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# Borehole Geophysical Logging Program: Incorporating New and Existing Techniques in Hydrologic Studies

## Overview

The borehole geophysical logging program at the U.S. Geological Survey (USGS)-Florida Integrated Science Center (FISC) provides subsurface information needed to resolve geologic, hydrologic, and environmental issues in Florida. The program includes the acquisition, processing, display, interpretation, and archiving of borehole geophysical logs. The borehole geophysical logging program is a critical component of many FISC investigations, including hydrogeologic framework studies, aquifer flow-zone characterization, and freshwater-saltwater interface delineation.

## New Borehole Geophysical Logging Capabilities in Florida

In addition to acquiring standard borehole-log information such as caliper, gamma, spontaneous potential, and electromagnetic induction data (table 1), FISC utilizes new technologies and procedures to generate advanced logs. Of particular importance are digital borehole imaging and electromagnetic flowmeter logging, both of which are now used to augment existing techniques.

Digital borehole optical televiewers equipped with a high-resolution cameras can create detailed, 360-degree images of borehole walls and simultaneously collect borehole deviation data. The digital borehole images can be used to (1) accurately determine the depths for a well completion interval, (2) position a recovered core to its proper depth, (3) acquire a high-resolution borehole image that serves as a surrogate for intervals having no core recovery (Ward and others, 2003), and (4) characterize aquifer pore systems. Fracture and bedding plane orientations can also be determined, because borehole images can be oriented to magnetic north. In combination with a new digital log acquisition system, a digital borehole image can be acquired at relatively high logging speeds (about 3-15 feet per minute, depending on desired pixel density). Various log presentation software can be used to display these images, as well as standard logs on multilog-paper displays up to 36 inches wide. A digital copy of the display can be viewed on a computer using nonproprietary software readers.

To address difficulties in accurately quantifying relative transmissivity in aquifer flow zones, FISC is now using an electomagnetic flowmeter to accurately measure flow at intermediate velocities. Previously, heat pulse flowmeters and spinner flowmeters were solely used to measure flow across all velocities. Heat pulse flowmeters, however, can only measure low-velocity flow and do not generate continuous logs. Spinner flowmeters adequately measure high velocity flow and generate continuous logs, but quantifying the amount of flow from spinner revolutions is time consuming and difficult. The electromagnetic flowmeter accurately measures medium flow velocities, generates a continuous log of flow velocity and direction, and can make stationary measurements like the heat pulse flowmeter. The logs generated by the electromagnetic flowmeter can help show the relative transmissivity of flow zones within a well. A fluid meter built into the tool also displays changes in temperature and fluid resistivity, which also aids in the identification of flow zones.

Although most borehole geophysical log acquisition is performed from a vehicle, equipment portability also allows easy transport to remote well sites, such as those in offshore marine or wetland environments. Wells up to 3,200 feet deep and greater than 2 inches in diameter can be accommodated, providing access to all major aquifers in Florida, including much of the Floridan aquifer system.

## FISC Hydrologic Investigations Employing Borehole Geophysical Logging Techniques

Geophysical logs run in exploratory or investigative boreholes can provide valuable hydrogeologic information, especially in areas with poor lithologic and (or) hydrologic control. Geophysical logs also can provide much needed information to help in determining the correct placement of well completion depths or intervals. The acquisition of borehole geophysical logs can become the determining factor in solving complex subsurface issues. The following studies highlight new and existing techniques used by FISC to resolve geologic, hydrologic, and environmental issues.

### Hydrogeologic Framework Studies

Partially recovered core samples typically can only be placed within a 5- to 10-foot range of core barrel depth. Placement of core material or recognition of void space within these poor recovery intervals is often difficult using examination of the core and standard borehole geophysical methods. With the aid of a digital optical borehole image log, a trained user can accurately