# Inventory and Review of Aquifer Storage and Recovery in Southern Florida

**Problem**

Aquifer storage and recovery (ASR) in southern Florida has been proposed on an unprecedented scale as part of the Comprehensive Everglades Restoration Plan (CERP). Smaller scale ASR wells have been constructed, and in most cases tested, at 27 sites in southern Florida, mostly by local municipalities or counties in coastal areas. The Upper Floridan aquifer, the principal storage zone of interest to the Restoration Plan, is the aquifer being used at 22 of the sites. The aquifer is brackish to saline in southern Florida, which can greatly affect the recovery of the freshwater recharged and stored.

**Purpose**

The purpose of this study is to inventory and compile data for existing ASR sites in southern Florida and identify various hydrogeologic, design, and management factors that control the recovery of freshwater injected (recharged) into ASR wells. Each cycle during testing or operation includes periods of recharge of freshwater, storage, and recovery that each last days or months. Cycle testing data include calculations of recovery efficiency, which is the percentage of potable recharged water recovered for each cycle.

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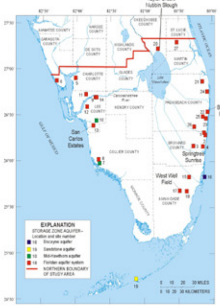


ASR sites in southern Florida and storage zone aquifer. Locations of five case studies are indicated.

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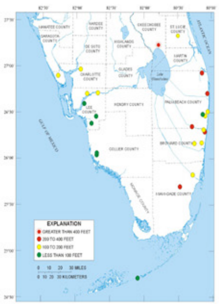


Thickness of storage zone in ASR wells, in feet.

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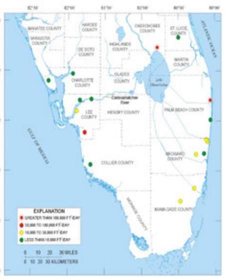


Transmissivity for storage zone in the Floridan aquifer system, in ft²/day.

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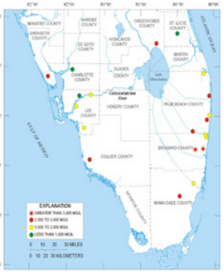


Ambient chloride concentration in storage zone in the Floridan aquifer system, in mg/L.

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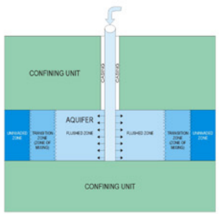


ASR well in a confined aquifer depicting idealized flushed and transition zones.

### Some Factors to Consider for Successful ASR as Defined by Recovery Efficiency:

- Transmissivity of storage zone
- Degree of confinement
- Native water salinity
- Structural setting
- Thickness of open interval (storage zone)
- Distribution of permeabiltiy in storage zone or dispersivity
- Depth of top of open interval compared to top of aquifer
- Volume recharged during a cycle
- Number of repeated cycles

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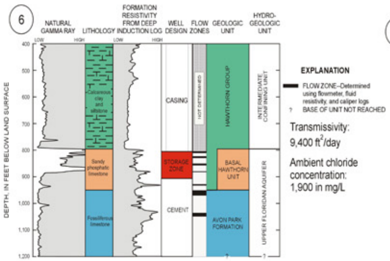


Boynton Beach ASR well in Palm Beach County. Storage zone is thin and located at the top of the Upper Floridan aquifer.

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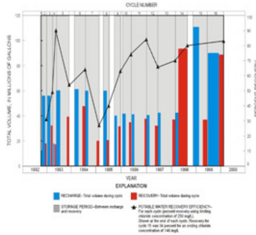


Recharge, storage, and recovery cycles for Boynton Beach ASR well. Recovery efficiency has improved to over 80 percent.

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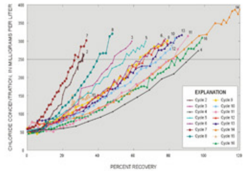


Chloride concentration during recovery for each cycle for Boynton Beach ASR well. Shows 250 mg/L chloride concentration limit for potable water. Recovery for cycle 14 was continued until a chloride concentration of about 1,000 mg/L was reached.

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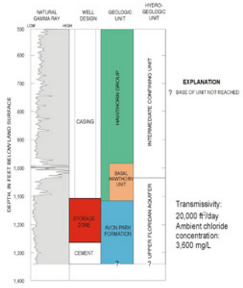


Springtree Sunrise ASR well in Broward County. Top of storage zone is 70 feet below top of the Upper Floridan aquifer.

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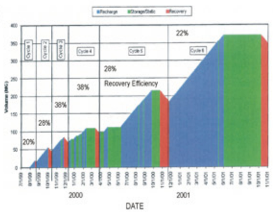


Springtree-Sunrise ASR cycle testing volumes and recovery efficiencies. Recovery efficiencies did not improve with repeated cycles or increased recharge volume per cycle. Poor recovery efficiencies could be explained either by the storage zone not located at the top of the aquifer or high ambient chloride concentration or both. Source of chart: *Montgomery Watson Harza, 2002, Springtree WTP ASR system cycle testing report-cycles 1 through 6.*

11


Springtree Sunrise ASR well head, piping, valves, and control system

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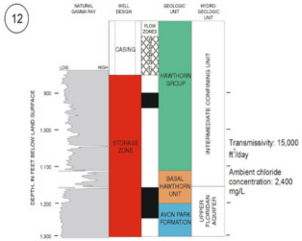


West Well Field ASR well number 1 in Miami-Dade County. Storage zone is 452 feet thick and includes 310 feet of intermediate confining unit. Recovery efficiency for cycle 3 was 40.5 percent. This cycle included 3 ASR wells that recharged a combined volume of 714 million gallons.

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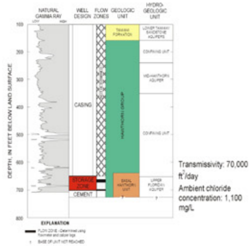


San Carlos Estates ASR well in Lee County. Transmissivity of storage zone is very high and recovery efficiency was poor (about 3 percent for 2 or 3 cycles).

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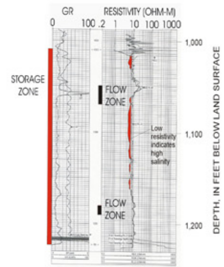



Recently constructed Palm Beach County Eastern Hillsborrow WTP 9 ASR well completed in the Upper Floridan aquifer. Shows gamma-ray and resistivity borehole geophysical log. Water sample of storage zone had a chloride concentration of 1,900 mg/L, but the chloride concentration of ground water calculated from the borehole resistivity curve is much higher for most of the storage zone, as high as 5,000 mg/L. This could negatively affect recovery efficiencies.

**Findings:**

Potable water recovery efficiencies for 16 of the 27 sites were calculated and, generally, recovery efficiency improves with the number of cycles. Except for two sites, the highest number of cycles was five. Only nine sites had a recovery efficiency above 10 percent for the first cycle or two. However, at two out of the other seven sites, low recharge volumes per cycle of less than 10 million gallons (Mgal) could explain the poor recovery. Ten sites achieved a recovery efficiency above 30 percent during at least one cycle. The highest recovery efficiency achieved per cycle was 84 percent for cycle 16 at the Boynton Beach site. Recharge volume per cycle ranged from 0.6 to 714 Mgal and averaged 95 Mgal for 55 cycles at 14 Upper Floridan aquifer sites.

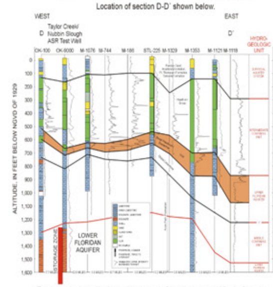
Based on review of four case studies and data from other sites, several hydrogeologic and design factors appear to be important to the performance of ASR in the Floridan aquifer system. Performance is maximized when the storage zone is thin and located at the top of the Upper Floridan aquifer, and transmissivity and ambient salinity of the storage zone are moderate (less than 30,000 ft²/d and 3,000 mg/L of chloride concentration, respectively). High transmissivity can adversely affect recovery, because it may equate to high dispersive mixing in a limestone aquifer. Additionally, depending on the ambient salinity of the storage zone, the probability of buoyancy stratification increases as transmissivity increases. At three sites that have transmissivities above 70,000 ft²/d, with 3 to 5 cycles at each recovery efficiencies over 10 percent per cycle were not obtained. Results from the first phase of this project are provided in Reese (2001).

**Publications:**

Reese, R.S., 2001, Inventory and review of aquifer storage and recovery in southern Florida: U.S. Geological Survey Water Resources Investigation Report 02-4036, 56 p.

15


Location of section D-D' shown below.




East-west hydrogeologic section through Okeechobee and Martin Counties. Shows storage zone in the Taylor Creek/Nubbin Slough ASR test well. Storage zone is in the Lower Floridan aquifer in a dolostone sequence that has a transmissivity of 590,000 ft²/day. Recovery efficiencies were poor (7 percent or less for 3 cycles).

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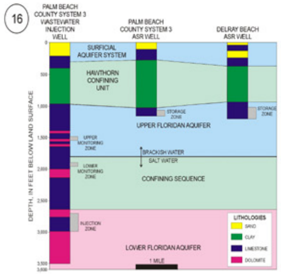


Section in Palm Beach County showing relation of a deep injection well to two ASR wells.

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