Caught in the Balance: Capital Improvement Planning to Integrate Traditional and Alternative Water Supply Sources

Brian Megic, Oscar Vera, Ed Talton, Chad Meisel, and Brandon Bryant

In 2011, the City of St. Cloud, Toho Water Authority (TWA), Orange County Utilities (OCU), Polk County Utilities (PCU), and Reedy Creek Improvement District (RCID) worked together to complete an individual water use permit (WUP) through the South Florida Water Management District (SFWMD) for the Cypress Lake Wellfield Project (project), a regional brackish groundwater alternative water supply (AWS) project located in central Osceola County. The WUP for the project authorizes the withdrawal of 37.5 mil gal per day (mgd) annual average daily flow (AADF) of brackish groundwater from the Lower Floridan aquifer. The City of St. Cloud, Toho Water Authority, Orange County, Polk County, and Reedy Creek Improvement District (STOPR) Group members are currently implementing the project as the Water Cooperative of Central Florida (WCCF), consisting of the five organizations.

By the beginning of 2013, WCCF and RCID initiated two reports to further the development of the project:

- Cypress Lake Potable Water Transmission, Optimization, and Interconnect Analysis and Conceptual Design – Conceptual Design Report (CDR): Reiss, 2014
- Cypress Lake Water Treatment Plant, Wellfield, and Raw Water Main – Preliminary Design Report (PDR): Tetra Tech, 2014

The CDR project provided a conceptual design for how treated water would be delivered from the Cypress Lake Water Treatment Plant (WTP) to WCCF and RCID. The PDR developed preliminary designs for the raw water facilities and treatment process that would be required for the brackish groundwater supply source.

As part of the CDR, the project was divided into two primary phases. Phase 1 involved developing a plan to interconnect the five project partners to facilitate the ability of the utilities to wholesale existing fresh groundwater supplies to one another on an interim basis, referred to in the CDR as "water wheeling." Phase 1 would allow the utilities to maximize the use of existing permitted water supply sources and delay the higher capital expenditures associated with alternative water supplies, such as the project. Phase 2 involved developing a plan for treated water from the project to be conveyed to the project partners, including water supply transfers among the project partners to reduce the transmission needs of the project. The CDR identified a series of conveyance infrastructure projects (e.g., pipelines, pump stations, interconnects, etc.) that each utility, groups of utilities, or all of the participating utilities would need to develop to successfully implement the project.

The project was initiated by OCU in 2017 to develop an implementation plan to identify the infrastructure required to accept water from the project into its water distribution system. The plan also considered the implementation of the Taylor Creek Reservoir/St. Johns River (TCR/SJR) water supply project, which is an additional regional AWS project that OCU is implementing with several regional partners. This project leveraged the use of water supply modeling and hydraulic modeling to identify capital improvement program (CIP) projects to balance the use of OCU's existing permitted fresh groundwater supply and planned AWS supplies, while incorporating system flexibility that will provide for OCU to meet demands under a wide array of conditions, including varying AWS project implementation timing and phasing and the ability to implement service area transfers as needed to meet demands.

Brian Megic, P.E., D.WRE, is supervising engineer, and Oscar Vera, P.E., Ph.D., D.WRE, is water resources engineer with Liquid Solutions Group LLC in Geneva. Ed Talton, P.E., is project manager, and Chad Meisel is project engineer with Reiss Engineering Inc. in Winter Springs. Brandon Bryant, P.E., is chief engineer with Orange County Utilities in Orlando.

Table 1. Potable Water Demand Conditions

Service Area	Demand Condition (MGD AADF)			
	Full Phase 1	Half Phase 2	Full Phase 2	Full AWS
East (ESA)	38.51	40.31	42.11	46.60
South (SSA)	27.06	28.36	29.66	32.90
Southwest (SWSA)	7.45	8.25	9.05	11.04
West (WSA)	18.07	18.67	19.27	20.76
Total	91.1	95.6	100.1	111.3

Alternative Water Supply Project Timing

The analyses performed and plans developed as part of this study were based on demand conditions, which are presented in Table 1.

The evaluations and modeling performed in support of this plan were based on demand conditions, in lieu of standard five-year planning increments. This was done to allow OCU to implement projects based on system demands in lieu of years, which often change as plans are updated based on variations in system growth due to economic conditions, changes in a demand system profile, and changes in per capita demand resulting from conservation, reclaimed water, and AWS project implementation, among other factors. The demand conditions are:

- *Full Phase 1*: OCU's total combined fresh groundwater allocation (91.1 mgd AADF). This demand condition represents the time by which

Continued on page 10

Continued from page 8

OCU needs to have an AWS source online to meet demands beyond those met by existing fresh groundwater supplies.
- *Half Phase 2*: OCU's capacity share of the project is 9 mgd AADF (finished water capacity). The half phase 2 demand condition represents a demand equal to OCU's total combined fresh groundwater allocation and half of OCU's capacity share of the project.
- *Full Phase 2*: The full phase 2 demand condition represents the demand associated with OCU's total combined fresh groundwater allocation and OCU's capacity share of the project.
- *Full AWS*: OCU's capacity share of the TCR/SJR water supply project is projected to be between 10 and 15 mgd AADF, depending on the available yield of the supply source. The full AWS demand condition represents the demand associated with OCU's total combined fresh groundwater allocation, its capacity share of the project, and its approximate capacity share of the TCR/SJR water supply project.

The half phase 2 demand condition was initially performed as a sensitivity analysis and to assess water quality within OCU's distribution with regard to water age and associated water quality constraints; however, it was later determined that this demand condition was not constraining with regards to the identification of infrastructure required to integrate AWS sources into OCU's distribution system.

Water Supply Model

History

As part of the project CDR, the Coop-RCID water supply (CRWS) model was developed. The CRWS model is a times-series or continuous-simulation model that allows for the statistical evaluation of the water balance between a utility's demands and water supplies throughout the planning period. This model was developed to simulate the following:

1. Daily customer demands for each utility.
2. Fresh groundwater supplies for each utility.
3. Service area transfers of water conveyed through interconnects between the utilities.
4. Peak daily flows from the Cypress Lake WTP.
5. Peak daily flows delivered to the utilities through transmission piping or interconnects.
6. Peak daily fresh groundwater use required to meet the conjunctive use needs of the project, which were associated with the project being planned to provide a base-loaded supply due to the membrane treatment processes being proposed.

The CRWS model was developed to simulate OCU's service area and water supply facilities within SFWMD. For this project, the portion of the CRWS model dedicated to simulating OCU was extracted and expanded to simulate all of OCU's service area and water supply facilities. This version of the model is referred to as the OCU water supply model (OCUWS model).

Conceptual Model

The OCUWS model is a spreadsheet-based, continuous-simulation, water-balance model. The basis for the model is the continuity of mass, which is represented by the following equation:

$$\Delta Storage = Inputs - Outputs = \Sigma Supplies - \Sigma Demands$$

where:
$\Delta Storage$ = Volume of water conveyed to or extracted from storage;
$\Sigma Supplies$ = The sum of the volume of water available from all existing and future OCU potable water supply sources; and
$\Sigma Demands$ = The sum of OCU's projected potable water demands.

The OCUWS model evaluates OCU's supply and demand on a daily basis. Storage in the continuity of mass equation is defined as seasonal storage. Diurnal (or other short-term) storage needs for OCU's facilities are not incorporated into the daily model.

Based on the information, the mass balance equation previously presented can be expanded as follows:

$$S = GW + AWS + CU - D$$

where:
S = Storage as previously defined;
GW = Fresh groundwater use within OCU's historical practices;
AWS = The sum of water available from AWS sources (project and the TCR/SJR water supply project);
CU = Conjunctive use requirement met by fresh groundwater; and
D = Projected potable water demand.

The OCUWS model was developed using daily timesteps for OCU's east service area (ESA), south service area (SSA), and the combined west service area/southwest service area (WSA/SWSA). Incorporating the daily timestep and analysis of multiple service areas, the mass balance equation further expands as follows:

$$S_{SA,n} = GW_{SA,n} + AWS_{SA,n} + CU_{SA,n} \pm SAT_{SA,n} - D_{SA,n}$$

where:
SA = Service area;
n = Day n;
CU, GW, AWS, D, and *S* = as previously defined; and
SAT = Service area transfers.

The service area transfers term was added because some future AWS sources will be used to meet projected potable water demands in multiple OCU service areas, but the source will enter OCU's system via one or two service areas. This is due to geographic proximity.

The OCUWS model was developed to simulate the following:

1. OCU's daily customer demands by service area.
2. OCU's fresh groundwater supplies by service area.
3. Service area transfers of water conveyed between OCU's service areas.
4. OCU's capacity share of planned AWS sources, including transfers through planned interconnects.
5. Peak daily fresh groundwater use required to meet OCU's conjunctive use needs associated with planned AWS supplies.

Model Modules

The OCUWS model was set up as a series of modules that contain input parameters and calculate the individual components of the mass balance equation previously presented. The OCUWS model modules are:

- *Annual Demand*: Based on long-term average climatic conditions.
- *Rainfall*: National Oceanic and Atmospheric Administration (NOAA) rainfall data for Orlando from 1892 through 2016.
- *Daily Demand*: Developed for ESA, SSA, and combined WSA/SWSA based on a multiple-linear regression analysis that considered deterministic (water use trends, seasonal variation by day of year, and cross-correlation with rainfall) and statistical (auto-correlation and statistical noise) components and was calibrated to observed daily potable water demand data from 1998 through 2016.
- *Fresh Groundwater*: Based on current consumptive use permit (CUP)/WUP allocations.
- *Cypress Lake Wellfield Project*: Allows the user to vary the following:
  - Project phasing
  - The distribution of OCU's 9-mgd AADF project capacity received through interconnects with TWA (SSA near International Drive and the SWSA near County Road 545)
  - Supply source variability (base-loaded or on-demand)
  - Supply source priority

- *TCR/SJR Water Supply Project*: Allows the user to vary the following:
  - Project phasing
  - Supply source variability (base-loaded, on-demand, or supply-based)
  - Supply source priority
- *Service Area Transfers*: Calculates the magnitude, frequency, and timing of potential service area transfers based on a water balance of available supplies and demands within each of OCU's service areas.

For the simulations performed in support of this plan, water received from the project was assumed to be base-loaded, water received from the TCR/SJR project was assumed to have a supply-based variability based on an external hydrologic yield model, and the use of AWS sources was assumed to be maximized to the extent feasible before the use of fresh groundwater supplies.

Water Supply Model Linkage to Hydraulic Model

The results of the OCUWS model were used as follows:

- To identify water supply simulations warranting simulation with the hydraulic model. Performing simulations with no predicted water supply deficits or significant water supply transfers with the hydraulic model was unnecessary.
- The OCUWS model defined potential ranges for the distribution of water from the project into OCU's potable water distribution system through the two planned interconnects with TWA.
- The OCUWS model developed anticipated ranges of water supply transfers between OCU's service areas considering predicted conjunctive use needs. These ranges were used in the set-up and corroboration of results from simulations performed with the hydraulic model.
- The OCUWS model set developed anticipated ranges of peak groundwater use considering predicted conjunctive use needs.

The initial step of performing water supply simulations facilitated the simulation of more-focused hydraulic model simulations within a broad range of future operational conditions.

Hydraulic Model

History

As part of the Cypress Lake Transmission CDR project, OCU's hydraulic model was linked with the hydraulic models of the other four project partners to create a regional hydraulic model; however, only the portions of OCU's service areas that are within the SFWMD are planned to be provided water from the project. As such, only those portions of OCU's distribution system within SFWMD were active as part of the analyses performed with the project's regional hydraulic model. The regional (combined) hydraulic model was then modified through the course of the project to integrate new infrastructure required to implement the project. As OCU has decided to maintain an individual hydraulic model as its master hydraulic model (and not the combined utilities hydraulic model) it was necessary to update OCU's master individual hydraulic model with components/inputs from the project's combined hydraulic model.

Model Updates

The master individual hydraulic model of OCU was structurally updated with the addition of new geographic information system (GIS) piping components and future facilities needed to integrate water from the project. This included the addition of new storage and repump facilities (SRFs), new booster pump stations (BPSs), new piping, additional pumping capacity, new valves and pressure-reducing valves, updated configurations at facilities based on as-built drawings, and new or proposed interconnects with adjacent utilities, including the two planned interconnects with TWA for the project. The hydraulic model was also updated at a parcel or node level, with the demand conditions developed in support of this project.

Partial Calibration Update

A partial hydraulic model calibration was performed by comparing the field pressure data with the hydraulic model-simulated output under similar system demand and operating conditions. The purpose of model calibration is to improve the accuracy of model results and outputs. The goal for the partial calibration performed in support of this study was to simulate the distribution system's performance within 90 percent (or greater) accuracy when compared to available operational data.

The county's hydraulic model was calibrated using a two-day period from March 19, 2016, to March 21, 2016, which included both irrigation and nonirrigation days. The diurnal pattern was developed and simulated at 10-minute intervals. In addition to this diurnal demand pattern, the hydraulic model extended-period simulation (EPS) scenario includes initial settings and high-service pump operating patterns at all facilities. The supervisory control and data acquisition (SCADA) data point of entry pressures and flows was compared to initial hydraulic model results. Input adjustments were made to improve field correlations, with the hydraulic model results correlating with field measurements within 90 percent accuracy.

The calibration efforts listed verify the point-of-entry flow, pressure, and ground storage tank-level comparisons, with an example presented in Figure 1.

Phase 1 Alternatives Analysis

Based on water supply and preliminary hydraulic modeling, simulations were selected for

Continued on page 12

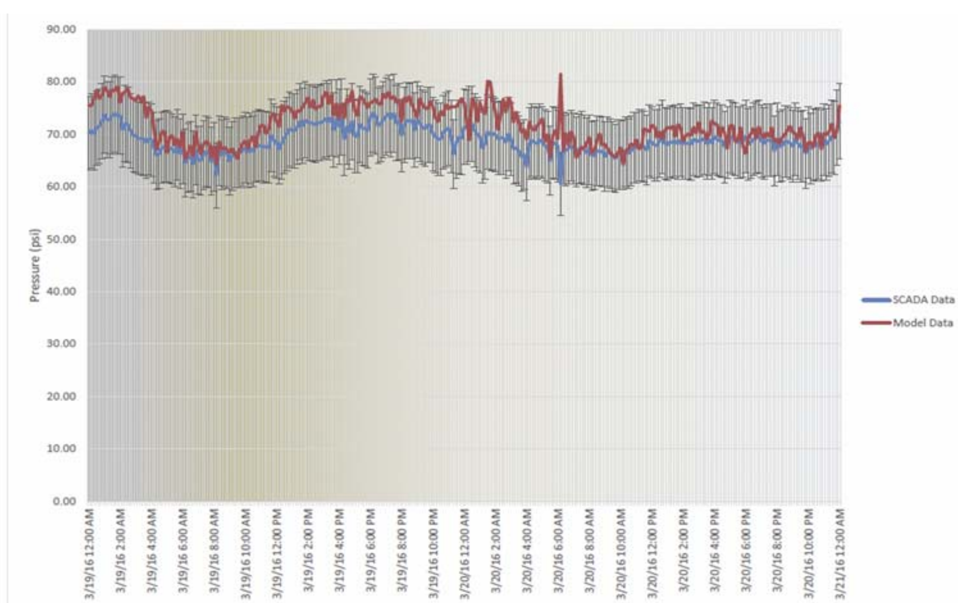

Figure 1. Orangewood Water Supply Facility Pressure Calibration

Continued from page 11

evaluation as part of an alternative analysis. The intent of the modeling performed in support of the alternatives analysis was to identify infrastructure projects and operational adjustments needed to meet OCU's service standards and balance CUP/WUP allocation limitations.

The phase 1 simulation alternatives hydraulically modeled are as follows:

- Simulation 1: Current demand (baseline condition)
  - Alternative 1: Existing operational conditions
- Simulation 2: Half phase 1 demand (demand condition approximately halfway between current demand and the full phase 1 demand condition)
  - Alternative 2.1: Existing operational conditions
  - Alternative 2.2: Modified operational conditions
- Simulation 3: Full phase 1 demand
  - Alternative 3.1: Existing operational conditions, SSA/ESA interconnect operational, and TCR/SJR project not implemented by phase 2
  - Alternative 3.2: Modified operational conditions, SSA/ESA interconnect operational, and TCR/SJR project not implemented by phase 2
  - Alternative 4.1: Existing operational conditions, SSA/ESA interconnect not operational, and TCR/SJR project not implemented by phase 2
  - Alternative 6: Modified operational conditions, SSA/ESA interconnect not operational, and TCR/SJR project implemented by phase 2

A Simulation 5 was deemed infeasible based on water supply modeling and was not evaluated with the hydraulic model. Alternatives 2.1, 3.1, and 4.1 were determined to not be feasible from an operational perspective based on hydraulic modeling.

Phase 2 and Full Alternative Water Supply Alternatives Analysis

The purpose of the hydraulic modeling performed in support of the phase 2 and full AWS alternatives analysis was to determine internal OCU infrastructure and service area water transfers required to meet demands with the project and make the TCR/SJR water supply project operational. After performing dozens of simulations with the water supply and hydraulic models, water supply simulations 16, 21, and 22 were selected. Different variations (alternatives) of simulations 16, 21, and 22 were then developed and hydraulically evaluated. A summary of the pertinent Phase 2 hydraulic alternatives is presented in Table 2.

Table 2. Hydraulic Model Simulation Summary

Alt. No.	Demand Cond. (MGD)	TCR/ SJR Project Flow (MGD)	Cypress Lake Project Flow into SWSA/SSA (MGD)	Flow Transfer between SSA and ESA		Flow Transfer between SWSA and SSA	
				Amount (MGD)	Dir.	Amount (MGD)	Dir.
16.2.1	100.1	6.8	4/5	0	Closed	0.6	SWSA to SSA
16.2.2	100.1	0	4/5	7.9	SSA to ESA	3.2	SWSA to SSA
16.2.3	100.1	0	2/7	7	SSA to ESA	0.3	SWSA to SSA
16.2.4	100.1	6	2/2.5	1.9	SSA to ESA	0.9	SWSA to SSA
16.2.5	100.1	3.3	0/9	3.4	SSA to ESA	3.8	SSA to SWSA
21.1	111.3	12.8	6.8/2.1	0	Closed	1.9	SWSA to SSA
21.2	111.3	15	6.8/2.1	1.9	ESA to SSA	1.3	SWSA to SSA
21.3	111.3	15	4/5	1.7	ESA to SSA	0	Closed
21.4	111.3	14	4/5	1.5	ESA to SSA	0	Closed
21.5	111.3	15	0/9	1.7	ESA to SSA	4.3	SSA to SWSA
22.1	111.3	15	5.9/3.1	0	Closed	1	SWSA to SSA
22.2	111.3	15	4/5	0	Closed	0	Closed
22.3	111.3	15	0/9	0	Closed	4.3	SSA to SWSA

Implementation Plan

As part of the 2014 CDR, a series of infrastructure projects that OCU would need to implement in support of the project were identified. As a result of the modeling and evaluations performed, changes to the previous infrastructure plan and new infrastructure projects that OCU would need to implement in support of the implementation of the project and the TCR/SJR water supply project were identified.

The results of this study indicate that OCU can implement the project and the TCR/SJR water supply project successfully with minor to modest infrastructure and operational improvements above what is already planned by OCU. The recommended additional CIP projects required in order for OCU to implement planned AWS sources have an estimated capital cost of $20,400,000. These expenditures are distributed over a 20-year planning horizon. The recommended improvements generally include the following types of projects:

- Installation of variable frequency drives (VFDs) and pumping expansions at some water supply facilities
- Interconnects with project partners
- New and expanded BPSs
- New distribution system flow control valves
- Pipeline modifications

It was estimated by OCU that the share of the capital cost of the TCR/SJR water supply project and the project will be approximately $165,000,000 and $100,000,000, respectively. This implementation plan initiates the various phases of these projects, and OCU has required the infrastructure to implement these projects as needed to meet OCU's demands.

The plan that was developed also incorporates system flexibility that will help OCU meet demands under a wide array of conditions, including varying AWS project implementation timing and phasing, and the ability to implement service area transfers as needed to meet demands. As demand projections are refined in the future, the need for the infrastructure recommended in this plan could be required sooner or later than projected.