Reservoirs: Florida's Future Sustainable Water Supply

Randall Bushey and D. Edward Davis

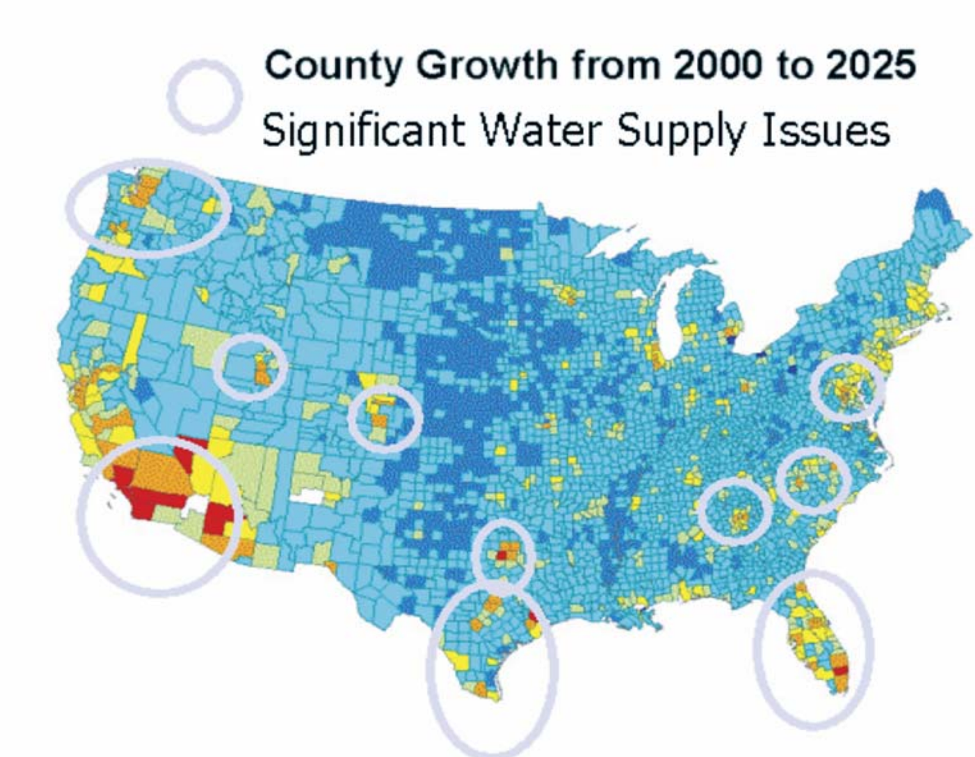

Figure 1. Significant Water Supply Issues in Florida by 2025

(Source: USACE, 2008. U.S. Water Demand, Supply, and Allocation: Trends and Outlook. 2007-R-3. December 22.)

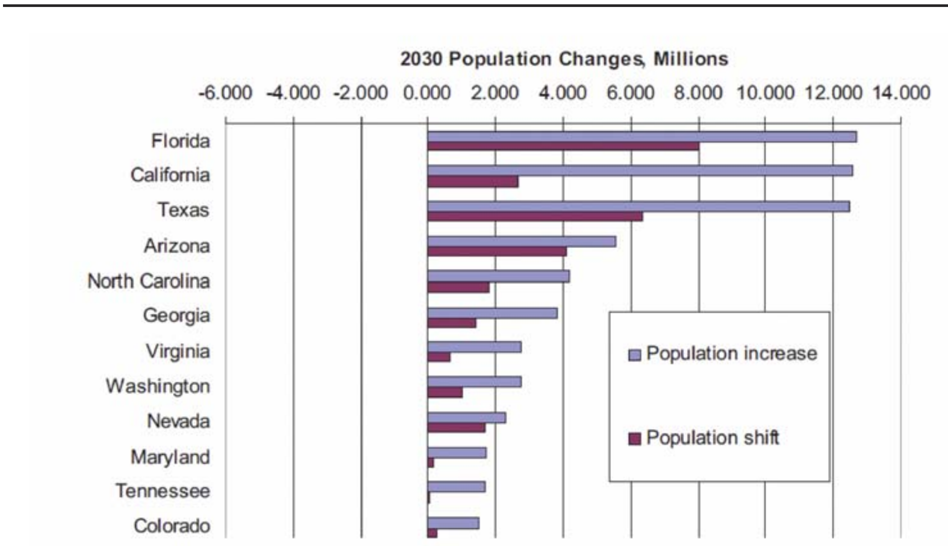

Figure 2. Population Projections for 2030 (Top 12 States)

(Source: USACE, 2008. U.S. Water Demand, Supply, and Allocation: Trends and Outlook. 2007-R-3. December 22.)

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Sustainability of a potable water supply for a growing population and a static or decreasing groundwater supply is a conundrum that is impacting many water supply agencies within peninsular Florida and the southeastern United States. Florida has been recognized by the United States Army Corps of Engineers (USACE) Institute of Water Resources as one of 10 hot spots in the lower 48 states that will have significant water supply issues (USACE, 2008) by 2025, based on water availability and population growth (Figure 1).

Given the importance of this issue, alternative solutions have been put forth to augment the water supply and meet future water demands. Examples of alternative solutions for water supply augmentation were identified as follows:

- Surface water storage
- Artificial groundwater recharge through aquifer storage (AS) wells and reclaimed water infiltration through wetlands and rapid rate infiltration basins
- Supplemental desalination capacity of brackish groundwater for urban water supply
- Reclaimed water for replacement of groundwater and potable water used as irrigation (residential and agricultural)
- Conservation of potable water in residential household and irrigation use

The groundwater resources within peninsular Florida have become overextended, resulting in the need for water management districts (WMDs) to restrict future expansion of the resource and limit groundwater withdrawals to currently permitted levels. Even as WMDs are limiting the current and future water use permits, Florida is projected to have the greatest population increase of all the states (Figure 2) between 2015 and 2030, which will intensify the need for sustainable potable water. To bridge the gap between the available, naturally occurring water resources and the future need for water to support the population, other options must be investigated beyond traditional water sources, such as surface water and groundwater.

The annual average rainfall in Florida ranges from about 52 in. in the south Florida and greater Miami area to 42 in. in the Tampa Bay region, with approximately 70 percent of the rainfall occurring during the wet season (June through November). The volume of rainfall occurring during this season results in the discharge of approximately 1 bil gal (BG) of water to tide each day in each region. The sustainability of a future potable water supply requires capture and storage of the wet season stormwater runoff not needed to provide the environmental balance for the tidal estuaries and riverine floodplain ecologies. Capturing a portion of this flow and storing it in reservoirs for future potable water, aquifer recharge, irrigation, and desalination blending sources could assist in meeting the water needs in a future Florida scenario.

Reservoirs are key water resource features that can be used to support alternative solutions for water supply augmentation, including storage of raw (potable) water, capture of stormwater for increased post-event aquifer storage, increased storage of reclaimed water for maximum reuse capability, and as storage for maximizing post-stormwater event percolation through wetlands and infiltration basins.

Reservoirs can be implemented in various ways, but two popular implementation types are instream and offstream. An instream reservoir is placed within an existing watercourse or as part of an existing water impoundment; the Hoover Dam is an example of an instream reservoir. Offstream reservoirs do not interrupt natural watercourses and can be placed in areas that protect property and the natural environment, as well as in locations that make the most sense hydraulically within a system.

Offstream Reservoirs in Florida

Two major Florida water supply authorities have existing offstream reservoirs that are designed to capture excess water during rainfall events: Tampa Bay Water and Peace River Manasota Regional Water Supply Authority (PRMRWSA). Both agencies are located in southwest Florida.

Tampa Bay Water is an integrated potable and raw water supply agency serving the wholesale water supply needs of six member governments (three counties and three municipalities). It has an integrated groundwater, surface water, reservoir, and desalination portfolio that serves a population of more than 2.4 million, with more than 170 mil gal per day (mgd) of potable water (Figure 3). The variation in water sources allows flexibility in meeting permitted limits on groundwater average annual withdrawals, the cost to produce potable water (groundwater being the least expensive and desalination being the most expensive), and weather variabilities. To protect them, surface water withdrawals from local rivers and bypass canals are stage- and flow-limited to avoid impacts to the downstream estuarine ecological communities. The reservoir's 15-BG-capacity reservoir provides a "water supply savings account" to augment sur-

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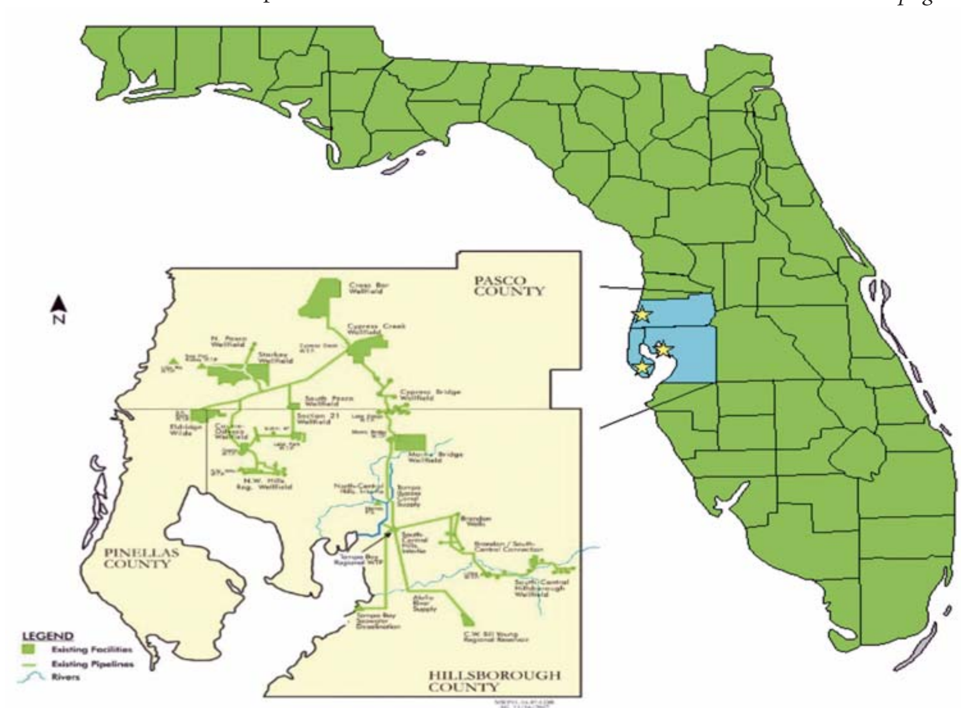

Figure 3. Tampa Bay Water System Layout

(Source: Tampa Bay Water Per-Statement of Qualifications Presentation to Renovation Contractors, June 28, 2010)

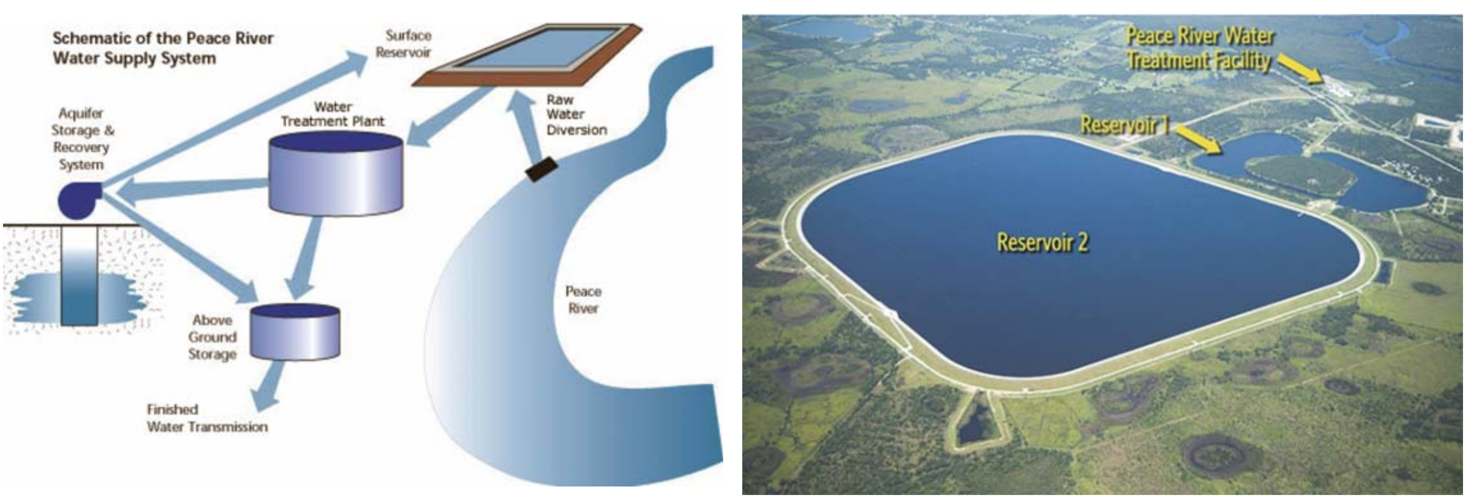

Figure 4. Peace River Manasota Regional Water Supply Authority Infrastructure

(Source: Peace River Manasota Regional Water Supply Authority, 2013. Lakewood Ranch, Fla. http://www.regionalwater.org/?page_id=1197)

Continued from page 39

face water supplies during the times of limited withdrawals.

The PRMRWSA infrastructure consists of a 120-mgd surface water intake on the Peace River (flow-based withdrawal schedule), 21 aquifer storage and recovery (ASR) wells (6.3 BG total capacity), and two offstream reservoirs (6.5 BG total capacity), as shown in Figure 4. The reservoirs provide the flexibility and sustainability to meet about 40 percent of the water treatment plant capacity throughout the year. The PRMRWSA supplies about 26 mgd to its customers in four counties.

Using Offstream Reservoirs to Meet Future Water Supply Demands

An offstream reservoir in Florida typically has no intrinsic watershed to provide stormwater as a means of filling the reservoir, and instead is constructed with an earthen embankment that provides a self-contained storage facility. However, in other states, such as Virginia, and in areas of the world such as Melbourne, Australia, offstream reservoirs can be located on minor streams, with instream dams. The reservoir can be filled with captured water from the upstream watershed and augmented with pumped water from other sources. The typical peninsular Florida offstream reservoir receives only the stormwater falling on the reservoir pool area and water pumped into the reservoir from an outside source, such as a river, stormwater collection system or impoundment, or a lake or other natural or human-made body of water.

Regionally, the Southwest Florida Water Management District (SWFWMD), in its 2015 five-year water supply plan, has identified the need for an increase in water supply of approximately 202 mgd by 2035. The SWFWMD plans to accomplish this through implementation of the following measures:

- Reduction of agricultural dependence on groundwater
- Increased capture and storage of stormwater
- Decreased use of potable water and groundwater for irrigation
- Increased use of reclaimed water for irrigation
- Increased storage of stormwater and reclaimed water for supplementing water sources during the dry period of the year

Increased storage, a major component of the plan, can be accomplished efficiently through the construction of more offstream reservoir capacity.

A Florida Institute of Phosphate Research (FIPR) study identified the feasibility of increasing offstream reservoir storage capacity within the SWFWMD through modifications of existing phosphate mine clay settling ponds. Figure 5, which is from the FIPR study, reflects the available clay settling acre-ft of storage potential that could be realized.

The USACE and South Florida Water Management District (SFWMD) authored the "Comprehensive Everglades Restoration Plan," initiated in 1998, and are in the process of designing and constructing four major offstream reservoirs to manage south Florida stormwater for recharging potable aquifers, augmenting agricultural irrigation, providing environmental water requirements, and enhancing flood control.

Reduced groundwater use and an increased need for development of surface water storage is not unique to Florida; the southeastern area of the United States is also addressing this future potable water supply shortage. Examples include the construction of instream dams (Duck River Dam in Cullman, Ala.) and Georgia's allocation of funding for reservoir construction passed in the last 10 years. The need to regionally manage water supplies is illustrated in the USACE's current legal actions over operation of Lake Lanier (an instream reservoir north of Atlanta) and its impact on Alabama's surface water supply for potable water and Florida's environmental needs (Apalachicola Bay).

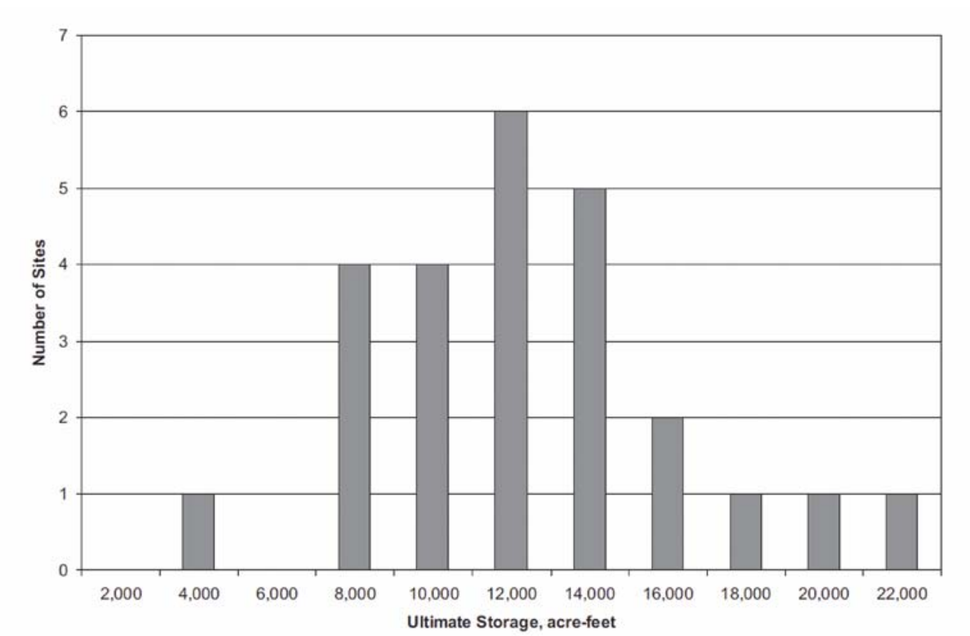

Figure 5. Phosphate Clay Settling Impoundments: Future Use as Offstream Water Supply Reservoirs

(Source: FIPR. 2005. Potential Technologies to Reduce or Replace Groundwater Consumption in the SWFWMD. Pub. No. 01-179-213. 43 pages.)

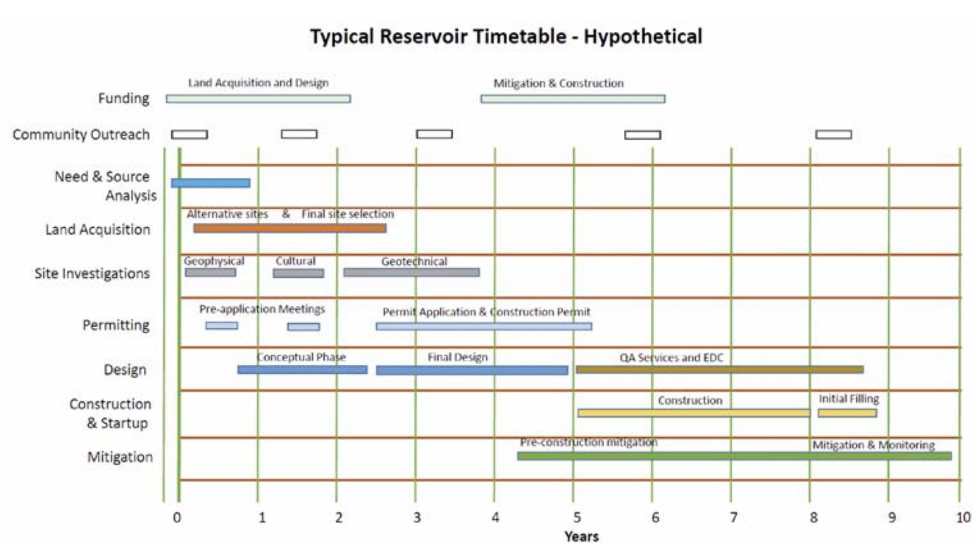

Figure 6. Typical Reservoir Timetable

Offstream Reservoirs: Concept to Operation

The time frame from conceptual planning to operation of an offstream reservoir can be eight to 10 years or longer, depending on land availability, permitting, and environmental considerations. A future reservoir development within peninsular Florida requires advanced planning, and Figure 6 presents an example of a hypothetical reservoir timetable from conceptual planning to operation. The time for Florida to develop a long-term plan using offstream reservoirs to augment potable water, agricultural irrigation, and environmental water resources is now.

Conceptual planning for an offline reservoir includes water supply needs forecasting, financing, land acquisition, water supply source, site investigations, community outreach, permitting, site mitigation, engineering design, and constructability analysis.

The spatial extent of an offstream reservoir depends on the geology of the area, volume of storage needed based on the demand analysis, economics of raising the height of the reservoir embankment versus expanding the reservoir's spatial extent and lowering the embankment height, seepage analysis, environmental impacts, ability to permit the reservoir, and dam safety considerations.

Site Characteristics: Geological and Environmental

Florida is primarily underlain with karst limestone formations that compose the Floridan aquifer with varying thicknesses of overburden. The Biscayne Aquifer dominates the southeastern Florida geology and is exposed to the surface with very little overburden. Where the overburden is relatively shallow, the slightly acidic groundwater causes a gradual (over thousands of years) loss of formation, and the result is a karst formation with sinkhole potential (Figure 7). All of peninsular Florida is prone to sinkhole activity, and extensive site investigations are required in siting the reservoir, specifically the reservoir embankment footprint.

Extensive site investigations include historical review (Figure 8), standard geological and geophysical techniques, environmental observations, and professional judgment (Florida Geological Survey, 2005, Publication No. 57). Site investigations performed include the following:

- Background data collection: regional and local geomorphology; U.S. Geological Survey topographic quadrangle map; county soil survey; and recorded historical sinkholes, historical photography, and site-specific design and investigation studies.
- Preliminary site inspection
- Professional judgment
- Design investigations
  - Ground-penetrating radar
  - Site borings: standard penetration testing and auger borings
  - Electrical resistivity profiling
  - Surface wave measurements
  - Magnetometer
  - Microgravity surveys
  - Cone penetration tests
  - Test pits
  - Geophysical logging
  - Aerial color photographs of the site
- Environmental delineation
  - Streams
  - Wetlands
  - Springs
  - Threatened and endangered species
  - Upland habitats

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Figure 7. Filled-in Sinkholes on a Highwall in a Brooksville, Fla., Limestone Mine (April 2013)
(Source: Florida Geological Survey Poster No. 11, 2004.)

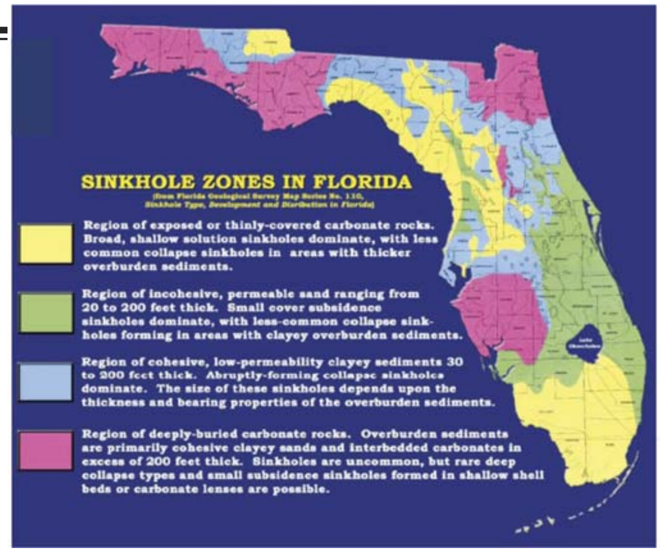

Figure 8. Sinkhole Zones in Florida
(Source: Florida Geological Survey Poster No. 11, 2004.)

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Environmental Concerns

Environmental site characteristics for siting a reservoir relate to the potential for disturbance of ecological features, such as wetlands, sloughs, lakes, threatened and endangered species habitats, springs, streams, and stream floodplains. In assessing the potential for a reservoir site, the impacts to these natural ecological features could represent permitting risks, time delays, and mitigation requirements that significantly impact the community acceptance of the site and project, contribute to lengthy permitting, and increase the time from conceptual to operational status of the reservoir. The environmental aspects of the reservoir site selection could significantly impact the project finances through timing, cost of mitigation, and community acceptance impact on the funding source (e.g., state and federal legislators).

Advance pre-application meetings, site visits, and workshops to educate the permitting regulators and allow the design team to understand potential permit-specific conditions can significantly reduce the permitting schedule and the quantity and intensity of the conditions.

Engineering Design

The reservoir's site characteristics, design, and operational considerations make every reservoir unique. Each reservoir is designed with safety as the highest priority. The engineering design will therefore include the following safety features:

- *Potential Failure Modes Analysis* (PFMA) – A design tool that is employed by USACE to improve the design and safety of the embankment through understanding the potential failure modes and implementation of design, construction, maintenance, and operational and quality assurance/quality control (QA/QC) improvements before, during, and after construction to mitigate these potential failures.
- *Risk Assessment* – An evaluation of the probability of loss-of-life scenario and design or construction changes needed to improve the safety and operational efficiency of the reservoir using PFMA.
- *Design Workshops* – These will be developed to:
  - Improve communication with the owner's engineering, maintenance, and operational staff with a goal of further defining the design criteria and improving reservoir safety.
  - Focus on engineering, survey, QA/QC, structural, hydrologic and hydraulic, and operation and maintenance issues.
  - Continue the dialogue with workshops through construction and initial operational startup.
- *Independent Technical Review* – The review is performed by QA/QC teams at major design milestones and work elements during construction.
- *Strong QA/QC Program* – This starts with conceptual design and continues through startup.
- *Development of an Emergency Action Plan* – This includes embankment breach analysis, inundation mapping, and emergency response coordination and communication protocols.

The conceptual design should start with a workshop to identify the characteristics, constraints, and requirements of an offstream reservoir site. Alternative site evaluations typically include potential environmental impacts, geophysical and geotechnical site characteristics, construction material availability, proximity to potable water demand and water sources, and community considerations. Figure 9 provides an example of a reservoir site-ranking matrix for evaluating and ranking alternative sites, with a focus on sites with the highest potential for success (environmental, geological/geotechnical, site characteristics, and location).

Figure 9. Potential Reservoir Site-Ranking Matrix Example

Pro/Con Initial Evaluation Analysis of a Potential Reservoir Site							
Site	Size	Environmental	Geological	Site Materials	Proximity to Water Source	Proximity to Demand Source	Ranking
A	+	-	+	+	-	-	3
B	+	+	-	+	+	+	2
C	+	-	+	+	+	+	1
D	-	+	+	-	-	-	5
E	+	-	-	-	+	+	4

Conclusion

Offstream reservoirs will play a key role in meeting Florida's future potable water demand. The implementation of these resource tools requires the immediate initiation of conceptual planning, site selection, operational considerations, and financial planning to meet the future needs of Florida's 2030 population.