Comprehensive Everglades Restoration Plan
Aquifer Storage and Recovery Program

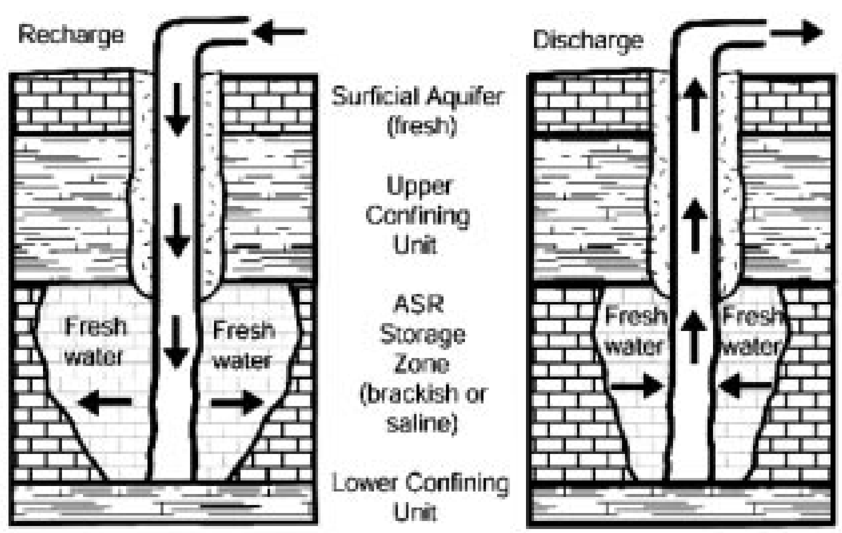
This document provides an overview of the proposed strategy for implementing aquifer storage and recovery (ASR) projects under the Comprehensive Everglades Restoration Plan (CERP). This document includes a summary of the concerns that have been identified by informed individuals and other interested stakeholders, an overview of the ASR technology, and a review of the associated uncertainties and a possible strategy for addressing them.

ASR facilities have been used in the United States for over 30 years and they were first operational in Florida in 1983. Currently, there are seven ASR facilities operating in Florida and at least twelve undergoing operational testing. The facilities are being used to inject and recover treated and untreated groundwater, partially treated surface water, and reclaimed wastewater. In general, the public poorly understands this technology and many people have questions regarding the application of ASR as a water resource conservation tool. However, ASR is not an unknown and untested technology.

How ASR Works

ASR refers to the process of recharge and storage of water in an aquifer system during times when water is plentiful (typically during the wet season in south Florida), and recovery of the stored water during times when it is needed. ASR can function in the manner of a traditional surface water reservoir; however, aquifer storage eliminates evaporative losses (which can be relatively large), and the requirement to convert large land areas into reservoirs. It may also increase availability of large volumes of water during severe, multi-year droughts to augment deficient surface water supplies for the human and natural system. **Figure 1** depicts a schematic diagram of an aquifer storage and recovery system.

FIGURE 1
SCHEMATIC DIAGRAM OF AN ASR SYSTEM



Most operational ASR facilities in Florida store treated drinking water in the upper Floridan Aquifer, mostly in areas where the aquifer contains brackish water. As part of the ASR concept in south Florida, excess surface or ground water is stored during the wet season, a time of the year when demands are low. Water is injected and displaces native water in the aquifer to form a 'freshwater bubble.' The shape of this 'bubble' may be highly irregular depending on aquifer system physical properties (e.g., fractures, conduits, and variable permeability). Injected freshwater is later withdrawn from the aquifer during high demand, dry summer months. When recovered from the aquifer, this water normally requires only disinfection before being conveyed to the water distribution system. **Figure 2** depicts the locations of the 50 ASR facilities in Florida that are either constructed or proposed

FIGURE 2
ASR FACILITIES

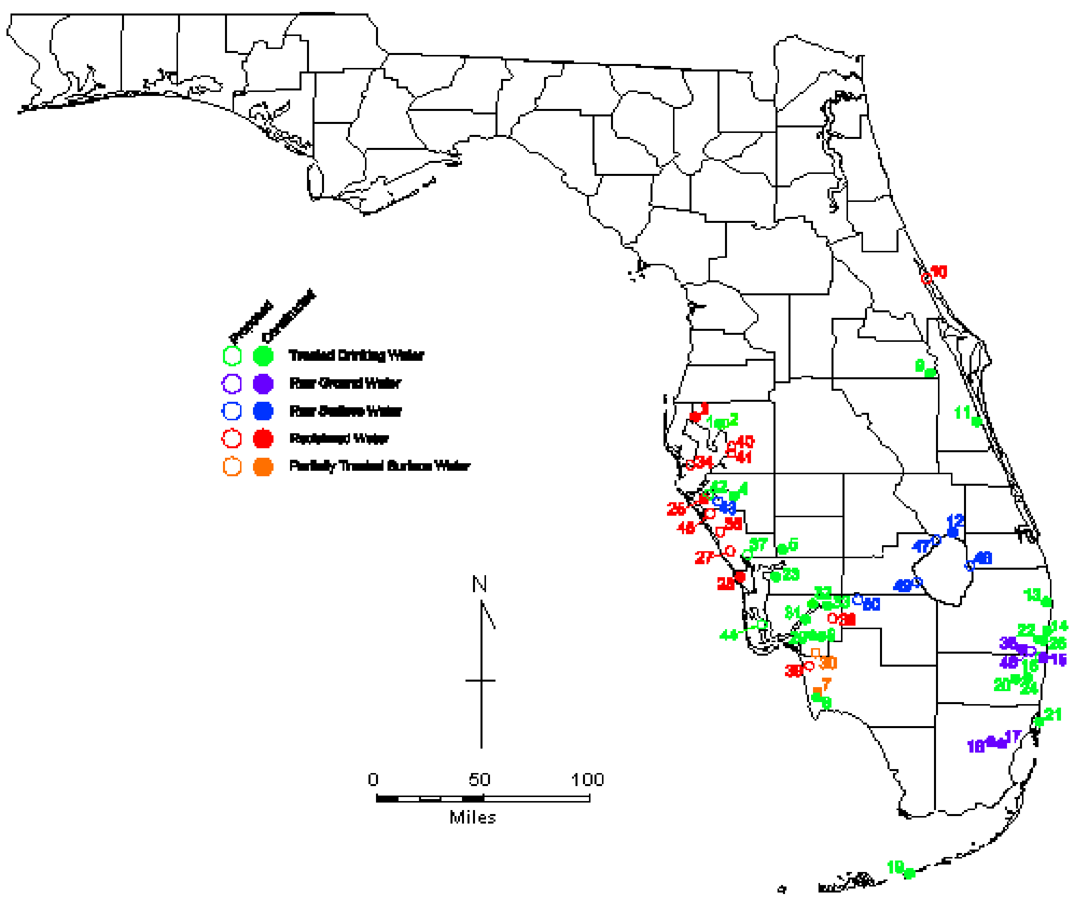


Table 1 lists these facilities and their status as provided by the Florida Department of Environmental Protection..

TABLE 1
ASR FACILITIES IN FLORIDA

Map #	Facility Name	Number of Wells	Capacity (MGD per Well)	Total Capacity (MGD)	ASR Type*	STATUS (from FDEP)				
						Construction Application Received	Construction Permit Issued	Well Constructed	Operation Testing	Operation Permit Issued
1	Tampa – Rome Avenue	8	1.3	10.0	TDW				X	X
2	Tampa – Hillsborough River	20	2.0	40.0	TDW		X			
3	Hillsborough County NW	1	1.5	1.5	RCW				X	
4	Lake Manatee	6	2.1	12.6	TDW		X			X
5	Peace River	21	1.0	21.0	TDW			X		X
6	Corkscrew (Lee County)	6	0.6	3.9	TDW				X	X
7	Marco Lakes	9	2.0	18.0	PTS			X	X	
8	Collier County	1	1.0	1.0	TDW					X
9	Cocoa - Claude H. Dyal	10	1.0	10.0	TDW				X	X
10	New Smyrna Beach Exploratory	1 Expl.	N/A		RCW		X			
11	Palm Bay	1	1.0	1.0	TDW					X
12	Taylor Creek ASR	1	5.0	5.0	RSW				X (not used)	
13	West Palm Beach ASR	1	8.0	8.0	interim PTS				X	
14	Boynton Beach ASR	1	6.3	6.3	TDW				X	
15	Broward County 2A Wastewater Treatment Plant	1	6.3	6.3	RGW				X	
16	Deerfield Beach ASR	N/A	Withdrawn		TDW	X				
17	Miami-Dade Southwest Wellfield	2	5.0	10.0	RGW			X		
18	Miami-Dade West Wellfield	3	5.0	15.0	RGW				X	
19	Florida Keys Aqueduct Authority Marathon	1	0.3	0.3	TDW				X (not used)	
20	Sunrise Springtree	1	2.0	2.0	TDW				X	
21	Miami Beach ASR	1	50 test		TDW				X	
22	Palm Beach County System #3	1	1.0	1.0	RGW			X		
23	Punta Gorda	4	1.4	5.6	TDW	X		X		
24	Fiveash Wastewater Treatment Plant	1	2.0	2.0	RGW				X	
25	Manatee Southwest	1	1.0	1.0	RCW			X		
26	Delray Beach	1	3.7	3.7	TDW				X	
27	Sarasota-Venice Gardens	1	2.0	2.0	RCW	X				
28	Englewood	1	1.0	1.0	RCW			X		
29	San Carlos Estates (Bonita Springs Utilities)	1	1.0	1.0	TDW				X	
30	Kehl Canal (Bonita Springs Utilities)	1	3.0	3.0	PTS		X			
31	Fort Myers	1	1.0	1.0	TDW			X		
32	North Reservoir (N. Ft. Myers)	1	1.0	1.0	TDW				X	
33	Olga	1	1.0	1.0	TDW			X		
34	St. Petersburg SW	1	1.5	1.5	RCW		X			
35	CERP Pilot -W. Hillsboro Basin	1 Expl.	N/A		RGW			X		

Map #	Facility Name	Number of Wells	Capacity (MGD per Well)	Total Capacity (MGD)	ASR Type*	STATUS (from FDEP)				
						Construction Application Received	Construction Permit Issued	Well Constructed	Operation Testing	Operation Permit Issued
36	Sarasota-Central County	1	1.0	1.0	RCW	X				
37	North Port-Myakkahatchee Creek	1	unknown		PTS	X				
38	Lehigh Acres	4	1.0	4.0	RCW		X			
39	North Collier County (Expl.)	1 Expl.	N/A		RCW	X				
40	Hillsborough-Cargill Park	1	1.0	1.0	RCW	X				
41	Hillsborough-South County	1	1.0	1.0	RCW	X				
42	Bradenton-HSPS Site	1	3.0	3.0	TDW	X				
43	Bradenton-Bill Evers Reservoir	10	5.0	50.0	RSW	X				
44	Pine Island	1	1.0	1.0	TDW	X				
45	City of Sarasota-Payne Park	1	1.5	1.5	RCW	X				
46	Eastern Hillsboro Canal	1	5.0	5.0	RGW	X				
47	CERP Pilot-Lake Okeechobee-Kissimmee River Site Expl.	1	5.0	5.0	RSW					
48	CERP Pilot-Lake Okeechobee-St. Lucie Canal Site Expl.	1	5.0	5.0	RSW					
49	CERP Pilot-Lake Okeechobee-Caloosahatchee River Site Expl.	1	5.0	5.0	RSW					
50	CERP Pilot-Caloosahatchee Reservoir Expl.	1	5.0	5.0	RSW					
	TOTALS	**21**		**82.5**						

***ASR Types:** TDW-Potable through drinking water plant; RSW-Raw surface water; PTS - Partially treated surface water; RGW-Raw ground water; RCW-Reclaimed water

X_A: Three additional wells proposed at time of the pre-application meeting for the exploratory well.

While most of these facilities are not in full operation, they will provide a vast amount of data to support planning of the ASR concept as proposed for the CERP. Further, the operational ASR facilities in Florida are used for seasonal storage, storing water during the wet season and recovering it during the following dry season. The CERP proposes to use ASR to assist in even longer-range water supply planning bystoring water during wet years and delaying recovery until it is needed years later. It is uncertain if such an application of ASR is feasible in south Florida. Data obtained from pilot projects and other ASR facilities will be used to help reduce these and other uncertainties.

What is CERP?

South Florida's existing water management system, the Central and Southern Florida (C&SF) Project, includes many miles of canals and levees with many water control structures that provided water supply, flood protection, water management and other benefits to south Florida. In the mid-1990s, Congress asked the U.S. Army Corps of

Engineers to review the current C&SF Project and develop a plan to restore the South Florida natural ecosystem, while enhancing water supplies and maintaining flood protection. Unlike previous studies, this review took a system-wide look at the water system.

The CERP was designed to enlarge the region's supply of fresh water and to improve how water is delivered to the natural areas, using a variety of technologies. The fundamental keys to restoration were identified as:

- Increase the amount of water available
- Ensure adequate water quality
- Reconnect the parts of the system that had been disconnected by canals and levees

Generally speaking, the CERP enhances the system by retaining excess water that previously was discharged to the ocean, causing damage to estuarine areas along the coast. Under the CERP, much of this water is retained within the system thereby creating 'new water' for distribution. Among the water storage methods proposed in the CERP are ASR, surface water reservoirs, water preserve areas, and abandoned limestone quarries.

ASR and its Role in CERP

The Comprehensive Everglades Restoration Plan relies heavily on ASR technology. The CERP includes approximately 333 ASR wells in South Florida with a total capacity of over 1.6 billions gallons per day. Much of the 'new water' in the CERP is derived from storing excess water that was previously discharged to the ocean. About 3 million acre-feet (about 1 trillion gallons) of fresh water is discharged to the Atlantic Ocean each year. However, this new water would not be very useful unless there is a place to store it for use during dry periods. ASR is included in the CERP as one mechanism to provide this storage. One of the primary advantages of ASR is the potential to store water for long periods of time. This multi-year carry-over capacity is critical for meeting future environmental, agricultural, and urban water supply demands

The ASR facilities proposed in CERP have different purposes for different areas. For this reason, the major applications have to be considered differently for the Lower East Coast, Caloosahatchee River Basin, and the Lake Okeechobee ASR components of CERP.

The primary purpose of ASR in the Lower East Coast is to provide dry season regional benefits to the Biscayne Aquifer - the area's primary water supply source. ASR is used to recharge the aquifer during drought conditions, thus enhancing water supply. Some secondary benefits are associated with flood management when co-located with a surface reservoir.

The purpose of ASR in the Caloosahatchee River Basin is to provide dry-season regional surface water deliveries to the Caloosahatchee River for both water supply (for utilities and agriculture located along the river) and minimum flows to the Caloosahatchee Estuary. Currently, there is no minimum flow delivered to the estuary, which leads to hypersalinity. Utility and agricultural water supply needs are met from Lake Okeechobee only after groundwater sources are depleted. There are secondary flood management benefits from the proposed Caloosahatchee ASR Project since it is combined with a surface storage reservoir.

The primary purpose of ASR wells around the Lake Okeechobee area is to provide an alternate source of water for the region, thereby improving the health of the lake, especially during low stage periods and prolonged high stage periods. There are secondary benefits to the Caloosahatchee and St. Lucie Estuaries due to an incremental reduction of regulatory-driven water releases, as well as a more reliable water supply for urban and agricultural interests in South Florida.

Issues of Uncertainty pertaining to ASR

While considerable knowledge on ASR technology has been gained over the last five decades, the proposed implementation scale for ASR to meet the objectives of the CERP has never been applied. The largest operational ASR site to date is at Las Vegas, Nevada, with about 30 wells and a total recovery capacity of 100 million gallons per day. A considerable number of significant uncertainties remain.

An ASR Issue Team was formed in September 1998 under the auspices of the South Florida Ecosystem Restoration Task Force for the explicit purpose of addressing the surface water, hydrogeological and geochemical uncertainties associated with large-scale ASR operations. In July 1999, the ASR Issue Team produced a paper entitled "Aquifer Storage and Recovery Issue Team Assessment Report and Comprehensive Strategy". That report identified seven critical issues associated with implementing ASR facilities on the scale proposed by the CERP.

Further, an independent scientific and technical review board, the Committee on the Restoration of the Greater Everglades Ecosystem (CROGEE) working under the auspices of the National Research Council, was created to provide scientific guidance to agencies tasked with the implementation of CERP. In late 2000, CROGEE reviewed the implementation strategy for the three ASR pilot projects and the ASR regional study to address uncertainties associated with the full-scale ASR implementation as proposed in the CERP.

In their report that was distributed in February 2001, CROGEE concluded that, "…*the pilot projects provide a valuable means for acquiring detailed information on ASR performance at a few specific sites. However, even if all the sites tested prove successful, they will not by themselves demonstrate the feasibility of ASR implementation regionally at the scale of 1.7 billion gallons per day (6.3 million* m^3*/day). A regional study* *involving construction of a regional flow model is an invaluable and indispensable tool to assess feasibility of ASR at the proposed scale.*" (Available online at http://books.nap.edu/catalog/10061.html).

The CROGEE report recommends three general areas in which additional data and studies are required to address uncertainties related to feasibility and optimal design of regional ASR systems intended to provide storage required by CERP. These areas include regional science issues, water quality issues, and local performance/feasibility issues. The seven issues identified by the ASR Issue Team in 1999 were considered as part of their assessment and in these recommendations and are summarized below.

Source Water Quality

Laws and regulations governing the quality of drinking water require that the source water for ASR meet drinking water standards prior to injection. Many CERP ASR components have conservatively assumed ultra-filtration treatment requirements prior to the injection of source water into the aquifer. This conservative design was based on the assumption that coliform bacteria (a primary drinking water standard) are present in surface water. These bacteria could be removed prior to ASR injection, but the ultra-filtration process is expensive, and there is a potential for the bacteria to die-off within the aquifer. Chlorination can be used to neutralize bacteria, but use of chlorine to treat highly organic water generates carcinogenic chlorination bi-products (Trihalomethanes).

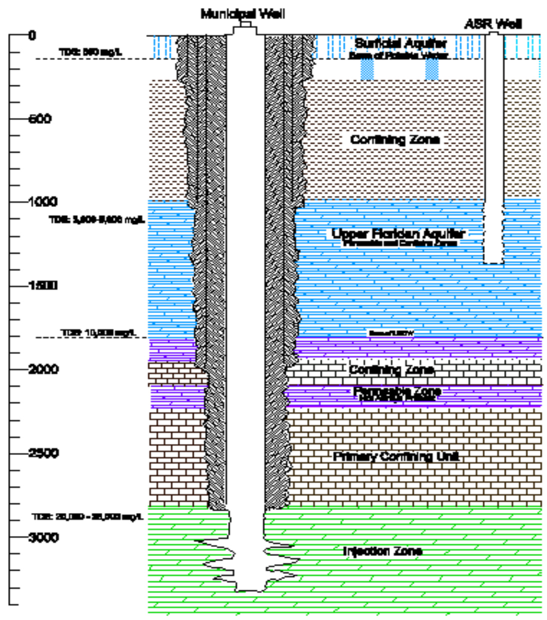
Uncertainties about Regional Hydrogeology of the Floridan Aquifer System

Limited information exists on the vertical and lateral distribution of the aquifer system, including confining layers (**Figure 3,** next page) in the proposed location of the ASR wells, both on site-specific basis and on a regional basis. This information is critical to the successful construction and operation of the ASR wells. Further, within the region covered by the CERP, migration of injected treated wastewater from lower portions to upper portions of the Floridan Aquifer System has been documented (some utilities use deep-underground injection wells (DIW) to dispose treated wastewater in lieu of ocean or river outfalls). DIWs located in Miami-Dade County are not in the immediate vicinity of the proposed CERP ASR facilities. However, the potential for upward migration of water (treated wastewater of formation water) from deeper portions of the Floridan Aquifer System has been identified as an issue.

Rock Fracturing

Although ASR has serves as an effective tool to help meet water supply demands, there is concern that simultaneous operation of several hundred ASR wells could result in a buildup in pressure sufficient to initiate fracturing of the aquifer system or cause existing fractures to become more severe. Fracturing could result in loss of stored water, as well as result in mixing water previously separated by strata that confine vertical flow of ground water.

FIGURE 3
TYPICAL DEEP-UNDERGROUND INJECTION WELL
And
ASR WELL IN SOUTH FLORIDA



<u>Regional Changes in Pattern of Flow</u>
Simultaneous operation of multiple ASR wells may result in an increase of pressure within the aquifer, potentially resulting in changes in local and regional flow patterns. These changes could impact existing ASR facilities, supply wells , and wells designed to monitor the upward leakage of effluent from deep-underground injection wells used to dispose secondary-treated municipal wastewater.

<u>Water Quality Changes</u>
There is a potential for water quality changes to occur due to chemical interaction between the injected water and both the native ground water and the aquifer system matrix (i.e., rocks). Surface water is usually rich in dissolved oxygen, whereas most confined aquifer systems are oxygen depleted. Injection could cause remobilization or increase the concentration of naturally occurring chemical constituents, including trace metals and radionuclides. Water recovered from the ASR facility will be monitored for these constituents. Likewise, the quality of recovered water will be evaluated to ensure that it will not cause or contribute to violations of water quality standards.

<u>Mercury Bioaccumulation</u>
Currently, there is no information about whether ASR will exacerbate the Everglades mercury problem. However, water recovered from ASR wells is likely to contain higher levels of sulfate and chloride than pre-injection water. These chemicals have been shown to play a role in the cycling of mercury in aquatic ecosystems. The potential for changes

in pH, chloride, and sulfate, must be evaluated to address the risk of increasing the toxic forms of mercury.

Anticipated Recovery Rates and Volume Required for Recharge
Recovery rates and the volume of water required for recharge are directly related to the properties of the rock material of the aquifer system. However, porosity plugging due to particulate matter and chemical reaction could, over time change these properties. Further, the number and size of other ASR wells operating in an area may also affect the efficiency of individual ASR systems. The CERP assumed that 70% of the total recharge volume is recoverable, which may be optimistic.

Implementation Strategy

Implementation of ASR technology under CERP will be conducted over the next 20 years. The strategy for addressing the uncertainties described previously is a combination of a regional study and the three pilot projects. Further, CERP is based on the principle of adaptive management in which an interactive mechanism is provided to evaluate the effectiveness of CERP implementation and to refine future program phases to achieve the plan's objectives. Built-in contingency planning also makes use of new information and technology throughout the life of the CERP.

In general, the proposed regional ASR study will address both regional science issues and some water quality issues identified by CROGEE. The pilot projects will address the local performance/feasibility issues and water quality issues important to an individual site analysis. Information from all the pilot projects and the regional study will be collectively synthesized in the overall feasibility assessment of regional ASR implementation recommended by CROGEE.

The three proposed pilot projects (with start dates) are Western Hillsboro ASR Pilot Project (2000), Lake Okeechobee ASR Pilot Project (2000), and the Caloosahatchee ASR Pilot Project (2001). The pilot projects will provide information necessary to evaluate ASR technology at individual sites, and also provide some relevant information needed for the regional evaluation. For example, the pilot projects will address concerns associated with source water quality by establishing a rigorous and regular water quality sampling protocol that documents how source water changes over a wide variety of conditions throughout the year. In this way, operators can determine what level of pre-treatment is needed prior to storage in the aquifer.

To address the water quality changes that can occur while the stored water is in the aquifer, the pilot projects will establish additional pre- and post-injection water quality monitoring to understand and anticipate water quality changes. Monitoring wells located in proximity of ASR wells will evaluate water quality variations within the aquifer as well. The pilot projects will also provide detailed hydrogeologic testing of selected ASR and test wells to obtain aquifer parameter data. Additionally, numerical models of the local sites will assist in optimizing ASR well placement.

The regional study is scheduled to begin in 2001 and will be conducted parallel to the pilot projects. It will address the concerns of the full-scale ASR system and consider the regional interference implications of many ASR wells. The collaborative use of data, interpretive information, and scientific conclusions among all ASR projects will help to raise the knowledge level of ASR technology, and should reduce uncertainties currently associated with the regional implementation of an ASR infrastructure in south Florida.

To assess the impacts of the full-scale ASR implementation as proposed in CERP, the regional study will include hydrogeologic and hydrologic exploration and characterization as well as the development of a regional groundwater model that can simulate large-scale movement of water across broad areas. Expertly planned, it is envisioned that the regional study will be conducted in three phases to provide feedback to the pilot projects and for contingency planning, if necessary. Issues identified by the 1999 ASR Issue Team and the CROGEE report are also being addressed in the regional study.

In combination, the regional study and ASR pilot projects are designed to resolve uncertainties posed by the ASR issue team and incorporate the technical suggestions of CROGEE. Ultimately, these projects can answer the basic question: Will a regional ASR infrastructure function as designed?

What if ASR Doesn't Work?

The proposed scale of ASR in the Comprehensive Everglades Restoration Plan is unprecedented. Accordingly, significant uncertainties remain. These uncertainties make people uncomfortable about solely relying on the extensive use of ASR as part of the CERP to achieve restoration goals. There is little doubt that ASR will work nearly everywhere in South Florida at some scale and some degree of efficiency. In the event, however, that ASR implementation in some (or all) areas is not feasible, contingency plans have been considered.

During the planning of the CERP, alternative ASR performance scenarios were considered. These scenarios included reduction of ASR recovery efficiency from 70% to 30% and eliminating proposed ASR facilities. The scenarios with decreased ASR efficiency at the Caloosahatchee and Lower East Coast Basins required additional water from Lake Okeechobee and Water Conservation Area 1 to offset deficits. Scenarios with reduced ASR efficiency for Lake Okeechobee and Lower East Coast Basins show increased discharges to tide and more high flows to Lake Worth Lagoon. The scenario removing Lake Okeechobee aquifer storage and recovery more than tripled Lake Okeechobee regulatory discharges to the St. Lucie Estuary and doubled discharges to the Caloosahatchee Estuary. In addition, if the Lake Okeechobee ASR is removed, southerly discharges from the lake to the Everglades Agricultural Storage Area and Water Conservation Areas would increase.

Based on these scenarios, potential alternative plans were considered. These alternatives included desalinization plants, increasing the capacity and number of surface storage reservoirs, and increasing Lake Okeechobee water levels. These alternatives have consequences that make them less desirable than the present ASR technology proposed in the CERP. Specifically, reservoirs require extensive land resources, which can adversely impact the economy and/or the environment. Desalinization requires more deep-well injection or other environmentally harmful deposition of its by-products.

Conclusion

Full-scale implementation of the ASR facilities is expected to proceed over a 20 or more year timeframe. Pilot studies, currently underway are designed to evaluate ASR feasibility in selected locations in South Florida including sites near Lake Okeechobee, the Hillsboro Canal and Caloosahatchee River. The pilot projects will take place over the next 8 years. As a result of the pilot program and a regional ASR study, an informed decision can be made regarding the feasibility of ASR on the scale currently envisioned. If ASR technology is to be used, periodic evaluations will continue. If ASR does not prove to be a viable water conservation alternative, other water supply alternatives exist.