Comparison of Costs and Operational Requirements for an Off-Stream Raw Water Storage Reservoir and an Aquifer Storage and Recovery System at the Peace River Water Treatment Facility

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High wet-season river flows in southwest Florida offer opportunities to harvest and store seasonal resources to meet drinking water (and other) needs, while preserving the freshwater flows needed to support estuaries. Average annual rainfall in southwest Florida is about 52 inches, with 60 percent of that occurring during four summer months (see Figure 1).

River flow patterns correspond to rainfall, yielding high wet-season flow and often very low dry-season flow. Mean river flow in the area is skewed toward high-flow events such as hurricanes and tropical storms, so median flow data is more useful as a general indication of reliable water supply yield. Figure 2 shows an example for the Peace River at Arcadia gage.

A withdrawal schedule, allowing harvest of a small percentage of river flow once a minimum flow trigger is exceeded, has provided an environmentally sustainable, highly reliable public water supply from the Peace River. The schedule reserves most of the river flow to support the estuary, yielding relatively large quantities of water for harvest during the wet season and little or no water for harvest during extended periods in the dry season. Under the circumstances, the key to making the Peace River and other similar river systems reliable public water supplies is large-volume water storage and the ability to fill that storage rapidly.

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Storage Options

The four major in-stream dams creating impoundments for public water supply in southwest Florida range in size from about 330 acres to 1450 acres, and have total volumes from 700 MG to 5.9 BG. All dams were installed between the 1920s and late 1960s (Bellino et al., 2010; Nguyen et al., 1981; SWFWMD 2000; and Trommer et al., 1999). These characteristics reflect the challenges of developing large-volume surface water storage in southwest Florida, as was done in the past. The first is the physical challenge presented by the low-relief terrain, which necessitates flooding large areas to provide adequate storage for supply reliability; the second is the environmental regulations implemented after the late 1960s that essentially preclude damming of major water courses in the state.

Two storage options employed by the Peace River Manasota Regional Water Supply Authority (Authority) at the Peace River facility in DeSoto County are working examples of the large-volume storage needed to effectively utilize southwest Florida rivers. These include an off-stream reservoir system and aquifer storage and recovery (ASR). The systems are utilized conjunctively at the Peace River facility to support drinking water supply operations. Each system has advantages and disadvantages, and unique operational requirements, regulatory issues, and costs that need to be considered. The Authority's experience with each system is presented here for

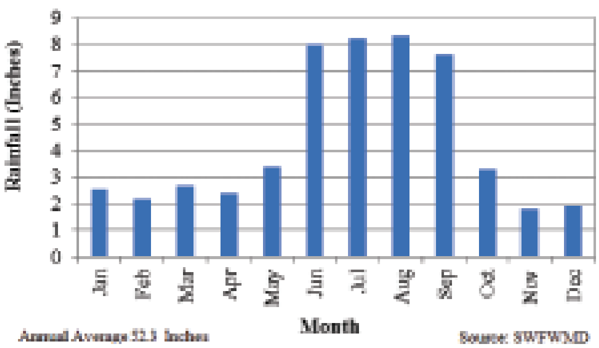

Figure 1. Southwest Florida Average Monthly Rainfall

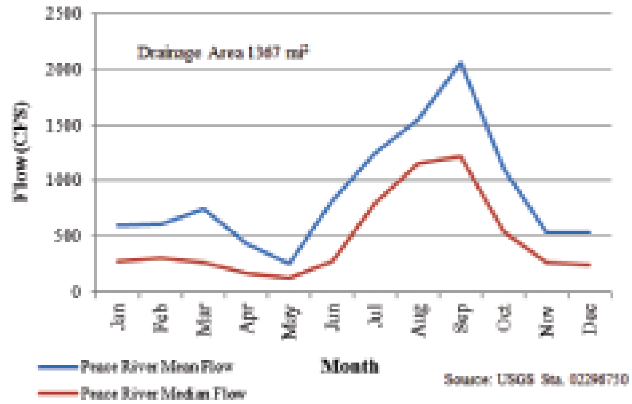

Figure 2. Historical Flow – Peace River at Arcadia

consideration by those contemplating such installations.

Peace River Service Area and Facilities

The Authority is an interlocal governmental agency created in 1982 to supply drinking water to the counties of Charlotte, DeSoto, Manatee, and Sarasota, and the City of North Port in southwest Florida (see Figure 3). The Authority's facilities include a 48-mgd conventional surface water treatment plant, 120-mgd water intake on the Peace River, 6.5 BG in off-stream raw water storage (two reservoirs), two ASR wellfields (total of 21 ASR wells) with 6.3 BG in finished water storage capacity, 50 miles of large-diameter water transmission mains, and associated booster stations and finished water storage throughout the system. The facilities currently serve an average demand of 25 mgd.

Figues 3. Peace River Manasota Regional Water Supply Authority Service Area

Peace River Operations

At the Authority's facilities there are distinct wet-season and dry-season operating scenarios, which are depicted in Figures 4 and 5 respectively, and summarized below. These scenarios are the basis for the operational costs presented and also identify some of the constraints of each storage system.

Wet Season Operation

During the wet season, water is harvested from the Peace River using the flow-based withdrawal schedule identified in the Authority's water use permit. Water withdrawn at the river pump station is conveyed to a 640-acre (6 BG) aboveground reservoir (Reservoir 2) at rates of up to 120 mgd. Controlled flow by gravity from Reservoir 2 feeds a separate 85-acre (520 MG) inground reservoir (Reservoir 1). Water is pumped from Reservoir 1 to the surface water treatment facilities, treated, and distributed to Authority customers. If customer demand is below the 48-mgd treatment plant capacity, and raw water storage conditions are adequate, additional water is treated (full treatment) and injected (recharged) into the ASR system at rates up to about 20 mgd.

Filling of the raw water reservoir system is constrained by the water use permit authorized withdrawal schedule and the river pump station capacity (120 mgd). Recharge to the ASR system is constrained by raw water storage conditions, the availability of excess treatment capacity, and recharge rate limits on the wells. Figure 4 depicts the typical wet-season condition in which storage is filled.

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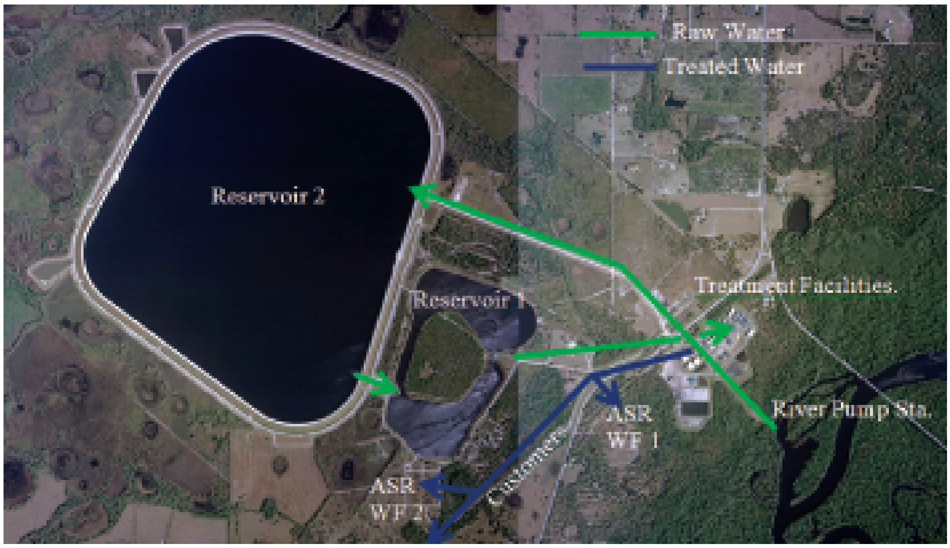

Figure 4. Wet Season Operation

Figure 5. Dry Season Operation

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Dry Season Operation

During the dry season, little or no water is available for harvest from the Peace River, and stored supplies are used to meet customer demand. In this scenario, water follows the same path (from Reservoir 2 to Reservoir 1, to the water treatment plant, and to customers), as during the wet season. Based on raw water storage conditions and time of year, water may be recovered from the ASR system back to the reservoir system, where it blends with the raw water and is retreated. Retreatment is required due to arsenic concentrations above the drinking water standard in water recovered from the ASR system. The arsenic is picked up from naturally occurring arsenopyrite in limestone aquifer and is removed in the conventional surface water treatment process.

Recovery from the raw water reservoir system is constrained by the amount of water in reservoir storage and the 48-mgd capacity of the surface water treatment facility. Recovery from the ASR system has a permitted limit of about 17 mgd, but is further constrained by recovered water quality, which deteriorates quickly at higher pumping rates to the native total dissolved solids (TDS) concentrations in the aquifer of about 1000 mg/L. In order to avoid exceeding the secondary standards for TDS in finished water, recovery of stored supply from the ASR system commences well in advance of projected low-reservoir storage conditions. In addition, the ASR system is operated at low rates for extended periods to maximize recovery of quality water. Figure 5 depicts the dry-season condition in which storage is used to meet customer demand.

Table 1. Annual Fixed Operating Costs

Item	Reservoir System	ASR System
Algae Treatment	$30,000	N/A
Environmental Monitoring in River	$200,000	$200,000
Maintenance and Repairs	$285,000	$100,000
Wetland Mitigation Area Monitoring and Maintenance	$150,000	N/A
Permit Compliance and Reporting	$300,000	$60,000
Reservoir Aeration	$120,000	N/A
Sampling and Analysis	$75,000	$125,000
Staffing	$75,000	$75,000
Annual Seepage and Evap. Loss from Reservoir (1)	$16,000	N/A
Annual Total	$1,251,000	$560,000

(1) Based on electric costs for annual average pumping of additional 1.2 mgd from river.

Table 2. Variable Unit Costs

Item	Reservoir System ($/1,000 gal. delivered)	ASR System ($/1,000 gal. delivered)
River Pumping	$0.037	$0.037
Pumping Reservoir 1 to Water Treatment Plant	$0.018	$0.036
ASR Pumping to Reservoir	N/A	$0.004
High Service Pumping	$0.082	$0.164
Water Treatment Chemicals	$0.51	$1.02
Water Treatment Plant Power	$0.095	$0.19
Sludge Disposal	$0.017	$0.035
Annual Total	$0.76	$1.49

Table 3. Capital Costs

Item	Reservoir System ($/1,000 gal. delivered)	ASR System ($/1,000 gal. delivered)
Construction Cost (1)	$91,555,000	$11,410,000
Investment in Target Storage Volume (unrecoverable) (2)	N/A	$2,508,000
Total	$91,555,000	$13,918,000

(1) All costs adjusted to 2009 values to coincide with completion and in-service of Reservoir 2
(2) 3.3 BG of finished water invested @ $0.76/1000 to establish buffer to native water

Aquifer Storage and Recovery Considerations

The Authority has in the past utilized the ASR system as primary large-volume storage in conjunction with the 85-acre (520 MG) inground reservoir. However, since completion of the 640-acre (6.0 BG) aboveground reservoir in 2009, the ASR system is now used as a secondary (backup) storage system to the reservoirs. Construction, operation, and regulatory considerations associated with the Authority's ASR system are summarized below:

- Provides large-volume storage at relatively low capital cost and with a small footprint (6.3 BG at the Peace River facility, <100 acres).
- Relatively low annual maintenance and repair costs.
- No wetland impacts during construction or operation.
- Requires significant excess finished water treatment capacity to effectively recharge.
- Water is treated twice: full treatment on recharge, than comingled with reservoir water on recovery and retreated due to arsenic concentrations. Costs associated with this twice-through application reflect additional energy and chemical requirements.
- Fill (recharge) rates and duration depend on excess treatment capacity and seasonal resource availability. Recharge is typically limited to summer wet season.
- Recovery rates are constrained by permitted withdrawal rates and by water quality deterioration associated with native water in the aquifer. High withdrawal rates increase recovery of poor-quality water.
- Requires investment of about 3.3 BG of finished water to establish a buffer to native water. This water is theoretically never recovered, but has a cost.
- Requires lengthy cycle testing to comply with state permitting. For example, wellfield No. 2 is on cycle No. 11. This involves a prescribed recharge and recovery cycle each year, regardless of whether the recovered water is needed to meet customer demand. The result has been increased operational costs and an inability to build significant storage in this wellfield.
- Requires extensive water quality monitoring program, including installation of monitor wells and associated regulatory reporting.

- Improves system reliability, particularly during extended drought, but not appropriately sized to support current average demands.

Off-Stream Reservoir Considerations

The 85-acre (520 MG) inground off-stream reservoir has been a part of the Peace River system since the water works was acquired by the Authority from General Development Utilities in 1991. In 2009, the Authority completed construction of a 640-acre (6.0 BG) off-stream, aboveground earthen embankment reservoir. The raw water reservoir system is now the primary storage for the Peace River facility. Construction, operational, and regulatory considerations associated with the Authority's off-stream reservoir system are summarized below:

- Provides large-volume storage at relatively high capital cost and large footprint (6.5 BG at the Peace River facility, about 1000 acres total reservoir system footprint).
- Higher annual maintenance and repair costs than ASR.
- 150 acres of wetland impacts during construction, mitigated by restoring 1,100 acres on- site. (The site is the 6,000-acre RV Griffin Reserve owned by the Southwest Florida Water Management District and managed by the Authority.)
- Can be filled rapidly when river resource is available.
- Recovery from storage is essentially unconstrained.
- Buffers raw-water quality changes, providing consistent quality supply to the water treatment plant.
- Net evaporative and seepage losses relatively low (estimated at average 1.2 mgd).
- Requires extensive embankment monitoring, safety programs, and associated regulatory reporting.
- Associated wetland mitigation area also requires monitoring and maintenance.
- Reservoir requires periodic algae treatment to minimize water supply taste and odor events.
- Greatly improves drinking water supply reliability.

Comparison of Costs

The capital and operational costs for the off-stream reservoir system and the ASR system are very different from one another. A comparison of the costs was developed based on an assumed average 27-mgd future delivery to customers. Costs are divided as follows:

Annual Fixed Operating Costs (Table 1). These are annual reoccurring costs that generally don't vary based on amount of water pumped. However, for the purpose of the final unit cost comparison, delivery of annual average 27 mgd to customers was assumed.

Variable Unit Costs (Table 2). These reflect unit costs per 1,000 gallons delivered to customers. Variable costs are for power, chemicals, and sludge disposal.

Capital Costs (Table 3). These are capital costs for construction of off-stream reservoir and ASR facilities. Since the Peace River storage facilities have been constructed incrementally since the 1980s, original costs have been adjusted to reflect 2009 values, which correspond with the Reservoir 2 completion date. Capital costs shown do not include land costs, as the property for the reservoir and ASR systems was already owned by the Authority or by the Southwest Florida Water Management District and provided at no capital cost to the Authority for water supply purposes.

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Conclusions

The harvest of sustainable percentages of seasonal river flows in southwest Florida offers a viable and important alternative water supply option for public drinking water and other needs. Effective use of this resource requires large volume reservoirs in which to store seasonally available resources, providing the reliability needed for public water supplies without overharvesting, which could damage the estuaries.

In-stream reservoir development on major water courses in Florida is generally infeasible due to the flat terrain and environmental regulations. Two alternatives to in-stream reservoirs include off-stream reservoirs and ASR. Both off-stream reservoirs and ASR are successfully utilized at the Authority's facilities in DeSoto County, facilitating a side-by-side comparison of operational and regulatory requirements, and costs for each.

Entities considering installation of these large-volume storage options should have a clear vision of how the proposed facilities will be operated on a day-to-day basis, and in the long term, to meet their needs. Not all Florida wet seasons are created equally, so the ability to harvest and store large volumes of water quickly is critical to making reliable use of this resource. The conjunctive use of off-stream reservoirs and ASR can offer advantages in cost-effective sizing of facilities, and has proven particularly useful at the Peace River facility during extended drought conditions.

The side-by-side "all-in" cost comparison shows that for similar-sized ASR and off-stream reservoir facilities at the Peace River facility, unit costs for water are very similar. While the capital cost of the 6.3 BG ASR system is significantly lower than the 6.5 BG off-stream reservoir, the annual operating costs associated with treating water twice for the ASR system level the field on unit costs. In addition, other annual operational and regulatory compliance costs on each system can be higher than anticipated. All of this indicates the need for an "all-in" evaluation of capital, operational, and regulatory costs as part of the storage selection process.

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Table 4. Assumptions for Unit Cost Comparison

Item	Reservoir System	ASR System
Design Storage (gallons)	6,520,000,000	6,300,000,000
Functional Storage gallons (1)	6,500,000,000	3,000,000,000
Functional Storage Units	6,520,000	3,000,000
Annual Debt Service Cost (2)	$5,956,000	$905,000

(1) Design storage less unrecoverable buffer
(2) Total capital costs from Table 3 financed 30 years @ 5% APR.

Table 5. Unit Cost Comparison

Item	Reservoir System ($/1,000 gal. delivered)	ASR System ($/1,000 gal. delivered)
Fixed Annual Cost (from Table 1)	$0.13	$0.06
Variable Unit Costs (from Table 2)	$0.76	$1.49
Debt Serv. on Capital Costs per Functional Storage Unit	$0.91	$0.30
Unit Cost Total	$1.80	$1.85

Note: The costs summarized in Table 5 are comparative and should not be construed as the actual burden of each storage facility on current Authority water rates.