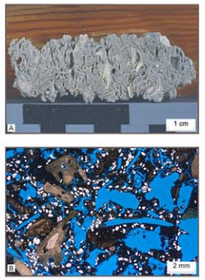
Origin of High Salinity Groundwater in the Surficial Aquifer System at the Herbert Hoover Dike, Southeastern Shore of Lake Okeechobee, Florida

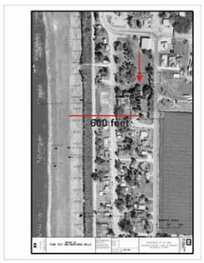
Introduction

As part of a U.S. Army Corp of Engineers study to determine aquifer characteristics of the surficial aquifer system along the Herbert Hoover dike in support of seepage studies along the eastern and southern shores of Lake Okeechobee, the U.S. Geological Survey (USGS) is collecting borehole geophysical logs. High salinity groundwater has been observed at shallow depths in the surficial aquifer system at one of the aquifer tests sites (HHD R1C), and this saline water, defined as having a dissolved-solids concentration of above 10,000 milligrams per liter, has the potential to increase the salinity in the upper part of the aquifer system above drinking water limits. The purpose of this investigation is to determine the origin of this saline water.

To investigate the origin of saline groundwater at the HHD R1C site and other inland areas of central Palm Beach County geochemical samples were collected and borehole geophysical logs were analyzed. Water samples were collected from 19 constructed wells in inland Palm Beach County and at three depths in a production well open over a long screened interval at the HHD R1C site. Samples were analyzed for concentrations of major ions, strontium, boron, and dissolved solids, and for isotopic ratios of strontium, boron, hydrogen, and oxygen. Borehole geophysical log data collected by the USGS in the wells at the site include gamma ray, caliper, induction resistivity, flow meter, fluid properties (temperature and resistivity), water-quality, optical image, acoustic image, and full waveform sonic. Flow meter and fluid property logs were conducted under ambient and stressed (pumping) conditions.

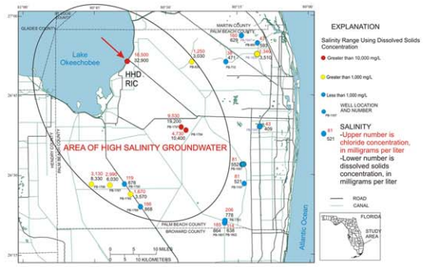


Core photograph and thin-section photomicrograph from the gray limestone aquifer or Zone 3.



The HHD R1C is located approximately 500 to 600 ft from the top of the Dike and on the eastern landward side of the Dike near the toe of the Dike

Aerial Photo of Herbert Hoover Dike Reach 1C site (HHD-RIC)

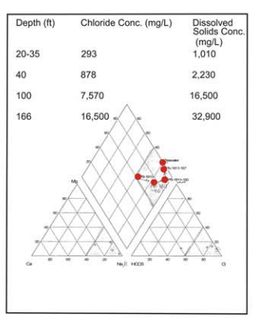


Study Area, Location of HHD RIC site, Wells Sampled, and Chloride and Dissolved Solids Concentrations Measured

Thief or Kemmerer Sampler for collecting a sample at a particular depth

Series	Lithostratigraphic units	Approximate thickness (feet)	Lithology	Correlation Marker	Hydrogeologic unit: Previous Studies WEST	Previous Studies EAST	This Study WEST	This Study EAST
HOLOCENE	UNDIFFERENTIATED	0 - 5	Marl, peat, organic soil, quartz sand					
PLEISTOCENE	PAMLICO SAND	0 - 80	Quartz sand with some shell beds, sandstone and limestone					
	MIAMI LIMESTONE	0 - 12	Oolitic limestone, quartz sand and sandstone					
	ANASTASIA FORMATION	0 - 140	Coquina, shell, quartz sand and sandy limestone					
	FORT THOMPSON FORMATION	0 - 50	Marine limestone and minor gastropod-rich freshwater limestone, quartz sandstone and sandy limestone					
	CALOOSAHATCHEE MARL	0 - 507	Sandy to shelly marl, clay, silt and quartz sand					
PLIOCENE	PINECREST SAND MEMBER	20 - 100	Quartz sand, pelecypod-rich quartz sandstone and sandy limestone, shell, terrigenous mudstone, local abundant phosphate grains	T	SEMICONFINING UNIT	BISCAYNE AQUIFER AND ZONE OF SECONDARY PERMEABILITY	SEMICONFINING UNIT	ZONE 1
	OCHOPEE LIMESTONE MEMBER	40 - 130	Pelecypod lime rudstone and floatstone, pelecypod-rich quartz sand and sandstone, moldic quartz sandstone	O	SEMICONFINING UNIT	GRAY LIMESTONE AQUIFER	SEMICONFINING UNIT	ZONE 2
	PEACE RIVER FORMATION	300 - 500	Quartz sand, sandstone, clay-rich quartz sand, silt, marl, terrigenous mudstone or clay, diatomaceous mudstone, local abundant phosphate grains	H	INTERMEDIATE CONFINING UNIT		INTERMEDIATE CONFINING UNIT	ZONE 3

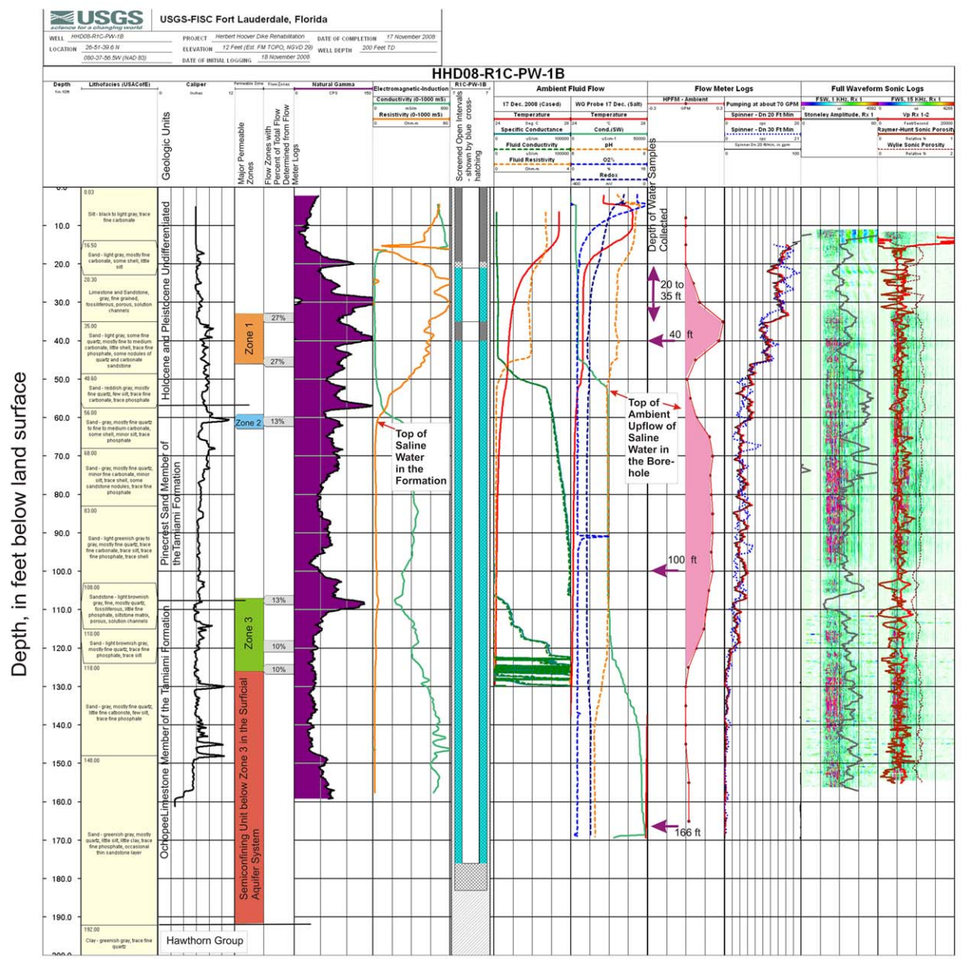
Lithostratigraphic and Hydrogeologic Units in the Study Area



Piper Diagram, -a type of trilinear diagram

Shows 4 samples at HHD R1C site with increasing depth

All samples are Sodium Chloride Water Type and plot with a signature that approaches seawater with increasing depth



Lithologic description and geophysical logs run in Production Well B at the HHD R1C site. Also shown from left to right are major permeable zones, flow zones, open screened intervals in constructed well and depths of water samples collected.

At the aquifer test site, which is near the toe of the dike on the eastern landward side, upwelling of saline water is strongly indicated by geophysical logs and water samples, including measurements of ambient upward flow of saline water in the borehole, reaching upward to a depth of about 50 ft. This upwelling may be caused by flow of groundwater under the dike from the lake.

The depth below land surface of the top of saline water in the formation is 60 ft at this site, as defined by the induction resistivity log, and saline water is present in the lower part of the shallow, more permeable section of the system (zone 2), as well as in the deep, permeable sections (zone 3 and below). This depth of the top of saline water is 60 to 100 ft shallower than typically observed in the surficial aquifer system in central Palm Beach County.

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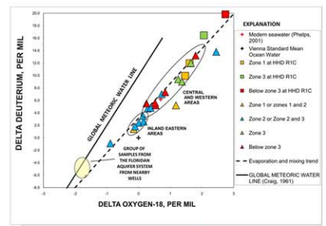
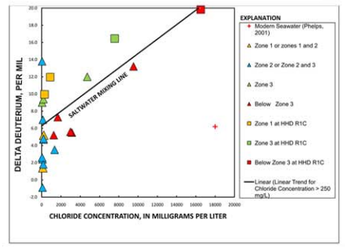
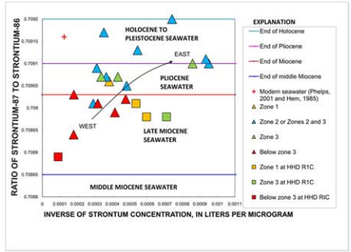


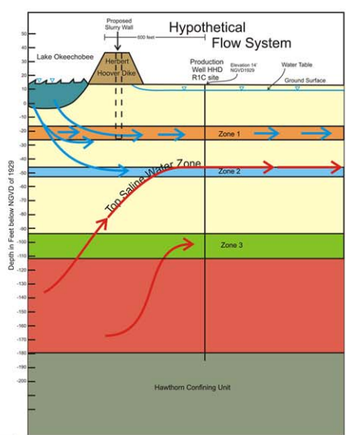
Data plot along a evaporation and mixing trend with the HHD R1C samples falling at the extreme isotopically light end of the trend. This indicates increasing evaporation with increasing salinity. Samples from Floridan aquifer system wells located nearby group at the other end of this trend.



Data plotting along a saltwater mixing line show the range of salinity as indicated by chloride concentration. The high salinity end point of this trend (salinity close to that of seawater), shown by the deepest sample from the HHD R1C site, plots at much more isotopically light delta deuterium than seawater.



Generally, data plot with a lower strontium concentration and younger indicated seawater age from west to east. Except for the 4 samples from the HHD R1C site, the indicated age is similar to the age of the rocks from which the water came, based on correlation with the age of the formations. All of the HHD R1C samples indicate an age that is older than the interpreted age of the rocks, but they are not older than a seawater age of Late Miocene.



Conclusions:

- The strontium isotope ratios of water samples from four depths at the HHD R1C site indicate a seawater age older than the probable ages of the formations from which the water came, but probably not older than the age of the deepest sediments in the surficial aquifer system.
- Based on the salinity of this water, which can approach that of seawater and the strontium, hydrogen and oxygen isotope data, this water is indicated to have a residual, shallow origin rather than a deep origin. It may have resulted from invasion of the aquifer system during high stands of sea level occuring in the Pleistocene.
- These data do not provide evidence for the upwelling of brackish or saline water from a deeper aquifer system, such as the Floridan, but some contribution from a deeper aquifer cannot be ruled out.
- Upwelling of saline ground water at the HHD R1C site is indicated and may be caused by flow of groundwater under the dike from Lake Okeechobee due to the high head in the lake.

Publications:

Reese, R.S. and Wacker, M.A., 2009, Hydrogeologic and Hydraulic Characterization of the Surficial Aquifer System, and Origin of High Salinity Groundwater, Palm Beach County, Florida: U.S. Geological Survey Scientific Investigations Report 2009-5113, 42 p.