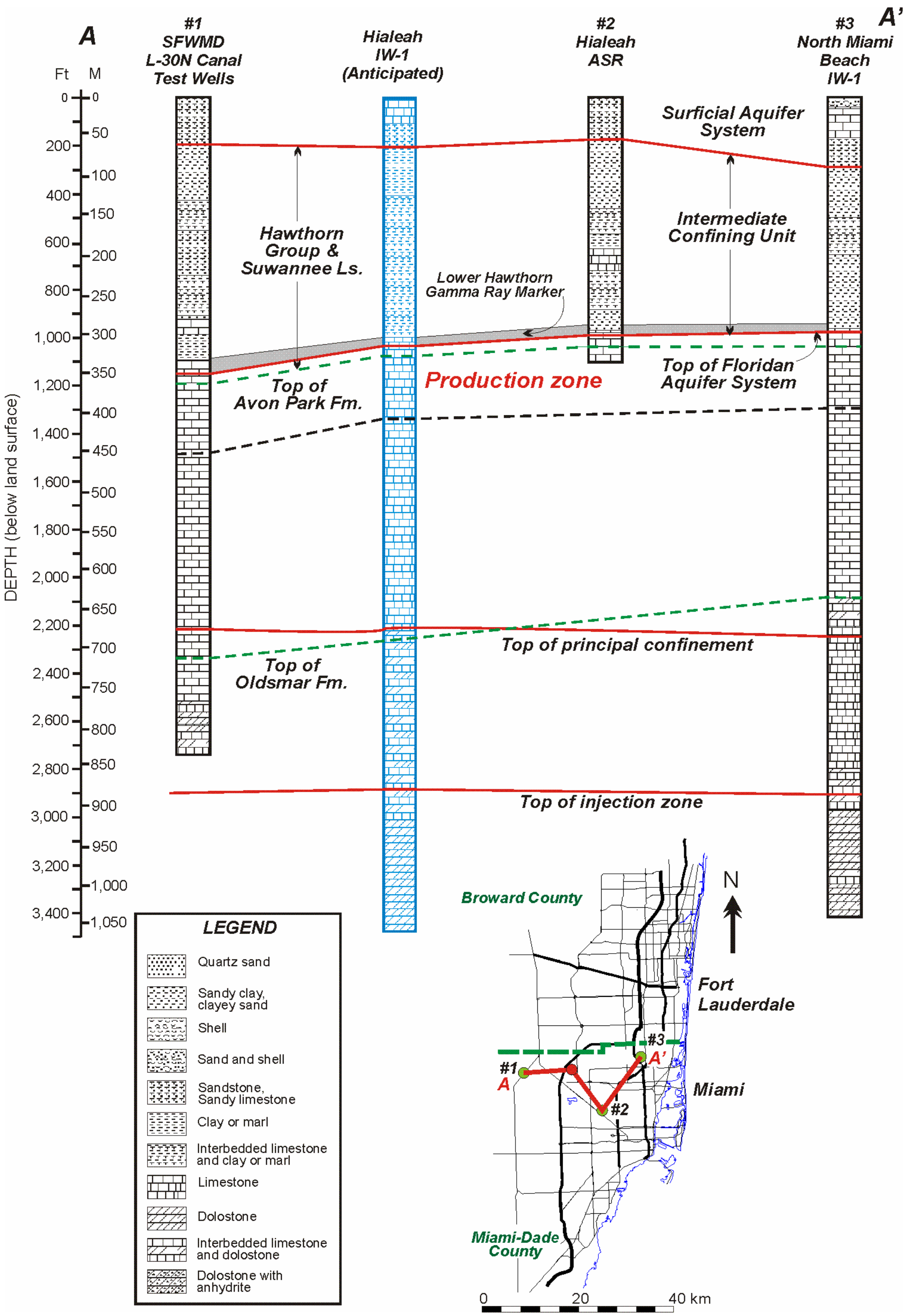

Fig. 5. West-East Hydrogeologic Cross-Section through the Hialeah WTP vicinity.

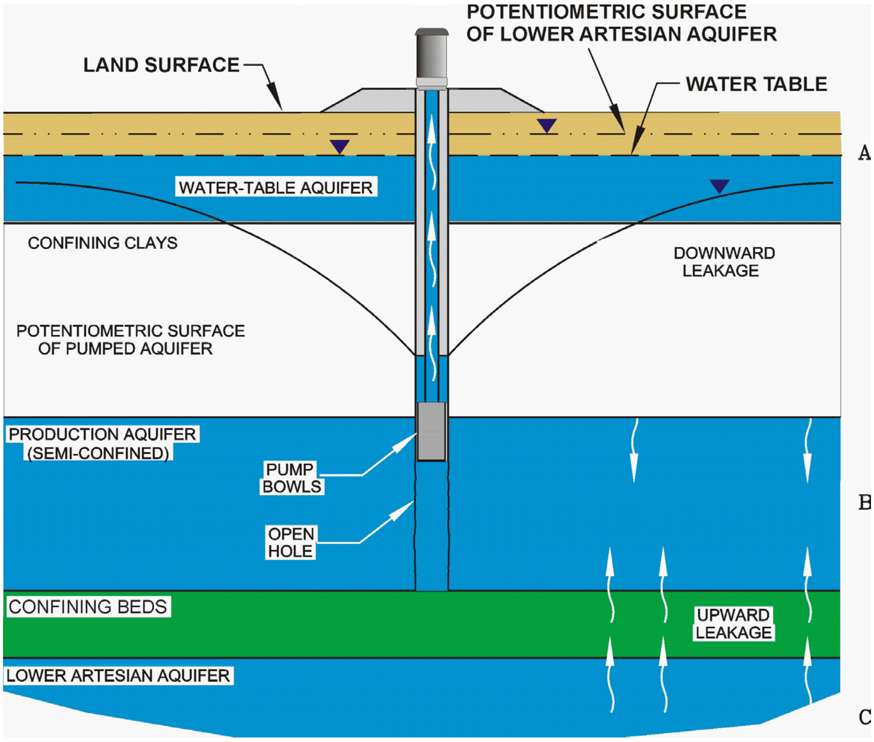

Fig. 6. Vertical leakage of water into a semi-confined aquifer under a pump condition (from [15]).

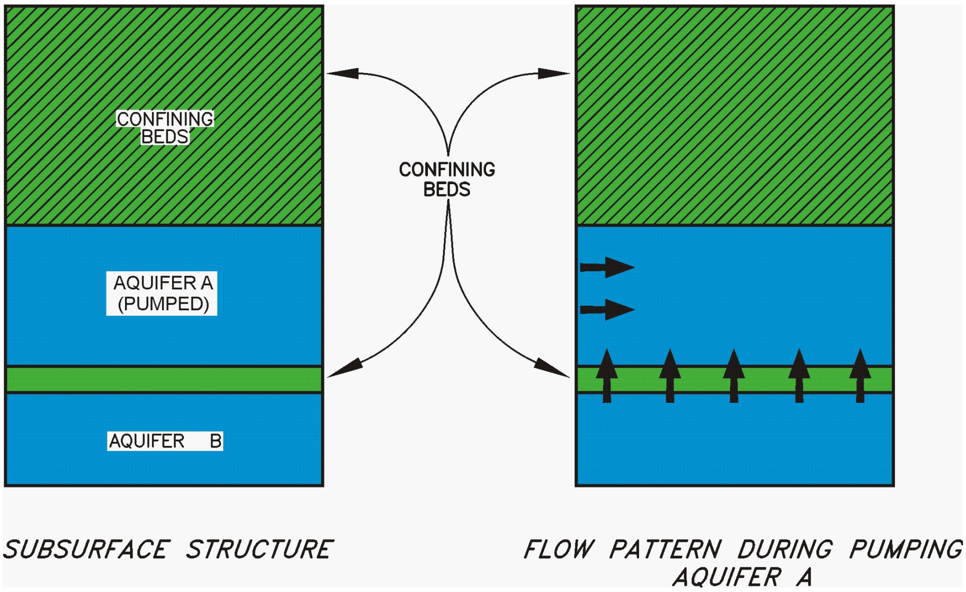

Fig. 7. Unidirectional vertical flow into a pumped aquifer caused by wellfield pumping (from [15]).

such as strontium, barium, sulfate, and silica, can create significant design challenges for the process to prevent fouling. Also, the increase in TDS over the operational life of the RO plant can cause causes in the operating pressures, resulting in variation in permeate recovery and in the actual process design (e.g. use of brackish-water vs. seawater membranes). When the increase in salinity is anticipated to be rapid, it may be necessary to have the ability to add stages to the high pressure pumps used to move raw water through the RO trains or the pretreatment design may have to be flexible to allow higher dosages of anti-fouling chemicals.

In southern Florida, most brackish-water RO facilities have exhibited a slow, long-term increase in raw water salinity with time along a predictable curve. The City of Cape Coral, the South Collier County, the Island Water Association, the Greater Pine Island Water Association, the Bonita Springs, and the City of Hollywood facilities have operated within acceptable ranges of salinity change in the raw water. Sudden changes in water quality have occurred at the North Collier County and City and the City of Fort Myers facilities in selected wells [15].

In order to design the wellfield for optimal performance and assess the potential water quality changes, it is necessary to conduct a detailed hydrogeologic investigation. The combination of regional and site-specific hydraulic and water quality data are then used to develop both groundwater flow and solute transport models.

4. Hydrogeologic investigation

A substantial hydrogeologic investigation of the proposed wellfield site is being conducted to assess the site-specific aquifer hydraulic characteristics and water quality variation with depth. A test-production well was drilled penetrating the Floridan Aquifer System from the top at about 1,080 ft (329 m) to a depth of 1,733 ft (528 m) below surface. Samples will be collected of the geology throughout the section and water quality samples were collected each 10 ft (3 m) or change in lithology during drilling of the open-hole using the reverse-air rotary method.

The borehole was then backfilled to the base of the Upper Floridan Aquifer. This is necessary to prevent any upward migration of higher salinity water from deeper parts of the aquifer system.

Three monitoring wells were constructed to penetrate the full thickness of the upper Floridan Aquifer at differing distances and directions from the production well. These wells were constructed to allow the hydraulic properties of the aquifer to be measured during a conventional aquifer performance test. The distances and directions for the monitoring wells were made to assess variability in aquifer coefficients and anisotropy of the aquifer.

Field investigations for the measurement of the aquifer and confining bed hydraulic properties were performed at the site. Schlumberger advanced geophysical logs were obtained from the test-production well, which was drilled through the full thickness of the Upper Floridan Aquifer, through the lower confining unit and into the Middle Floridan Aquifer. This allowed the thickness and distribution of hydraulic conductivity to be assessed within the production aquifer. Upon completion of logging and the back-filling of the test-production well, a 5-day aquifer performance test was conducted to determine the aquifer hydraulic properties. The test-production well was pumped and the three monitoring wells were used to observe the decline in heads within the aquifer.

5. Hydraulic and solute transport modeling of the Floridan Aquifer System

A three-dimensional density-dependant groundwater flow and solute transport model of the wellfield area was constructed using the SEAWAT model [16,17]. This model includes a hydraulic model using the MODFLOW code to assess the wellfield impacts to the potentiometric surface of the Upper Floridan Aquifer. This assessment of drawdowns within the wellfield is being using to determine the spacing between wells and the optimal yields of the individual wells. The SEAWAT model was constructed to assess the long-term, anticipated change in water quality caused by the pumping as previously explained.

Currently, the model indicates that the well spacing will likely be 2000 ft (610 m) and the individual well yields will be 2 MGD (7570 m^3/d). The overall capacity of the wellfield will be 26 MGD (97,500 m^3/d) based on a conversion factor of 80% for the RO treatment process with about a 4 MGD (15,000 m^3/d) reserve capacity. The reserve capacity can be used if the conversion factor falls below 80% and/or if there is a well or well pump failure.

6. Discussion

The City of Hialeah RO facility will provide the Miami-Dade County Water & Sewer Authority and the City of Hialeah with a new and reliable water supply. This supply will lessen the impacts of pumping on the Biscayne Aquifer and will allow the utility system to have greater flexibility in operation. Completion of the facilities should occur with the next two years.

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