U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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SOUTH FLORIDA WATER MANAGEMENT DISTRICT and U.S. ARMY CORPS of ENGINEERS
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COMPREHENSIVE EVERGLADES RESTORATION PLAN

SCIENTIFIC INVESTIGATIONS MAP I-2846
Cunningham, K.J. and others, 2004, Hydrogeology and ground-water flow at
Levee 31N, Miami-Dade County, Florida, July 2003 to May 2004

INTRODUCTION

The Levee 31N Seepage Management Pilot Project began in 2001, as part of the Comprehensive Everglades Restoration Plan (CERP). The pilot project seeks to determine the appropriate technology needed to control seepage from Everglades National Park (ENP), and provide the appropriate amount of ground-water flow to minimize potential impacts to the West Well Field and Biscayne Bay (fig. 1). To meet these needs, a levee cut-off wall (vertical subsurface barrier) has been proposed along Levee 31N in Miami-Dade County to reduce seepage flow from ENP. During the wet season, ground water would be captured by wells adjacent to Levee 31N and diverted into a buffer area adjacent to ENP where sheetflow would be reestablished (Trulock and Shaffer, undated).

An integrated, multidisciplinary investigation of ground-water flow is currently in progress by the South Florida Water Management District (SFWMD) and U.S. Army Corps of Engineers as part of the Levee 31N Seepage Management Pilot Project. Pre-seepage pilot wall ground-water flow patterns are being assessed through use of *in situ* heat-pulse flowmeter measurements, monitoring the vertical changes in hydraulic head and temperature, ground-water age dating, and measurement of the vertical change in ambient ground-water quality. A high-resolution hydrogeologic framework is needed as part of this effort.

In 2003, the U.S. Geological Survey (USGS) initiated a study to characterize the surficial aquifer system in detail to a depth of about 100 feet below ground level in the Levee 31N study area (fig. 1), and to delineate karst preferential ground-water flow zones. This study was part of a cooperative agreement between the USGS and the SFWMD (USGS Joint Funding Agreement No. 04E0FL208011 and SFWMD Agreement No. CPO40324), and funded through CERP.

Purpose and Scope

This report demonstrates the utility of sequence stratigraphic concepts for predicting the spatial distribution of preferred ground-water flow zones within a karst carbonate aquifer. Local, cross-sectional stratigraphy and the hydraulics of the surficial aquifer system were assessed in the Levee 31N study area using borehole geophysical and hydrologic data from selected test coreholes and monitoring wells, and a surface-water recorder. A conceptual hydrogeologic column was constructed by: (1) defining repetitive meter-scale vertical lithofacies successions (VLSs) (Kerans and Tinker, 1997); (2) attributing single, or bundles of, VLSs to high-frequency cycles (HFCs) (Kerans and Tinker, 1997); (3) assigning one of three carbonate ground-water flow classes (Cunningham and others, 2004b) to each lithofacies; and (4) utilizing upper and lower surfaces that bound cycles as a reliable marker horizon to map the distribution of flow classes. A ground-water flow class is defined as a subdivision of the range of types of ground-water flow that occurs within the Biscayne aquifer; each class contains a unique category of lithologies and pore systems.

Methods of Investigation

Table 1. Test coreholes and monitoring wells used for this study.

Corehole and well locations are shown in figure 1. Altitude of measuring point is at ground level, and depths are relative to ground level.
Abbreviations: TC, test corehole; MW, monitoring well; PVC, polyvinyl chloride; OH, open hole.

Local corehole/ well identifier	Type of site	Latitude	Longitude	Altitude of measuring point (feet, NAVD88)	Total depth drilled (feet)	Diameter of solid PVC casing (inches)	Depth of bottom of casing (feet)	Altitude of top of 2-foot screened interval (NAVD88)	End date of construction
G-3671	TC	25°44'56"	080°29'53"	7.5	150	3	10	open hole	08/07/98
G-3778	MW	25°44'47"	080°29'52"	14.85	109	2	104	-87.19	09/24/03
G-3779	MW	25°44'47"	080°29'52"	14.64	65	2	54	-38.01	09/18/03
G-3780	MW	25°44'46"	080°29'52"	14.88	34	2	34	-17.23	09/22/03
G-3781	MW	25°44'46"	080°29'52"	14.98	19	2	19	-2.12	10/01/03
G-3782	TC	25°43'52"	080°29'50"	7.41	68	6	9	open hole	07/27/03
G-3783	TC	25°42'57"	080°29'48"	7.54	69	6	9	open hole	08/06/03
G-3784	MW	25°42'07"	080°29'46"	14.21	108	2	100	-84.63	10/07/03
G-3785	MW	25°42'07"	080°29'46"	14.32	44	2	44	-28.70	10/15/03
G-3786	MW	25°42'07"	080°29'46"	14.12	28	2	28	-12.64	10/03/03
G-3787	MW	25°42'07"	080°29'46"	14.35	19	2	19	-2.96	10/02/03
G-3788	TC	25°41'28"	080°29'44"	7.05	68	6	9	open hole	08/26/03
G-3789	TC	25°38'13"	080°29'50"	6.47	68	6	9	open hole	08/25/03

Eight monitoring wells and four test coreholes were drilled on or along the eastern side of Levee 31N for this study (table 1 and fig. 1). The test coreholes (G-3782, G-3783, G-3788, and G-3789) were completed as open-hole stratigraphic tests, and the monitoring wells (G-3778, G-3779, G-3780, G-3781, G-3784, G-3785, G-3786, and G-3787) were constructed with screened polyvinyl chloride (PVC) casing near their bottom. A previously drilled test corehole, G-3671 (Cunningham and others, 2004b), also was used in this study (fig. 1). All five test coreholes were drilled along an undeveloped road between the Levee 31N canal and the Levee 31N berm, and the eight monitoring wells were drilled at the top of the Levee 31N berm. The four project test coreholes were continuously cored using a conventional coring method to depths of about 68 feet below ground level (table 1), which generally corresponds to the uppermost part of the Tamiami Formation in the study area (fig. 2). The conventional coring method uses hydraulic rotary coring using freshwater as a drilling fluid (Shuter and Teasdale, 1989).

The eight monitoring wells were drilled using one or more methods: conventional coring, standard penetration test (SPT), or hydraulic rotary methodology (Shuter and Teasdale, 1989). The SPT methodology employs a split-barrel sampler, and the hydraulic rotary method employs the tri-cone roller bit using mud as a drilling fluid. The deepest monitoring wells, G-3778 (109 ft) and G-3784 (108 ft) (table 1), were continuously cored using the conventional coring method and SPT methodology. With the conventional coring method, both wells were continuously cored to a depth of about 52 and 46 feet below ground level, respectively. The SPT methodology was employed at wells G-3778 and G-3784 to advance the split-barrel sampler in 1.5- to 2-foot intervals to the total well depths (109 and 108 feet, respectively). Well G-3779 was continuously cored using the conventional coring method to a total depth of 54 feet below ground level, and the remaining five monitoring wells (G-3780, G-3781, G-3785, G-3786, and G-3787) were drilled in accordance with the hydraulic rotary methodology. All of the monitoring wells were completed using 2-inch solid PVC casing with 2-foot length of screened PVC near the base of the casing (table 1). Drilling was conducted from July 8, 2003, to November 19, 2003. Well drilling and related information is presented in table 1.

The split-barrel sampler methodology was inefficient in terms of recovering quality sediment samples and SPT blow data. The driller would often wash down the corehole after changing the split-barrel sampler liner to keep the borehole open and fill part of the bottom of the hole with latence, which is sediment that has fallen to the bottom of the borehole after the drill string has been raised off the borehole bottom. This drilling procedure resulted in partial or full recovery of latence in the split-barrel sampler, as inferred from the highly variable mixture of sediment types recovered and a very low number of SPT blow counts. Each 2-foot long liner collected after a washdown contained a large amount of latence. The accumulation of latence also produced undercounting of SPT blows when the split-barrel sampler began its advance on top of the latence. After filling the split-barrel sampler with latence, the sampler was often advanced through undisturbed sediment to reach the desired depth without any further filling of the split-barrel sampler.

Geophysical logs were collected from three monitoring wells and five test coreholes that were continuously cored and included in this study. The types of logs include: natural gamma radiation, fluid conductivity and temperature, electromagnetic (EM)-induction, 3-arm caliper, full waveform sonic, heat-pulse flowmeter, ALT OBI-40 Mark III digital optical televiewer (RAAX BIPS digital optical televiewer in the G-3671 test corehole), and Laval video (except at G-3671). Vuggy porosity logs (Cunningham and others, 2004a) also were produced for each of the continuously cored wells. The heat-pulse flowmeter was used in the Biscayne aquifer to measure vertical borehole ground-water flow under ambient borehole conditions for seven of the continuously cored wells during the summer wet season. The accuracy of the measurements is limited by uncertainty in the amount of fluid flow bypassing the flexible-disk diverter on the flowmeter (Paillet, 2004).

Various hydrologic data were collected in the Levee 31N study area. Stage was recorded at a surface-water station (NESRS2) during 1-hour intervals to observe changes in wetland stage in ENP. Continuous ground-water-level data were collected every 15 minutes at the eight monitoring wells, and total daily precipitation was measured at a rain gage (K8652) (fig. 1). Rittmeyer pressure transducers were installed in the ground-water monitoring wells by the SFWMD. The pressure transducers are pressure rated to 15 pounds per square inch and have an accuracy of ±0.01 foot for water-level ranges of less than 15 feet.

HYDROGEOLOGY

Geologic units of varying permeability underlie southeastern Florida from land surface to depths between about 150 to 400 feet. These units constitute the unconfined surficial aquifer system, which is the principal source of potable water used in southeastern Florida (Fish and Stewart, 1991). In Miami-Dade County, a highly permeable part of the aquifer system has been named the Biscayne aquifer (Parker, 1951; Parker and others, 1955). Underlying the Biscayne aquifer are two semiconfining units that occur above and below the gray limestone aquifer (fig. 2). This study focuses on the Biscayne aquifer and the semiconfining unit above the gray limestone aquifer (fig. 2). The geology and hydrology of the study site have been previously reported by Causaras (1987), Fish and Stewart (1991), Solo-Gabriele and Sternberg (1998), Nemeth and others (2000), and Cunningham and others (2004b).

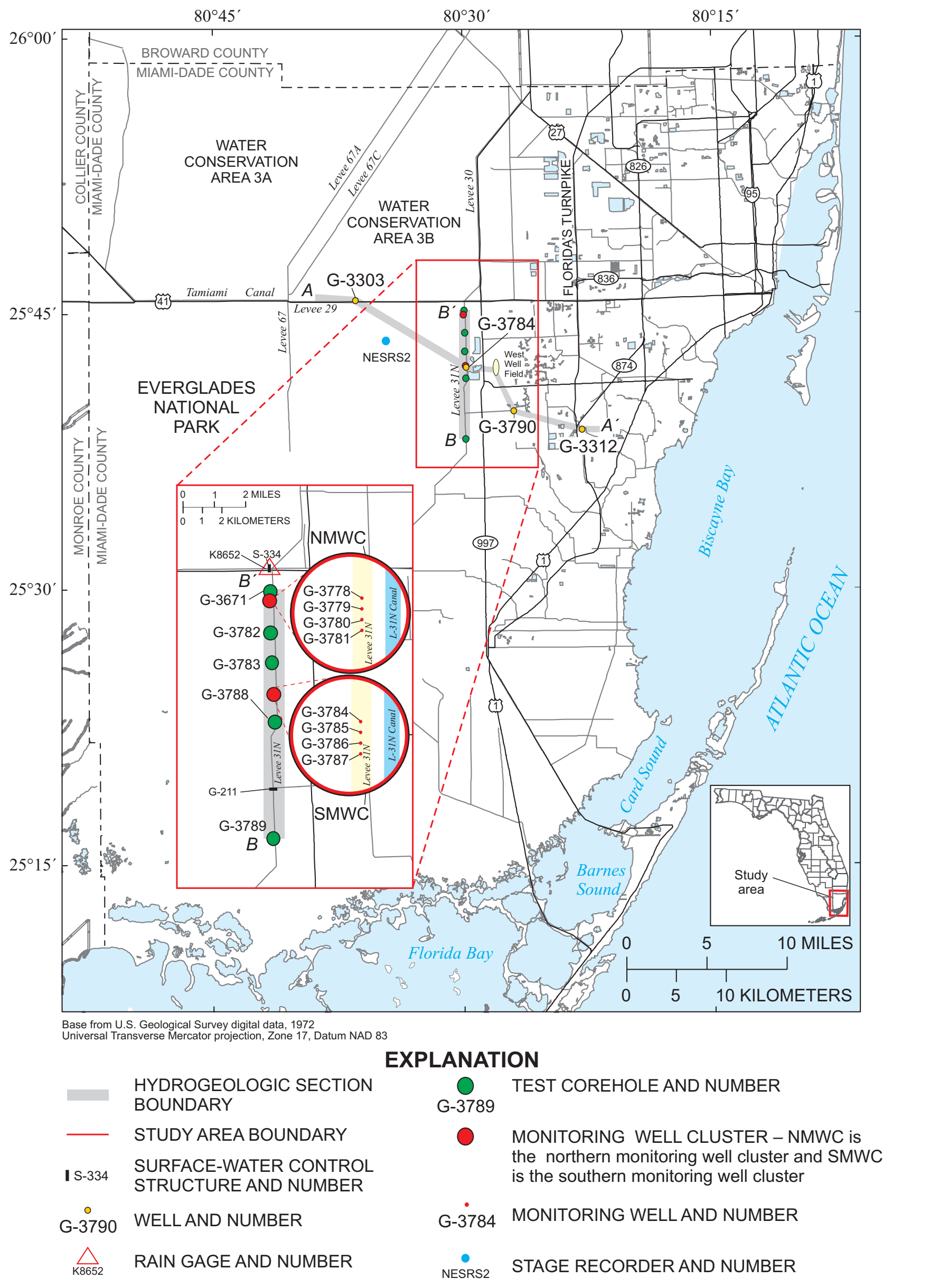

Figure 1. Location of the Levee 31N study area in Miami-Dade County and hydrogeologic sections *A-A′* and *B-B′*.

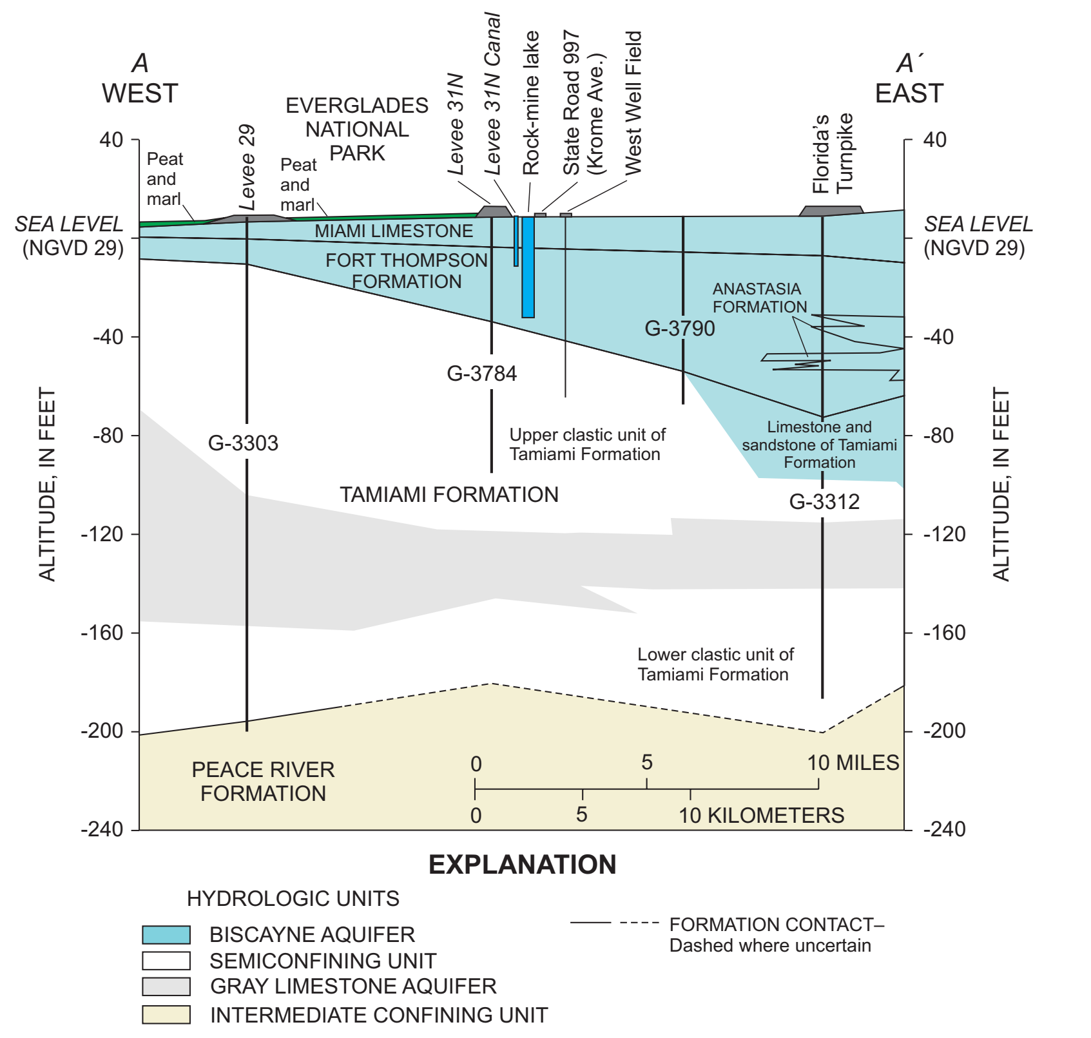

Figure 2. Hydrogeologic section *A-A´* showing schematic relations of geologic formations, aquifers, and semipermeable units of the surficial aquifer system across Levee 31N. Line of section *A-A´* is shown in figure 1.

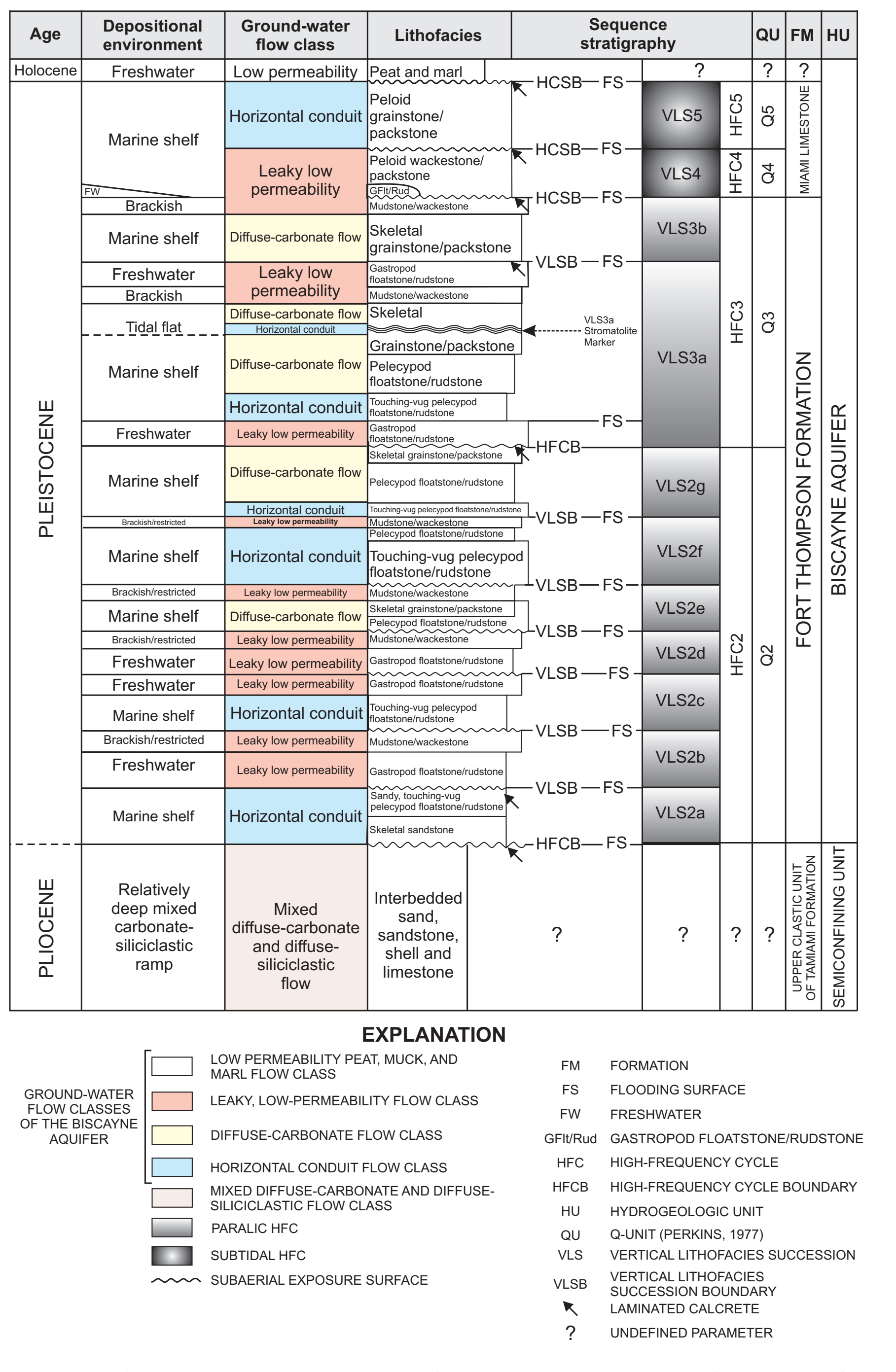

Figure 3. Conceptual hydrogeologic column for the Levee 31N study area. Ground-water flow classes of the Biscayne aquifer defined by Cunningham and others (2004b).

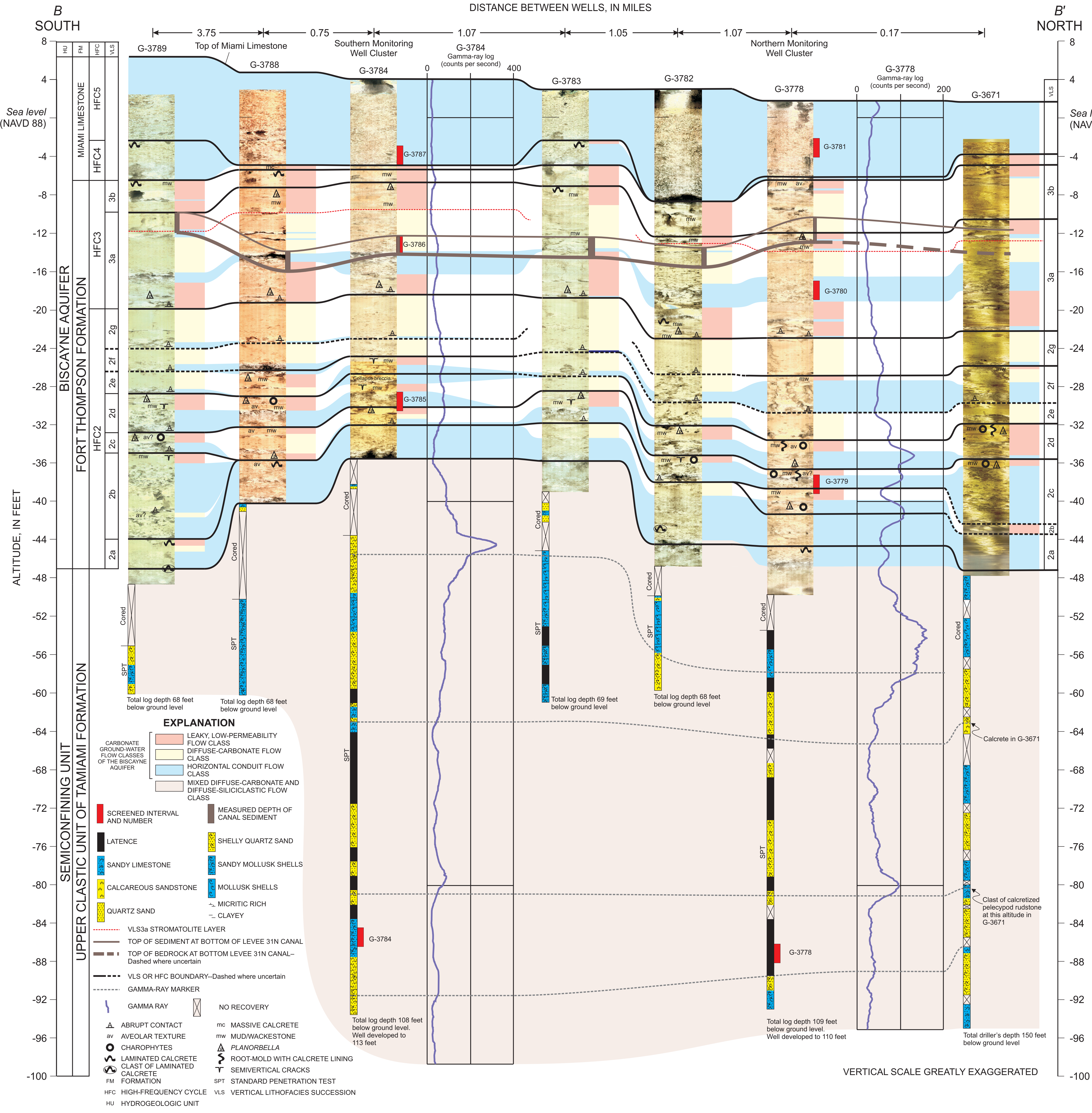

Figure 4. Hydrogeologic section *B-B′* showing schematic relations of geologic formations, hydrologic units, lithology, and sequence stratigraphy in the surficial aquifer system along Levee 31N. Line of section *B-B′* is shown in figure 1. Top of section is the top of the Miami Limestone and ground level is not shown.

HYDROGEOLOGY AND GROUND-WATER FLOW AT LEVEE 31N, MIAMI-DADE COUNTY, FLORIDA, JULY 2003 TO MAY 2004

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